



**Colorado Water  
Loss Initiative**

**Phase II  
Final Report  
June 2025**



**COLORADO**  
Colorado Water  
Conservation Board  
Department of Natural Resources



# Contents

---

|       |  |    |
|-------|--|----|
| 1     | Executive Summary.....                     | 1  |
| 2     | Program Background .....                   | 4  |
| 2.1   | Scope .....                                | 5  |
| 2.2   | Methods .....                              | 6  |
| 3     | Program Development.....                   | 12 |
| 3.1   | Outreach, Recruitment, and Retention ..... | 12 |
| 3.2   | Program Webpage.....                       | 13 |
| 3.3   | Workshops.....                             | 13 |
| 3.4   | Level 1 Validations.....                   | 15 |
| 3.5   | Direct Technical Assistance .....          | 24 |
| 3.5.1 | Source Meter Testing .....                 | 24 |
| 3.5.2 | Billing Data Analysis.....                 | 25 |
| 3.5.3 | Customer Meter Test Design.....            | 25 |
| 3.5.4 | Leak Detection Survey .....                | 26 |
| 3.5.5 | Real Loss Component Analysis .....         | 26 |
| 3.5.6 | Water Audit Compilation.....               | 26 |
| 3.6   | Post-Program Survey .....                  | 27 |
| 4     | Recommendations .....                      | 33 |

# Tables

---

|  |    |
|--|----|
| Table 1: New Learner Workshops.....                          | 14 |
| Table 2: Advanced Workshops.....                             | 15 |
| Table 3: Water Loss Volume Performance Indicators.....       | 20 |
| Table 4: Water Loss Cost Performance Indicators.....         | 20 |
| Table 5: Infrastructure Leakage Index .....                  | 23 |
| Table 6: Technical Assistance Conducted during Phase 2 ..... | 24 |
| Table 7: Summary of Source Meter Test Results.....           | 24 |

# Figures

---

|  |    |
|--|----|
| Figure 1. Phase 2 Pathways.....  | 5  |
| Figure 2: M36 Methodology Water Balance.....                             | 7  |
| Figure 3: FWAS Reporting Worksheet.....                                  | 9  |
| Figure 4: Water Loss Control Planning Guide .....                        | 10 |
| Figure 5. Screenshot of the Program Webpage.....                         | 13 |
| Figure 6: Audit Year for First Time Level 1 Validations .....            | 16 |
| Figure 7: Data Validity Grade Distribution Pre and Post Validation ..... | 17 |
| Figure 8: Water Audit Period .....                                       | 18 |
| Figure 9: Priority Areas for Colorado Water Audits .....                 | 19 |
| Figure 10: Audit Data Validity Tiers .....                               | 19 |
| Figure 11: Distribution of Water Loss Volume Performance Indicator ..... | 21 |
| Figure 12: Distribution of Water Loss Cost Performance Indicators .....  | 22 |
| Figure 13: Distribution of Infrastructure Leakage Index.....             | 23 |
| Figure 14: Summary of Source Meter Test Results.....                     | 25 |

# Appendices

---

- Appendix A: Workshop Participation
- Appendix B: Level 1 Validations Conducted in Phase 2
- Appendix C: Technical Assistance Summary and Reports
- Appendix D: Source Meter Test Reports
- Appendix E: Billing Data Analysis Reports
- Appendix F: Customer Meter Test Design Report
- Appendix G: Leak Detection Survey Reports
- Appendix H: Real Loss Component Analysis Reports

# Digital Files

---

- [Water Audit Compilation](#)
- [Water Audit Compiler file](#)
- [Individual Water Audits](#)

## 1 EXECUTIVE SUMMARY

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board (CWCB) to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

The CWLI teaches the best management practices for water loss control following the methods established in the AWWA Manual of Water Supply Practices M36 Water Audits and Loss Control Programs (M36 Manual), including the use of the most recent version of the AWWA Free Water Audit Software (FWAS v6) and conducting water audit validation following the Water Research Foundation's Project 5057: Level 1 Water Audit Validation Guidance Manual, Second Edition (WRF 5057).

The CWLI is nearing the successful completion of its second phase that was kicked off in August 2021. Due to the success of Phase 1, Phase 2 was developed as a continuation of Phase 1 to expand the program to additional participants and to provide more advanced technical assistance based on the unique water loss reality of each utility participating in the program.

The goal of Phase 2 was two-fold. First, it was an opportunity for systems that had not participated in Phase 1 to learn the concepts of water loss management. Second, an opportunity for Phase 1 participants to learn more advanced techniques and receive free technical assistance based on their water loss needs.

This document is the final report of Phase 2 of the CWLI and documents the program's results, including training activities, utility participation, a summary of advanced technical assistance provided, and an analysis of the Level 1 validated water audits completed by the participating utilities. It also presents a roadmap for the CWCB to continue assisting utilities through Phase 3 of the program.

The return of the CWLI kicked off in August 2021. There were two tracks of workshops, for new learners or advanced participants. Both types of workshops were conducted throughout all of Phase 2. As New Learners registered into the program, workshops were conducted, and as those New Learners progressed through the program, they were offered advanced training and technical assistance. A total of 66 utilities and approximately 121 individuals participated in the 8 New Learner workshops and the 6 Advanced Workshops that were offered throughout Phase 2.

In addition to training workshops, participants were able to perform a Level 1 Validation of their water audits and also received free technical assistance aimed at improving their water audits or helping manage water losses. During Phase 2, the CWLI team performed over 50 validations for 36 different water systems. Several systems performed annual validations for several years.

To get a snapshot of the water loss performance of CWLI participants, the CWLI Team compiled all water audits that were validated and compiled during Phase 2 of the program. For systems that performed validations or compiled water audits for multiple years, only the most recent water audit was considered. This dataset is comprised of 37 water audits for the period between 2022 and 2024.

The total water losses for the dataset varies from -23 to 450 gallons per service connection per day, while the water loss cost varies from \$-16 to \$200 per service connection per day. The Infrastructure Leakage Index for the data set varies from -1.9 to 11.5 with a median of 1.72. As explained in the report, negative losses are not physically possible, and any negative values are likely the result of data errors.

Once completed, the FWAS prioritizes three areas (Priority Areas 1-3) for improvement based on each audit input's data validity grade and volumetric impact on the estimated leakage. The most common Priority Area 1 is the Volume of Own Sources followed by Water Imported. Across all the Priority Areas, most of the audits prioritized Customer Metering Inaccuracies as either Priority Area 2 or 3, likely because many utilities used an estimate of average customer meter inaccuracy to inform this audit input. Billed Metered Authorized Consumption was the next most common Priority Area 2 or 3 in the water loss audits.

Utilities that completed Level 1 validations and the advanced workshop were offered the opportunity to receive Technical Assistance (TA) from a variety of offerings that included source meter testing, customer meter test design, customer meter test analysis, billing data analysis, real loss component analysis, leak detection water audit compilation and additional L1V. A total of 26 technical assistance was performed for 22 systems. Many systems performed more than one technical assistance. The most performed was source meter testing – supporting the prioritization from the water audit results.

Based on the program's achievements, feedback, and new regulations in the state of Colorado, it is recommended that the CWCB continue offering water loss management training and technical assistance through Phase III of the program. This program should continue to be available to all Colorado water providers. As new regulations require certain water providers to submit a water audit, and given the demonstrated benefits of an L1V program, Phase III should also provide a validator training program. This initiative will ensure that the water audits submitted to the CWCB comply with L1V standard guidance.

Throughout the over 6 years of CWLI, the team has learned several lessons and made adjustments that were necessary for the success of the program. The main general consideration is that the program was not linear as initially conceived. The initial concept had Utility A participating in New Learner Workshops, moving on to Level 1 Validation, Advanced Workshops, and then to Technical Assistance. The reality was that many systems did not follow that linear path. They either restarted at the basics after being advanced or many repeated Level 1 Validations, as is recommended.

Here are the main observations of Phase 2 of the program:

**Contact management is a crucial on-going activity.** The list of contacts must be updated frequently as staff changes at the water providers are common. The main person that was leading the water loss effort may or may not be replaced, needing the CWLI Team to either establish contact with the new staff or to engage the utility to identify a new leader for the initiative. In some cases, utilities paused participation for months or years until a new staff picked up the effort.

**Utilities will benefit from having a main Lead or Champion of water loss management.** Having an identified champion for water loss management will help the utility progress with time and not lose acquired knowledge and experience on this topic. This program will show water providers that the CWCB is fully committed to water loss management and will also aid with the training of this staff.

**Basics and advanced training continue to be needed.** The need for the new learner training was constant for a few reasons. Systems participating for the first time were still joining the program after more than 5 years. Also, utility staff that participated in the past wanted to get a refresher on the basic concepts. Or additional and new staff at a participating utility would need to get up to speed on water loss knowledge. Although the basic workshops were originally planned for the initial part of the program, these workshops were still being conducted at the end of Phase 2.

**Water Audit Compilation and Level 1 Validations should be an annual practice.** The best way to understand changing water loss performance is to conduct annual water audits with Level 1 Validations. Several participants understood this and requested the validation of multiple audits throughout the program. The more updated audit can also assist in determining the next best step for improving water loss performance.

**Some of the Technical Assistance offerings were not feasible for some water providers.** Different types of Technical Assistance have different requirements. Some of the analyses have data requirements and some of the field activities have requirements on the infrastructure setting. The program can assist utilities understand what changes may be necessary for some of the best practices.

The continuation of the CWLI can continue educating water providers in the M36 Methodology and help them understand the water loss management and how to manage the date for submittal to the CWCB and compliance.

Phase 3 of the program will build on the successes of the previous phases and adopt the improvements that have been implemented to ensure the program continues to provide valuable training and assistance to Colorado water providers. Water loss control has been identified by the drinking water industry as a top priority. With multiple states providing statewide water loss control training and having identified the AWWA M36 methodology in Colorado's Water Plan, the time is right to continue statewide training on the industry standard for water loss control and move on to prioritized interventions.

## 2 PROGRAM BACKGROUND

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board (CWCB) to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado’s projected growth.

The American Water Works Association (AWWA) water audit methodology, described in detail in the AWWA Manual of Water Supply Practices M36 Water Audits and Loss Control Programs, is a recommended best practice and is the North American industry standard approach for water loss management. This methodology allows for informed decision making for water loss control and management activities to reduce losses.

The CWLI is nearing the successful completion of its second phase that was kicked off in August 2021. The first phase of the program, which ran from August 2018 to October 2020, was comprised of a comprehensive program of training, and technical review and assistance for water systems across Colorado to attain a basic level of competency with the AWWA water balance and audit concepts, and the AWWA Free Water Audit Software (FWAS). The scope included, at a minimum, Level 1 validation of the utility prepared water audits and multiple “touch points” for reinforced understanding, with the possibility of two tracks: “Early Adopters” (EA) and “New Learners” (NL). Early Adopters with previous experience with water audits were also provided with more advanced technical assistance. Due to the success of Phase 1, Phase 2 was developed as a continuation of Phase 1 to expand the program to additional participants and to provide more advanced technical assistance based on the unique water loss reality of each utility participating in the program.

The goal of Phase 2 was two-fold. First, it was an opportunity for systems that had not participated in Phase 1 to learn the concepts of water loss management. Second, an opportunity for Phase 1 participants to learn more advanced techniques and receive free technical assistance based on their water loss needs. Like Phase 1, this second phase also had a track for New Learners and for Advanced participants. The program offerings were based on the participants level of experience with water loss management. However, even systems that started the second phase as New Learners had the opportunity to progress into advanced technical assistance (see Figure 1).

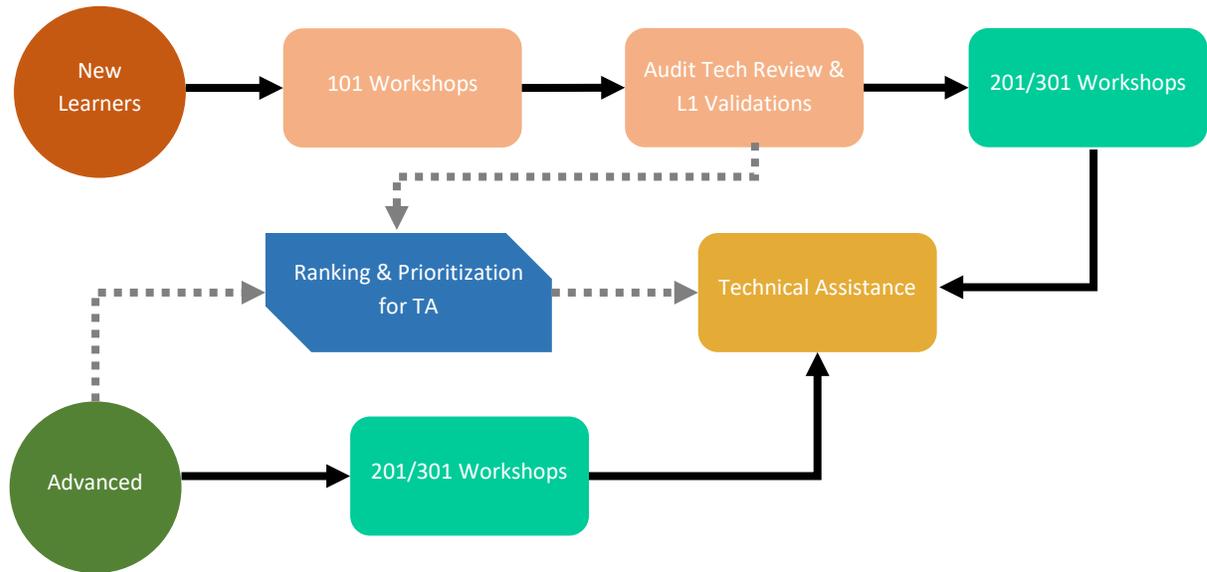


Figure 1. Phase 2 Pathways

This document is the final report of Phase 2 of the CWLI and documents the program's results, including training activities, utility participation, a summary of advanced technical assistance provided, and an analysis of the Level 1 validated water audits completed by the participating utilities. It also presents a roadmap for the CWCB to continue assisting utilities through Phase 3 of the program.

## 2.1 Scope

The scope of Phase 2 of the CWLI included five main tasks:

**Task 1: Development of Colorado Water Loss Initiative Phase 2, Program Administration, Management and Communications** – This task included general management of the program, outreach, communication, recruitment, coordination, and reporting.

**Task 2: Water Audit 101 Workshops and Level 1 Validation** – Introduced all introductory content for New Learners to compile their water audit using the most recent version of the FWAS and go through a Level 1 Validation.

**Task 3: 201 and 301 Workshops and Outreach** – This task focused on advanced techniques and concepts beyond what was covered in Phase 1 of the CWLI. This task initially involved Phase 1 participants and subsequently was offered to New Learners as they progressed through the program.

**Task 4: Ranking and Prioritization for Direct Technical Assistance** – This task identified and prioritized the best hands-on technical assistance (TA) area for each participating utility. This prioritization was based on the results of their water audit and Level 1 Validation.

**Task 5: Direct Technical Assistance** – This task offered the technical assistance identified in Task 4. TA options included source meter testing, billing data analysis, customer meter test design and result analysis, real loss component analysis, and leak detection.

## 2.2 Methods

The CWLI teaches the best management practices for water loss control following the methods established in the AWWA Manual of Water Supply Practices M36 Water Audits and Loss Control Programs (M36 Manual), including the use of the most recent version of the AWWA Free Water Audit Software (FWAS v6) and conducting water audit validation following the Water Research Foundation’s Project 5057: Level 1 Water Audit Validation Guidance Manual, Second Edition (WRF 5057).

### M36 Water Audits and Loss Control Programs

The M36 Manual explains the water audit methodology and provides an overview of loss control techniques. The practices described in the M36 Manual provide water utilities effective tools and methods to promote accountability and efficiency in their operations.

A water audit is a comprehensive method that entails a meticulous review of records and data to trace the journey of water from its original source through a distribution system to its final destination. This destination could either be the consumption by customers, where water is used for drinking, cooking, or other purposes, or it may be lost through leaks in the infrastructure, resulting in wasted resources. An essential aspect of this process is the water balance, which encapsulates the various components of the water audit.

The water balance serves as a critical tool for accountability, as it is based on the principle that the total volume of water entering the distribution system should equal the total volume exiting it. This relationship highlights the importance of accurate tracking to identify inefficiencies or losses. Figure 2 provides a clear illustration of the standard components of the water balance, making it easier to understand how each part contributes to the overall flow of water through the system.



### AWWA Free Water Audit Software

The Free Water Audit Software (FWAS) is a spreadsheet-based water audit tool designed to help quantify and track water losses associated with water distribution systems and recognize areas for improved efficiency and cost recovery following the M36 Methodology. Utility-specific data is entered into the FWAS to compute the water balance (see Figure 3).

The software also includes a method to assess the reliability of the data inputs and the results of the water audit through the concepts of Data Validity Grades (DVG) and Data Validity Score (DVS). DVG is a numerical grading system ranging from 1 to 10, automatically assigned based on how the utility responds to several criteria questions regarding their practices for a specific data input component. A DVS is then calculated for the water audit, based on the individual DVG. This interactive data grading reduces ambiguity in grade assignments.

The DVS can be a tool to assist in the development of water loss control measures, as shown in Figure 4: Water Loss Control Planning Guide. Depending on the score, utilities should focus their resources on different areas for water loss control. For example, a utility with a DVS in Level III (51-70) should focus on audit data collection, short and long-term loss control, target setting, and benchmarking. For systems that participated in the CWLI the most common DVS was within Level III.

AWWA Free Water Audit Software:  
Worksheet
FWAS v6.0  
American Water Works Association  
Copyright © 2020, All Rights Reserved.

Water Audit Report for: << Please enter system details on the Start Page >>  
 Audit Year:

To access definitions, click the input name Click 'n' to add notes Click 'g' to determine data validity grade To edit water system info: [go to start page](#)

PLEASE CHOOSE REPORTING UNITS FROM THE START PAGE BEFORE ENTERING DATA  
[Water Supplied Error Adjustments](#)

---

**WATER SUPPLIED**

VOS Volume from Own Sources:  n  g

WI Water Imported:  n  g

WE Water Exported:  n  g

VOSEA  
WIEA  
WEEA

WATER SUPPLIED: 0.000

---

**AUTHORIZED CONSUMPTION**

BMAC Billed Metered:  n  g

BUAC Billed Unmetered:  n  g

UMAC Unbilled Metered:  n  g

UUAC Unbilled Unmetered:  n  g  3 0.000 choose entry option:  
 0.25%  default

Default option selected for Unbilled Unmetered, with automatic data grading of 3

AUTHORIZED CONSUMPTION: 0.000

---

**WATER LOSSES**

0.000

**Apparent Losses**

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

SDHE Systematic Data Handling Errors:  n  g  3 0.000  0.25%  default

CMI Customer Metering Inaccuracies:  n  g  3 0.000  percent

UC Unauthorized Consumption:  n  g  3 0.000  0.25%  default under-registration

Default option selected for Unauthorized Consumption, with automatic data grading of 3

Apparent Losses: 0.000

---

**Real Losses**

Real Losses: 0.000

WATER LOSSES: 0.000

---

**NON-REVENUE WATER**

NON-REVENUE WATER: 0.000

---

**SYSTEM DATA**

Lm Length of mains:  n  g  (including fire hydrant lead lengths)

Nc Number of service connections:  n  g  (active and inactive)

Service connection density:

Lp Are customer meters typically located at the curbstop/property  select... (average distance between property line and meter)

AOP Average length of (private) customer service line:  n  g

AOP Average Operating Pressure:  n  g

---

**COST DATA**

CRUC Customer Retail Unit Charge:  n  g   Total Annual Operating Cost

VPC Variable Production Cost:  n  g  \$/  \$/yr (optional input)

---

**WATER AUDIT DATA VALIDITY TIER:**

Click 'g' for 7 parameter(s), then complete all visible data grading questions to enable the Data Validity Score to calculate
[go to dashboard](#)

---

**PRIORITY AREAS FOR ATTENTION TO IMPROVE DATA VALIDITY:** **KEY PERFORMANCE INDICATOR TARGETS:**

Based on the information provided, audit reliability can be most improved by addressing the following component: OPTIONAL: If targets exist for the operational performance indicators, they can be input below

|  |  |
|--|--|
|  | Unit Total Losses: <input type="text"/>              |
|  | Unit Apparent Losses: <input type="text"/>           |
|  | Unit Real Losses <sup>a</sup> : <input type="text"/> |
|  | Unit Real Losses <sup>b</sup> : <input type="text"/> |

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

**Figure 3: FWAS Reporting Worksheet**  
(Source: Free Water Audit Software v6)

| AWWA Free Water Audit Software:<br>Determining Water Loss Standing   |   |  |  |  |   |
|--|---|--|--|--|---|
| FWAS v6.0<br>American Water Works Association<br>Copyright © 2020. All Rights Reserved.  |   |  |  |  |   |
| Water Audit Report for: << Please enter system details on the Start Page >>  |   |  |  |  |   |
| Audit Year: <input type="text"/>   |   |  |  |  |   |
| Data Validity Tier: Additional data entry required   |   |  |  |  |   |
| Water Loss Control Planning Guide  |   |  |  |  |   |
| Water Audit Data Validity Tier (Score Range)   |   |  |  |  |   |
| Functional Focus Area  | Tier I (1-25)   | Tier II (26-50)  | Tier III (51-70)   | Tier IV (71-90)  | Tier V (91-100)   |
| Audit Data Collection  | Launch auditing and loss control team; address supply metering deficiencies                             | Analyze business process for customer metering and billing functions and water supply operations; Identify data gaps; Improve supply metering                          | Establish/revise policies and procedures for data collection   | Refine data collection practices and establish as routine business process   | Annual water audit is a reliable gauge of year-to-year water efficiency standing  |
| Short-term loss control  | Research information on leak detection programs; Begin flowcharting analysis of customer billing system | Conduct loss assessment investigations on a sample portion of the system: customer meter testing, leak survey, unauthorized consumption, etc                           | Establish ongoing mechanisms for customer meter accuracy testing, active leakage control and infrastructure monitoring                   | Refine, enhance or expand ongoing programs based upon economic justification   | Stay abreast of improvements in metering, meter reading, billing, leakage management and infrastructure rehabilitation      |
| Long-term loss control   |   | Begin to assess long-term needs requiring large expenditure: customer meter replacement, water main replacement program, new customer billing system or AMR/AMI system | Begin to assemble economic business case for long-term needs based upon improved data becoming available through the water audit process | Conduct detailed planning, budgeting and launch of comprehensive improvements for metering, billing or infrastructure management | Continue incremental improvements in short-term and long-term loss control interventions                                    |
| Target-setting   |   |  | Establish long-term apparent and real loss reduction goals (+10 year horizon)  | Establish mid-range (5 year horizon) apparent and real loss reduction goals  | Evaluate and refine loss control goals on a yearly basis  |
| Benchmarking   |   |  | Preliminary Comparisons - can begin to rely upon with PIs for performance comparisons for real losses                                    | Performance Benchmarking with PIs is meaningful in comparing real loss standing  | Identify Best Practices/ Best in class; PIs are very reliable as real loss performance indicators for best in class service |
| <i>For validity scores of 50 or below, the shaded blocks should not be focus areas until better data validity is achieved.</i> |   |  |  |  |   |

Figure 4: Water Loss Control Planning Guide  
(Source: Free Water Audit Software v6)

### Water Audit Validation

Research on water audit data has concluded that utilities often struggle to accurately and consistently assess the validity of their own data. A substantial portion of audit submissions have reported suspect data that produces technically impossible water loss scenarios. An inaccurate water audit may result in an incorrect assessment of water loss performance. Without an accurate understanding of the types and quantities of water loss or the practices contributing to these losses, developing a cost-effective strategy to address the inefficiencies may not be possible.

Water audit validation is the process of examining water audit inputs to improve the water audit's accuracy and document the uncertainty associated with the used data. The goals of the water audit validation are 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.

There are 3 levels of validation rigor:

- **Self-Reported:** Water audits have not been independently validated. This process does not confirm the accuracy of data validity grades and may contain subtle and/or egregious data errors.
- **Level 1:** Water audits are examined for inaccuracies evident in summary data and application of methodology.
- **Level 2:** Water audits have been corroborated with investigations of raw data and archived reports of instrument accuracy.
- **Level 3:** Water audits have been bolstered by field tests of instrument accuracy, such as source meter tests and the water audit's estimate of Real Losses has been confirmed through other sources of field data, such as with a Component Analysis of Real Losses.

Water audit validation should be performed by a proficient person in the current AWWA M36 Manual and WRF #5057 methodologies which codify best practices for water audit preparation and validation. In addition, the validator should not be the same person who compiled the water audit. Georgia, California, Indiana, Hawaii, and the province of Quebec require the submission of validated water audits to regulating agencies, recognize the importance of validation. Some of these states have created certification programs to certify qualified water audit validators.

Participants of the CWLI had the opportunity to perform a Level 1 validation of their water audits by professionals certified either (or both) in California's or Georgia's validator program. Advanced participants were also able to undergo Level 2 or Level 3 validation of their data.

### 3 PROGRAM DEVELOPMENT

The return of the CWLI kicked off in August 2021 with an announcement from the Colorado Water Conservation Board. The announcement encouraged new and previous participants to register into the program for activities scheduled in the Fall of 2021. Recipients of the announcement were also encouraged to visit the program webpage that was updated with Phase 2 content. The outreach network was also provided with content to spread the word among their networks and include in their digital platforms.

#### 3.1 Outreach, Recruitment, and Retention

Outreach, recruitment, and retention of participants was a continuous task throughout the whole program duration. Initially, a list of target utilities for the program was put together in collaboration with the CWCB. This list contained the updated target list that was developed during Phase 1 as well as all Phase 1 participants, and utility contacts from other state databases. Periodically, the CWCB would provide updated contacts from the 1051 reports. Additionally, as the CWCB received inquiries from other systems about the program, they would be invited into the program and added to the contact list.

The recipients for the announcement were encouraged to visit the program webpage, register into the CWLI Program, and answer a short survey to gauge the utility's experience with the M36 water audit methodology. This registration step also provided current and relevant contact information to keep participants updated on the program's activities.

Outreach and recruitment were mainly done through email, although the program staff also posted on social media, conducted phone calls, and even discussed the program in the CWCB Water Talk Podcast (Episode 9, September 2021). As part of the outreach effort over the program duration, the program sent periodic emails with tidbits of water loss information or when program activities were approaching. Outreach efforts, either emails or phone calls, were typically increased prior to a scheduled workshop or other program offering to encourage participation.

In addition to advertisement by the program staff and the CWCB, an Outreach Network was established to assist with advertising and recruitment. The Outreach Network consisted of a variety of organizations tied to the water industry throughout the state. Periodically, the program staff distributed content for the Outreach Network to distribute to their subscribers and blurbs for their own digital platforms.

### 3.2 Program Webpage

Like Phase 1, the program webpage ([www.ColoradoWaterLoss.org](http://www.ColoradoWaterLoss.org) – Figure 5) served as the home base for all information regarding activities, schedules, promotional and reference materials. Throughout the program the webpage was updated with the relevant resources for each stage.

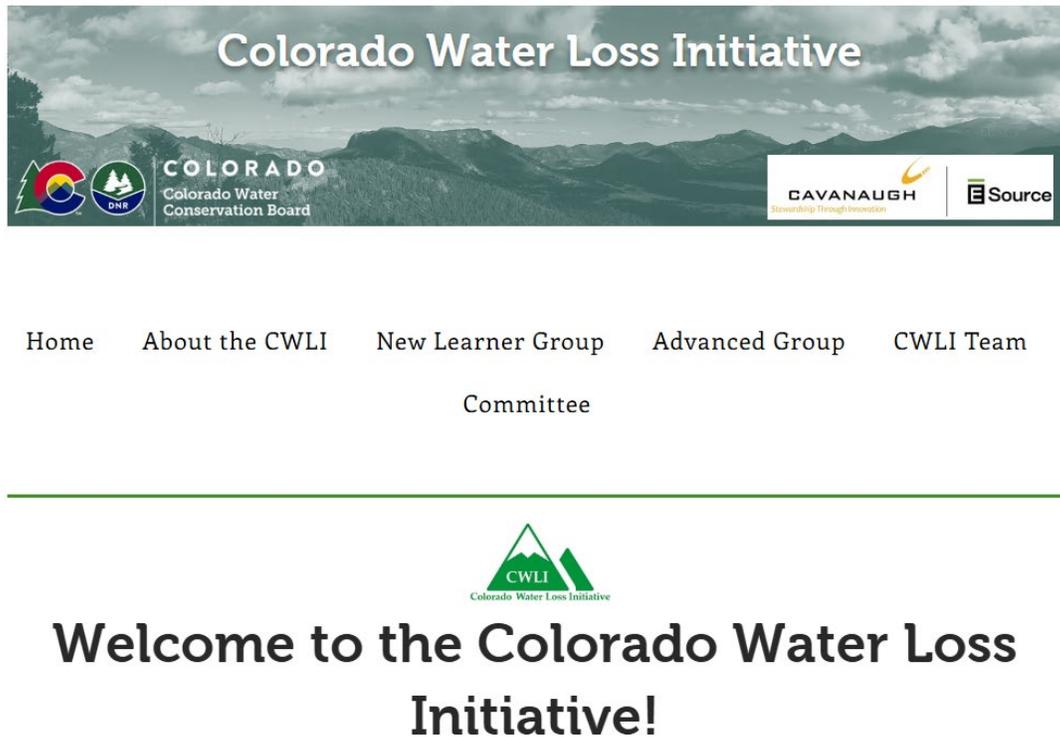


Figure 5. Screenshot of the Program Webpage

### 3.3 Workshops

There were two tracks of workshops, for new learners or advanced participants. For both tracks, introductory webcasts were conducted to introduce participants to the program, the team, and the program objectives. These were uploaded to the program website as open resources for utilities.

Both types of workshops were conducted throughout all of Phase 2. As New Learners registered into the program, workshops were conducted, and as those New Learners progressed through the program, they were offered advanced training and technical assistance.

### New Learners

The New Learner Workshop introduced basic M36 Methodology to utilities that did not participate in Phase 1. However, some utilities that participated in Phase 1 also took this workshop either as a refresher or for new employees that joined afterwards. Additionally, it introduced the participants to the updated FWAS software (v.6) that was released after the conclusion of Phase 1.

These workshops were geared towards providing the utilities with a basic understanding of the water audit process, the FWAS, and Level 1 Validations. Common mistakes in water audit preparation were discussed, along with tips and guidance on the preparation of their own water audits. After the webinar and workshop, each participating utility was expected to attempt to complete their own water audit.

A total of 8 New Learner Workshops were offered throughout Phase 2 in which a total of 51 different utilities participated. Several utilities participated in more than one workshop. A summary of workshops and participation is presented in Table 1.

**Table 1: New Learner Workshops**

| Date          | Participant Utilities | Participants |
|---------------|-----------------------|--------------|
| 12/14/2021    | 8                     | 12           |
| 3/8/2022      | 6                     | 9            |
| 4/25/2024     | 6                     | 8            |
| 5/1/2024      | 6                     | 15           |
| 10/29/2024    | 6                     | 8            |
| 10/31/2024    | 8                     | 8            |
| 11/19/2024    | 11                    | 14           |
| 12/17/2024    | 9                     | 13           |
| <b>Total:</b> | <b>60</b>             | <b>87</b>    |

### Advanced

The Advanced track was focused on more advanced techniques and concepts beyond what was covered in CWLI Phase 1. The workshops covered a detailed review of the assistance offered to participants such as source meter testing, customer meter testing, billing data analysis, real loss component analysis, and leak detection, among other advanced techniques.

A total of 6 Advanced Workshops were provided, in which a total of 33 different utilities participated. A summary of workshops and participation is presented in Table 2.

**Table 2: Advanced Workshops**

| Date          | Participant |              |
|---------------|-------------|--------------|
|               | Utilities   | Participants |
| 12/16/2021    | 7           | 7            |
| 3/10/2022     | 10          | 18           |
| 11/8/2022     | 4           | 5            |
| 12/14/2022    | 13          | 19           |
| <b>Total:</b> | <b>33</b>   | <b>49</b>    |

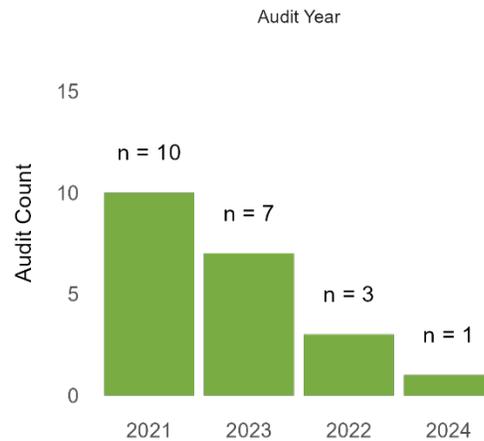
A total of 66 utilities and approximately 121 individuals participated in the workshops. This figure does not include those who attended only one day of the two-day workshops. Additionally, some utilities had one registration, but multiple individuals were present in the conference room, so the actual participation of individuals was higher. Eighteen of these utilities participated in both tracks during Phase 2. A summary table with participating utilities is in Appendix A.

### 3.4 Level 1 Validations

During Phase 2, multiple utilities had the opportunity to undergo a Level 1 Validation (L1V). There were two main groups of L1V: utilities performing a validation for the first time, and utilities that had previously gone through the validation process. Appendix B includes a list of all Level 1 Validations conducted during Phase 2. A digital version of all validated water audits has been submitted in digital format.

#### First Time Level 1 Validations

A total of 23 utilities completed water loss audits for the first time during Phase 2 and these were validated by the CWLI Team. As shown in Figure 6, most first-time L1V were for the 2021 audit period and were around the start of Phase 2. Some of these utilities repeated the L1V process at later stages of Phase 2 using data from subsequent years.

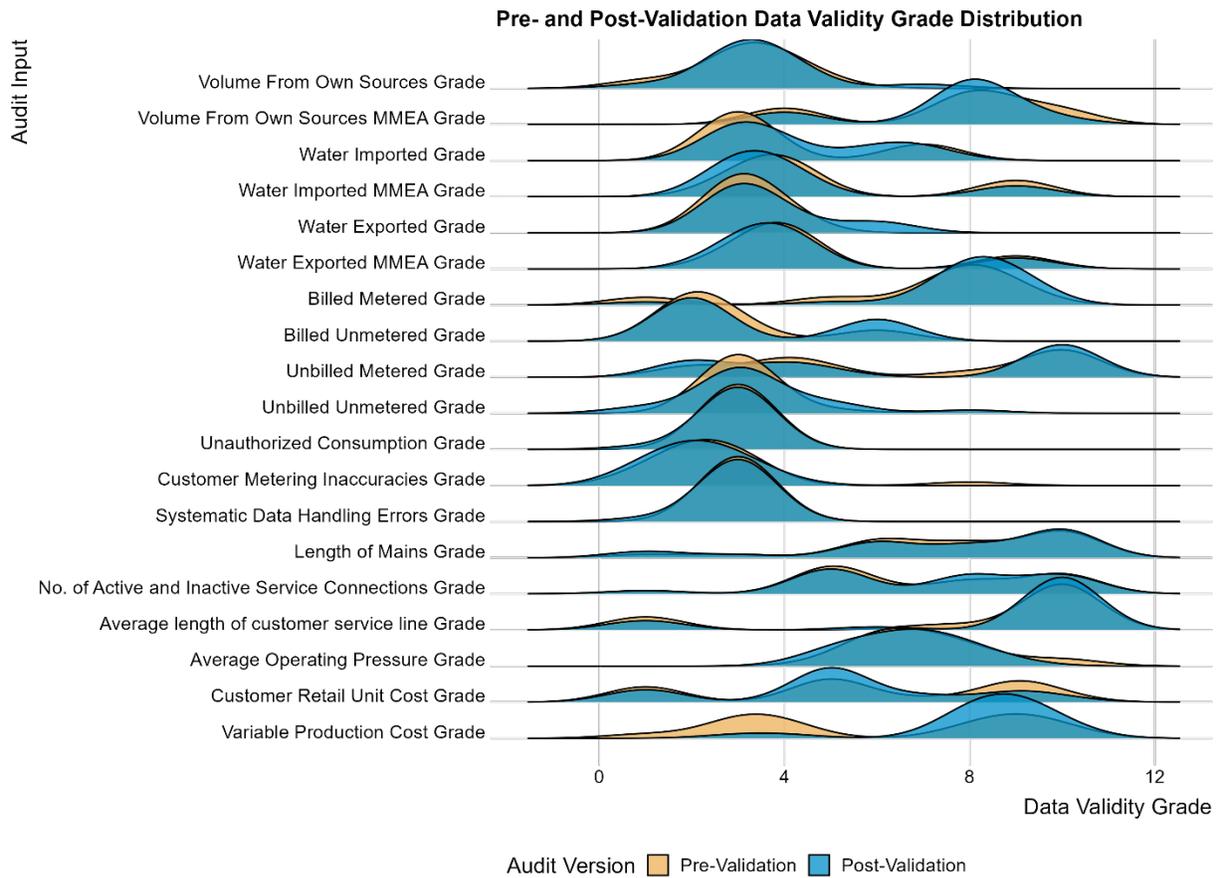


**Figure 6: Audit Year for First Time Level 1 Validations**

Nine of these utilities submitted their water audits incomplete, which limited the generation of performance indicators in the dashboard tab of the FWAS. During the validation, the CWLI Validator helped the utility complete all applicable water audit inputs.

Revising Data Validity Grades is also a key component of validation. Figure 7 shows the distribution of the data validity grade of the individual audit inputs before and after validation. The biggest variances in data validity grades pre and post validation were in the variable production cost, which some utilities had difficulties computing and understanding. The average Data Validity Score for the audits before validation was 49 while it slightly increased after validation to 52.

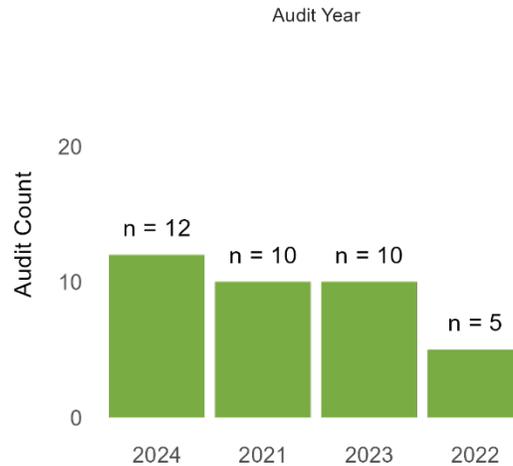
Besides adjustments to the data validity grades, several water audits had modifications to the inputs as a result of the L1V. About 43% of first-time users experienced changes in their water supply volume, and 68% of them had adjustments in their authorized consumption. It is key for both of these inputs to be as accurate as possible since they have the biggest impact on the computation of water losses.



**Figure 7: Data Validity Grade Distribution Pre and Post Validation**

### Water Audit Summary

To get a snapshot of the water loss performance of CWLI participants, the CWLI Team compiled all water audits that were validated and compiled during Phase 2 of the program. For systems that performed validations or water audit compilations for multiple years, only the most recent water audit was considered. This dataset is comprised of 37 water audits. As shown in Figure 8 the water audit periods for this data set were between 2022 and 2024.



**Figure 8: Water Audit Period**

Once completed, the FWAS prioritizes three areas (Priority Areas 1-3) for improvement based on each audit input’s data validity grade and volumetric impact on the estimated leakage. Figure 9 displays the audit inputs prioritized for this dataset. The most common Priority Area 1 is the Volume of Own Sources followed by Water Imported. Across all the Priority Areas, most of the audits prioritized Customer Metering Inaccuracies as either Priority Area 2 or 3, likely because many utilities used an estimate of average customer meter inaccuracy to inform this audit input. Billed Metered Authorized Consumption was the next most common Priority Area 2 or 3 in the water loss audits.

Volume of Own Sources (and/or Water Imported for some systems), and Billed Metered Authorized Consumption are typically the largest volumes in the audits and thus have a significant impact on estimated leakage. Any errors in the data used to derive these audit inputs will result in inaccurate water loss estimates.

The Data Validity Grades are weighed to produce a Data Validity Score and assign a Data Validity Tier for each utility. The Water Loss Control Planning sheet in the FWAS provides general recommendations for data management and operational improvements related to water loss per Data Validity Tier. The following figure shows the distribution of Data Validity Tiers among the Colorado water loss audits. Most fall under Data Validity Tier III with scores that range between 51 and 70.

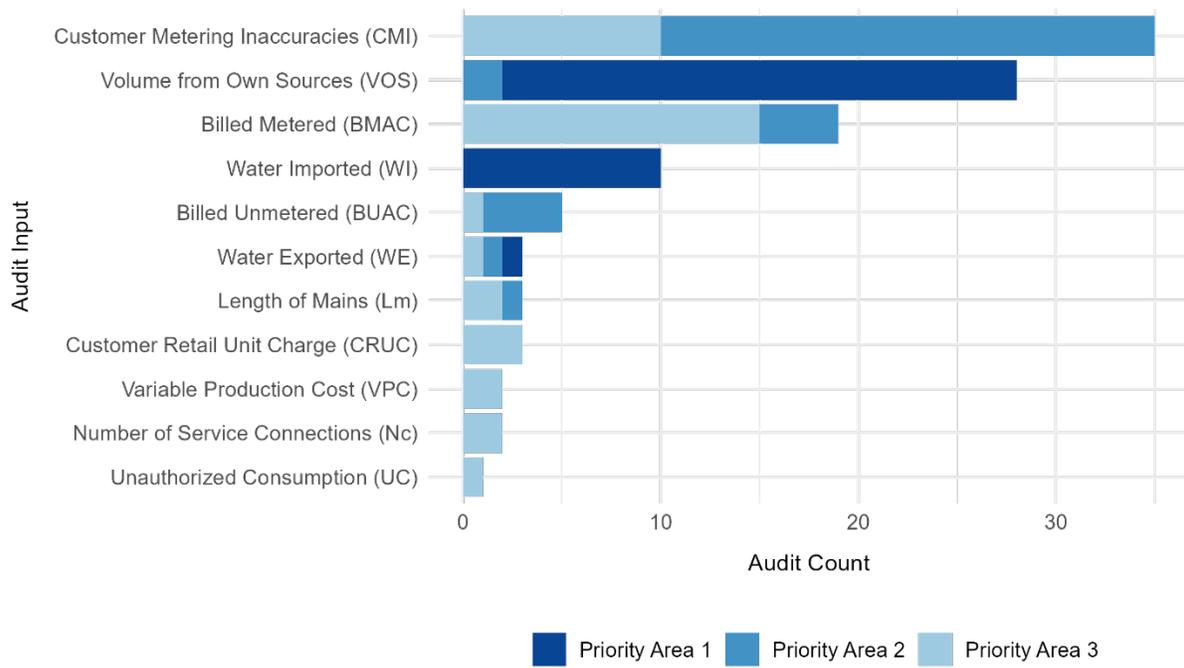


Figure 9: Priority Areas for Colorado Water Audits

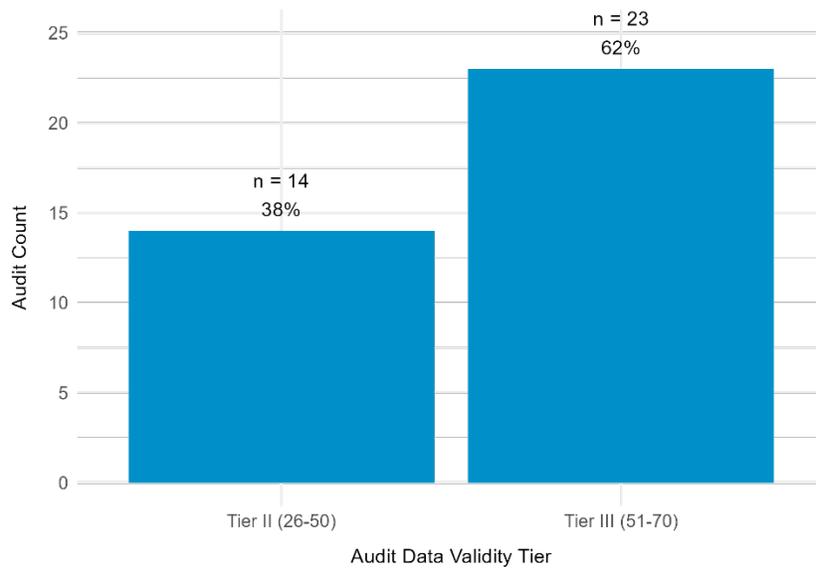


Figure 10: Audit Data Validity Tiers

## Water Losses

Water losses are categorized into two main types: Real Losses and Apparent Losses. Real Losses are estimated by subtracting Apparent Losses from Water Losses. Typically, a significant portion of Apparent Losses are estimated by conducting accuracy tests on customer meters. However, if test results for customer meters are unavailable, examining the total volume of Water Loss may provide more meaningful insights than analyzing the individual components separately.

The total annual volume of these indicators may vary greatly depending on utility size and other operational conditions. One way to compare and benchmark performance with these indicators is to normalize the value by volume per connection per day. Table 3 shows the volume-based performance indicators of the dataset, while Table 4 presents the monetary value of water losses. It should be noted that two of the audits in the data set presented negative water losses, which is not plausible. Negative water loss must be attributed to anomalous audit data.

Table 3: Water Loss Volume Performance Indicators

| Quartile  | Unit Total Water Losses   | Unit Apparent losses      | Unit Real losses          | Unit Real Losses     |
|-----------|---------------------------|---------------------------|---------------------------|----------------------|
|           | (gallons /connection/day) | (gallons /connection/day) | (gallons /connection/day) | (gallons /miles/day) |
| Q1        | 23.7                      | 5.4                       | 16.2                      | 986.2                |
| <b>Q2</b> | <b>43.3</b>               | <b>8.8</b>                | <b>36.0</b>               | <b>1,825.8</b>       |
| Q3        | 71.3                      | 12.1                      | 58.4                      | 3,104.7              |

Table 4: Water Loss Cost Performance Indicators

| Quartile  | Apparent Loss Cost Rate | Real Loss Cost Rate   | Total Loss Rate       |
|-----------|-------------------------|-----------------------|-----------------------|
|           | (\$/connection/ year)   | (\$/connection/ year) | (\$/connection/ year) |
| Q1        | 8.78                    | 3.18                  | 21.92                 |
| <b>Q2</b> | <b>14.10</b>            | <b>13.46</b>          | <b>28.04</b>          |
| Q3        | 30.25                   | 25.91                 | 52.63                 |

Figure 11 and Figure 12 below show the distribution of total water losses and water loss cost performance indicators for the Colorado dataset. The total water loss varies from -23 to 450 gallons per service connection per day, while the water loss cost varies from \$-16 to \$200 per service connection per day. As mentioned above, negative losses are not physically possible, and those results probably are the result of data errors. The dashed red line in both graphs represents the media for the data set. The median for water losses is relatively close to the median for the AWWA Water Audit Reference Dataset used for the FWAS dashboard (49 gallons per connection per day).

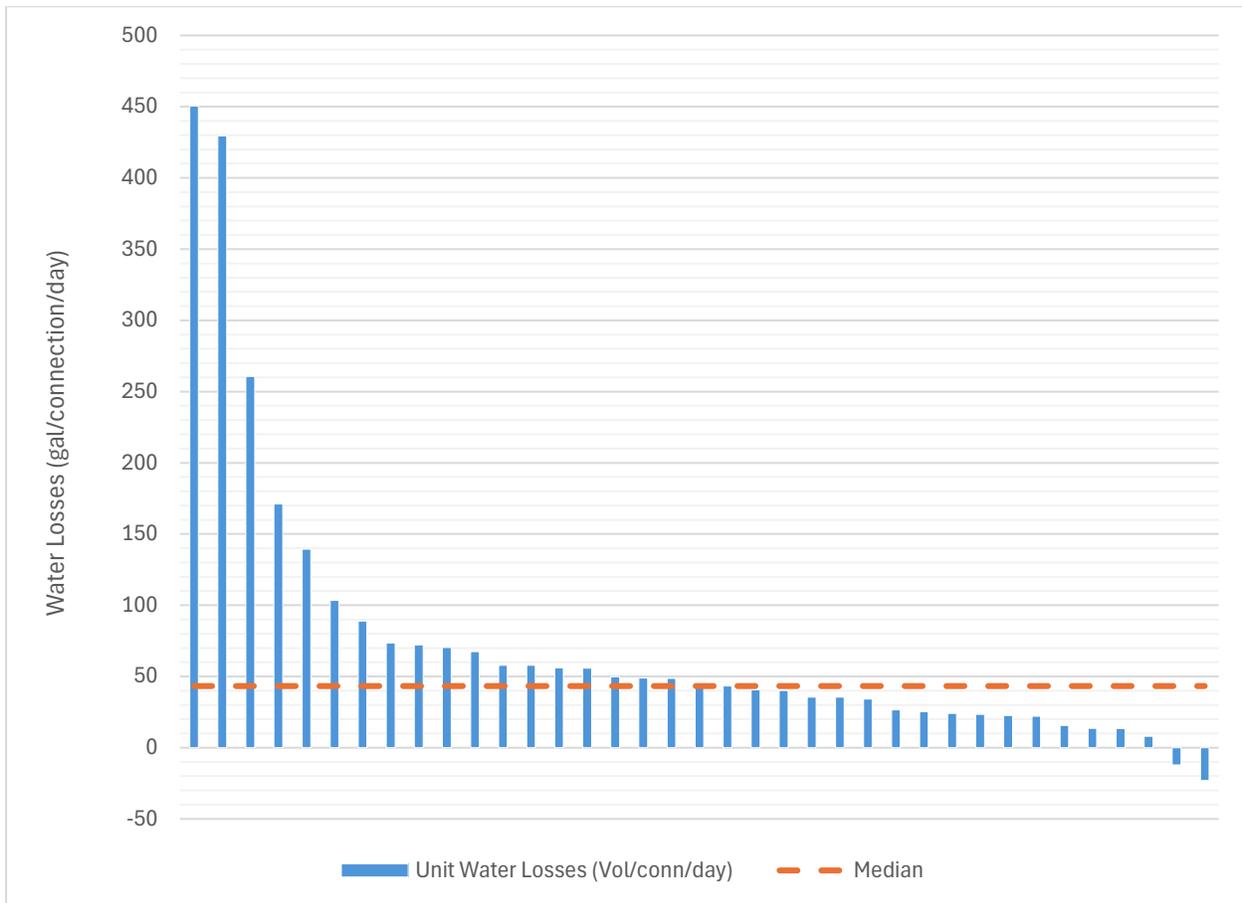


Figure 11: Distribution of Water Loss Volume Performance Indicator

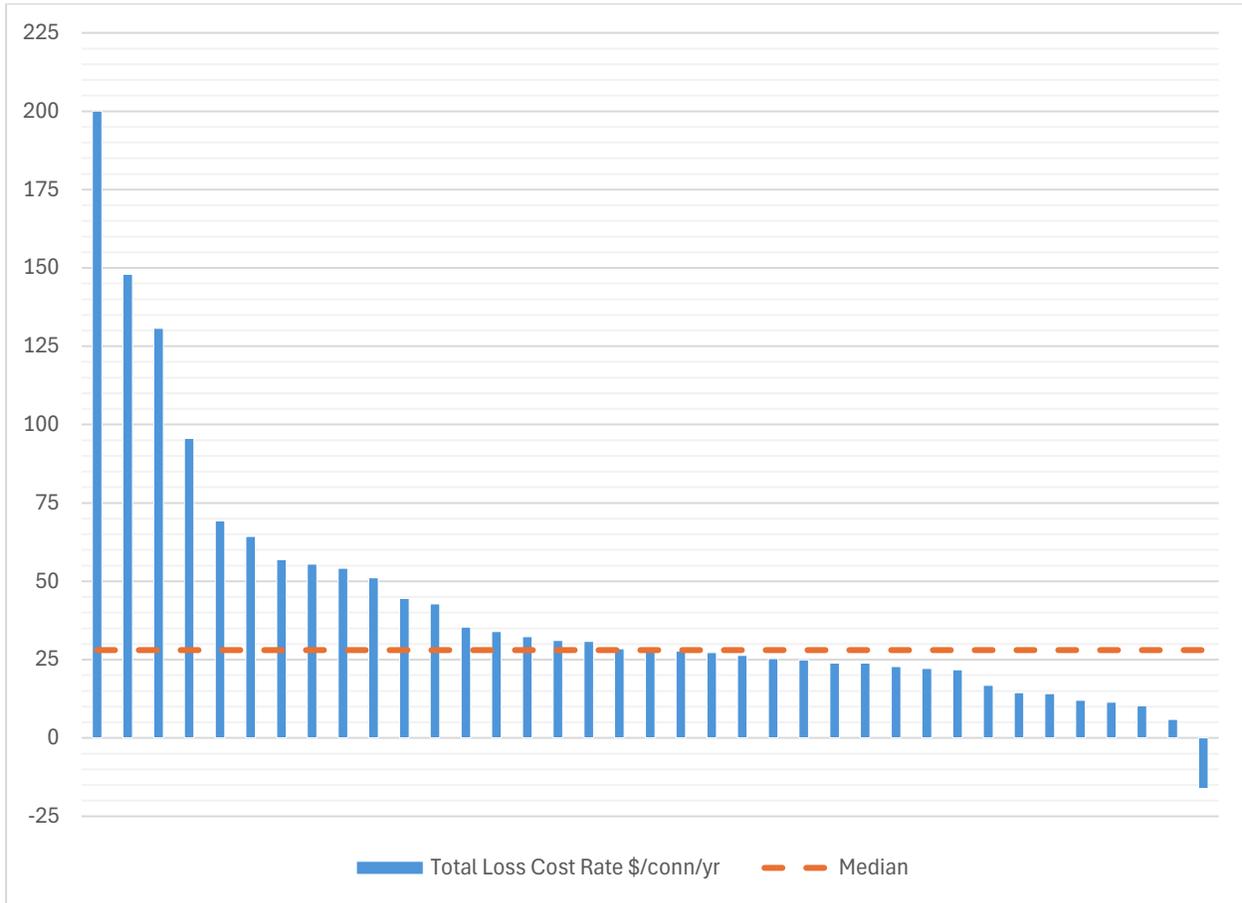


Figure 12: Distribution of Water Loss Cost Performance Indicators

### Infrastructure Leakage Index

Every system is expected to experience a certain level of unavoidable leakage. Any leakage beyond this unavoidable volume is considered recoverable. The Infrastructure Leakage Index (ILI) serves as a measure of a utility's real loss performance compared to the estimated unavoidable leakage levels specific to each utility based on its individual characteristics. The ILI is calculated as the ratio of the current level of leakage to the unavoidable level of leakage. An ILI of 1 indicates that the utility is operating at leakage levels deemed the minimum technically feasible. ILIs lower than 1 may be observed in well-performing utilities, but they typically suggest that there may be data issues that need to be addressed. Table 5 shows the distribution of ILI for participants in the dataset.

Table 5: Infrastructure Leakage Index

| Quartile  | ILI         |
|-----------|-------------|
| Q1        | 0.69        |
| <b>Q2</b> | <b>1.72</b> |
| Q3        | 2.63        |

Figure 13 shows the distribution of ILI for the Colorado data set. Approximately 38% of the utilities have an ILI higher than 2. Less than 14% have an ILI less than 0.5. Incorrect data or other system information may be resulting in these low ILI values.

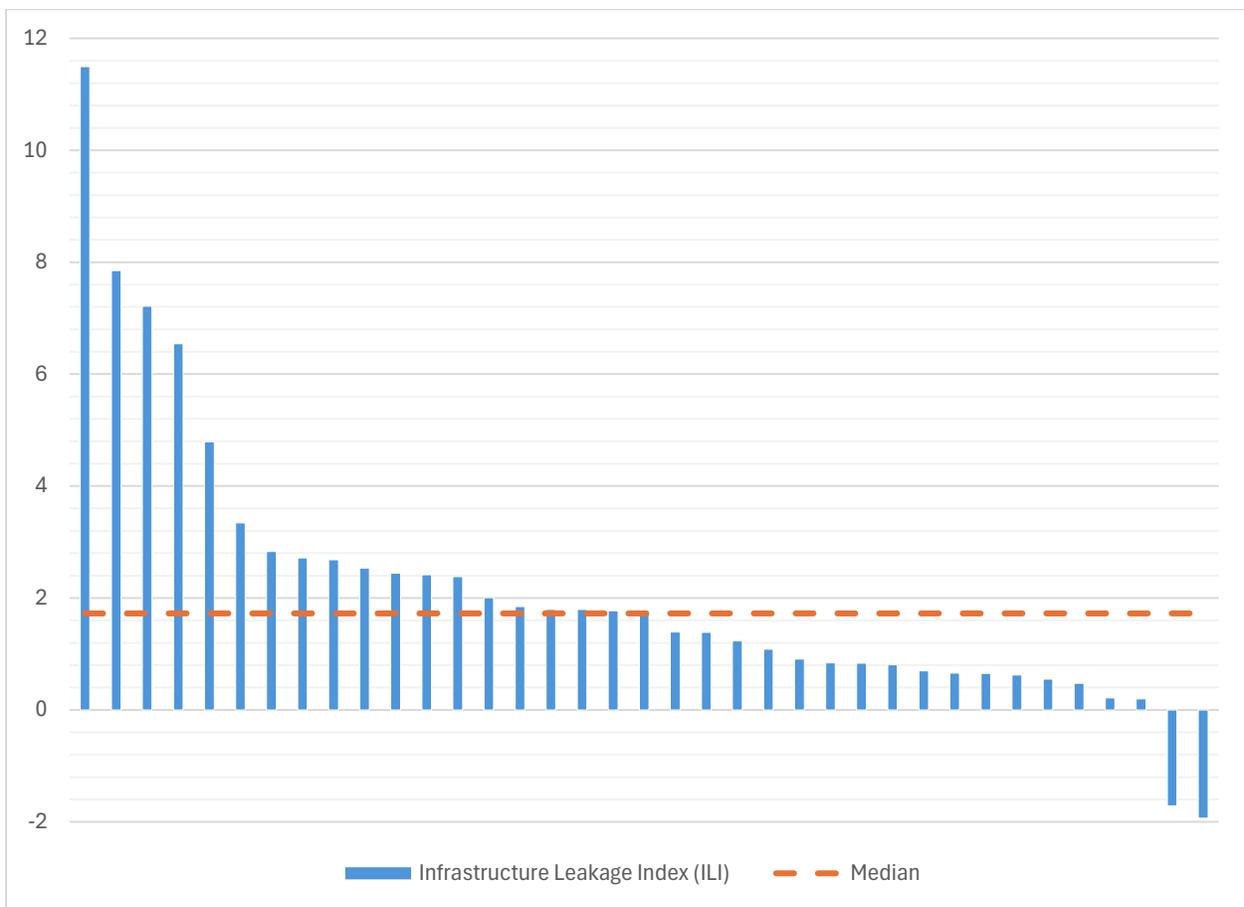


Figure 13: Distribution of Infrastructure Leakage Index

### 3.5 Direct Technical Assistance

Utilities that completed Level 1 validations and the advanced workshop were offered the opportunity to receive Technical Assistance (TA) from a variety of offerings that included source meter testing, customer meter test design, customer meter test analysis, billing data analysis, real loss component analysis, leak detection water audit compilation and additional L1V. Recommendations were made to program participants based on a ranking and prioritization, but participants had the opportunity to discuss different technical assistance.

Table 6 shows a summary of the TA provided during Phase 2. A summary table with the utilities that took advantage of technical assistance can be found in Appendix C.

**Table 6: Technical Assistance Conducted during Phase 2**

| Technical Assistance         | Count Completed |
|------------------------------|-----------------|
| Supply Meter Testing         | 14              |
| Billing Data Analysis        | 5               |
| Customer Meter Test Design   | 1               |
| Water Audit Compilation      | 3               |
| Real Loss Component Analysis | 1               |
| Leak Detection               | 2               |
| <b>Total</b>                 | <b>26</b>       |

#### 3.5.1 Source Meter Testing

Source Meter Testing is used to verify the accuracy of the water meters that measure the volume of water supplied into the distribution system. Tests must be in-situ and can be performed either by using a secondary meter that is installed in line with the meter being tested or by using an isolated tank/reservoir on-site to compare the change in tank volume with the volume recorded by the meter. During Phase 2, E Source completed 66 tests for 14 utilities. Eight meters were tested twice at the request of utilities, meaning 58 individual meters were tested. Of the 66 tests, 30 were performed using a tank and 36 were performed using a comparative meter (insertion, clamp-on, or portable test meter). Thirty-three of the tests (50%) had results within +/-3% accuracy, and 21 tests (32%) had results outside of +/-6% accuracy. The results of the tests are shown in the table and figure below. The individual reports for the testing can be found in Appendix D.

**Table 7: Summary of Source Meter Test Results**

| Accuracy | >94% | 94-97% | 97-103% | 103-106% | >106% |
|----------|------|--------|---------|----------|-------|
| Count    | 10   | 3      | 33      | 9        | 11    |

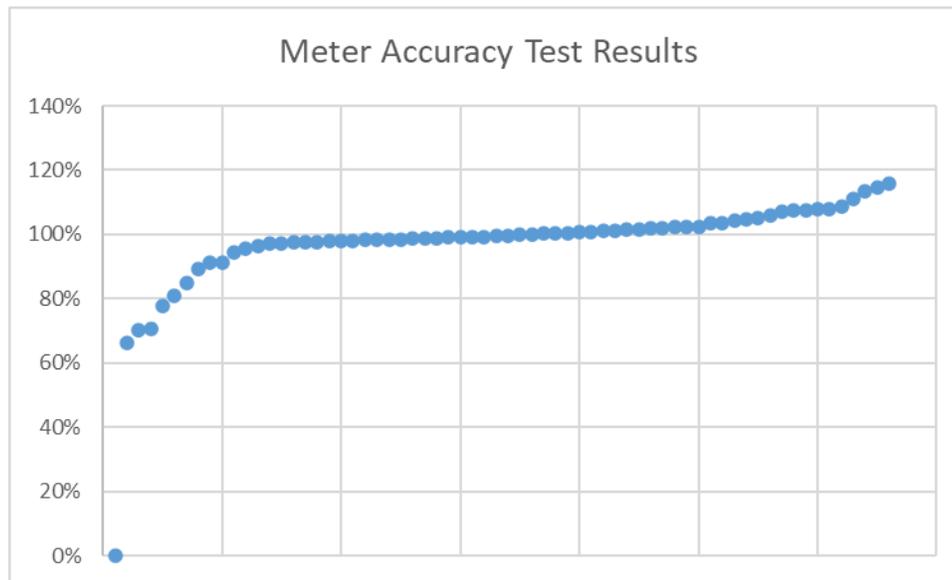


Figure 14: Summary of Source Meter Test Results

### 3.5.2 Billing Data Analysis

The Billing Data Analysis examines water consumption volumes from both metered and unmetered sources, differentiating between billed and unbilled usage. This clear categorization helps identify practices that may lead to water losses or that can impact revenue. Multiple utilities showed interest, with five completing the analysis. This type of analysis requires the utility to provide a raw data set from their meter reading or billing system which is not always possible for some systems. The reports of these five analyses can be found in Appendix E. The result of most of these analyses confirmed the consumption volume for water audits while some discrepancies were noted in the data evaluation for specific utilities.

### 3.5.3 Customer Meter Test Design

When designing a testing process for customer meters, several considerations need to be defined, such as:

- Testing strategy - Determine goals of testing program and agree upon a sampling strategy and number of meters to sample
- Meter sample selection - Evaluate meter inventory or billing data to generate a list of meters and alternates based on the agreed test design.

Small and Large meters should have different testing strategies. Meters should be tested at low, medium, and high flow, and test results should be weighted for averaging following the guidance of the AWWA Manual M6 Water Meters – Selection, Installation, Testing, and Maintenance. Although several utilities had interest in this analysis, one was ultimately able to provide the necessary data. The report can be found in Appendix F.

### 3.5.4 Leak Detection Survey

An acoustic leak detection survey was technical assistance that utilities could receive. It consists of a field investigation that uses specialized acoustic equipment to survey the water distribution system and locate non-surfacing leaks. The leak detection technicians surveyed a portion of the system, coming in contact with all available infrastructure assets such as hydrants, valves, meters, among others. Depending on the complexity, other equipment may be employed to confirm and pinpoint the leak. Two utilities took advantage of this type of assistance. A total of 5 leaks were identified in the surveyed areas. One of the reported leaks on a water main was confirmed by the utility, and their estimate of water loss was approximately 216 GPM. The individual reports are in the Appendix G.

### 3.5.5 Real Loss Component Analysis

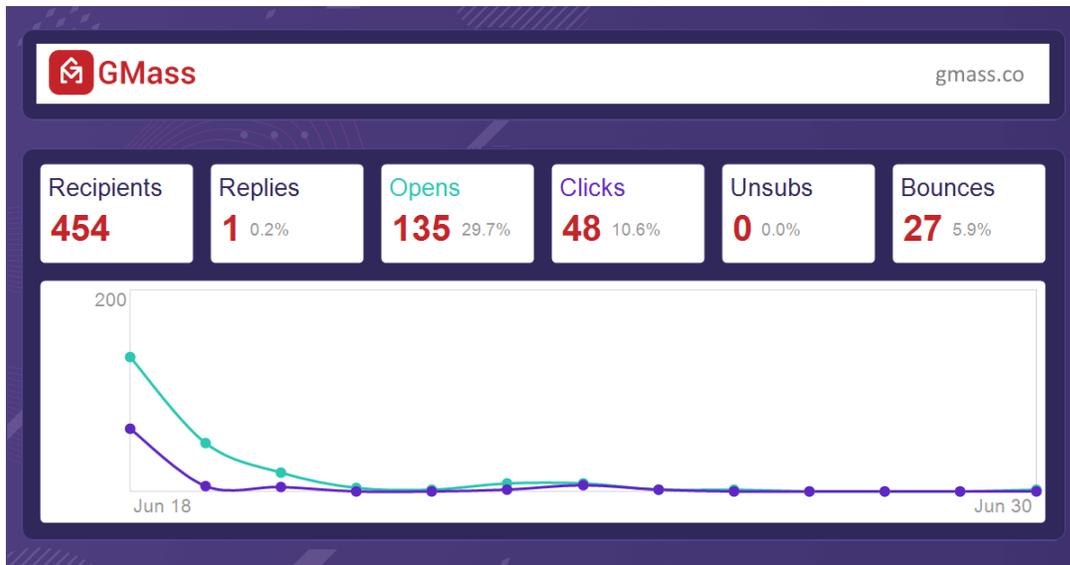
A Real Loss Component Analysis (RLCA) helps classify the types of leakage a system may be experiencing to determine the appropriate strategy to manage the real losses in a system. It considers the volume and type of leaks in a system, the value of the recoverable leakage, and the cost of leakage reduction interventions. One utility completed this analysis, and its report can be found in Appendix H.

### 3.5.6 Water Audit Compilation

Assistance in compiling and generating their water audit was also offered through this program. For this technical assistance, the system provided data, which was reviewed during the compilation process, to ensure the water audit is based on the best available information. As a result, utilities will get recommendations to enhance their data and identify the next steps to reduce their losses based on the results of their water audit. One utility took this assistance on three consecutive occasions.

### 3.6 Post-Program Survey

On June 18, 2025, an email campaign requesting CWLI participants to complete a survey covering Phase II of the program was distributed. At the time of this report, the following distribution report and survey responses were recorded:



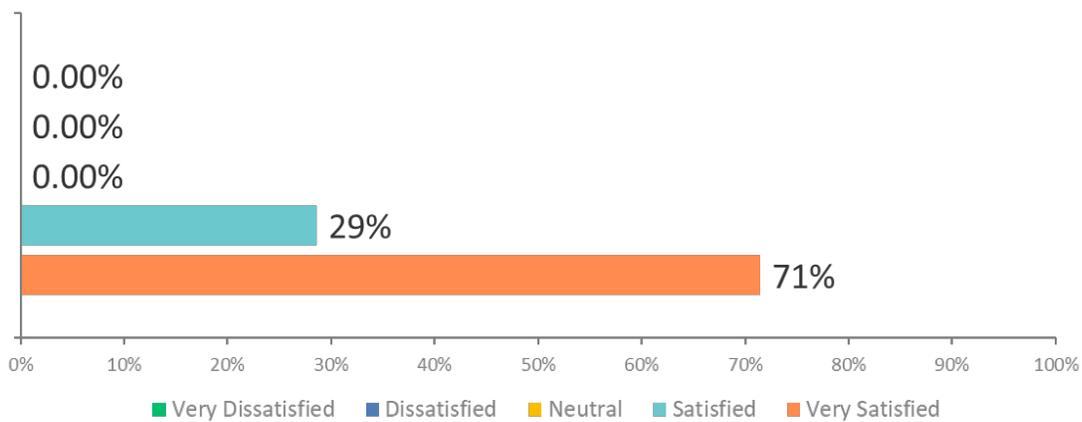
A separate email sent on June 24, 2025 was sent to the utility members of the Colorado Water Loss Control & Management Committee that participated in the program.

It is expected that survey results will continue to be received intermittently and will be shared with the Colorado Water Conservation Board as they are received.

### Overall Experience & Satisfaction

Participants expressed a high level of satisfaction with Phase II of the Colorado Water Loss Initiative. All respondents rated their experience positively, with 71% indicating they were 'Very Satisfied' and the remaining 29% 'Satisfied.' This strong endorsement suggests that the program is meeting participant expectations and delivering value.

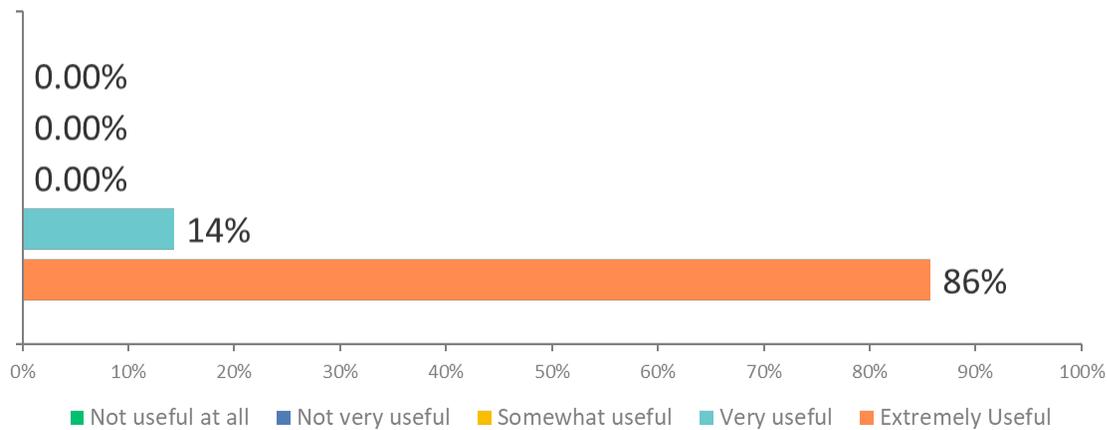
### How satisfied are you with your overall experience in Phase II of the Colorado Water Loss Initiative?



### Training & Technical Assistance

The training and technical assistance components were overwhelmingly well-received. A combined 100% of respondents found the training either 'Very Useful' or 'Extremely Useful,' with a weighted average score of 4.86 out of 5. Most utilities participated in Level 1 Validation (86%) and Water Audit Basics Workshops (57%), indicating strong engagement.

### How would you rate the usefulness of the training and technical assistance provided?



#### Water Audit Basics Workshop



57%

#### Level 1 Water Audit Validation



86%

#### Advanced Validation

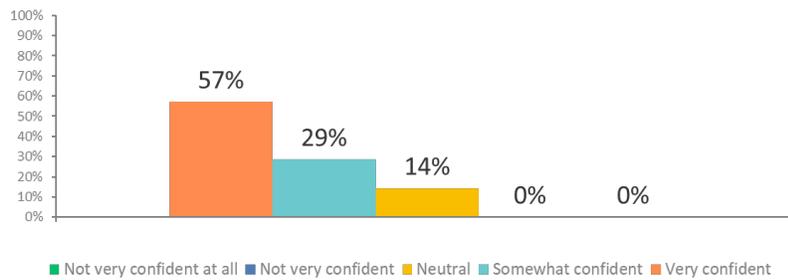


29%

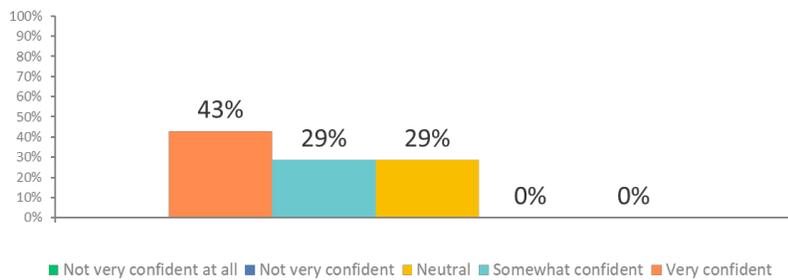
### Confidence & Knowledge Gains

The program significantly boosted participants' confidence in conducting water audits and validations. Over 85% of respondents felt 'Somewhat' to 'Very Confident' in preparing an AWWA water audit, and 71% felt similarly about conducting validations. Additionally, 86% reported moderate to significant improvement in understanding the AWWA M36 methodology.

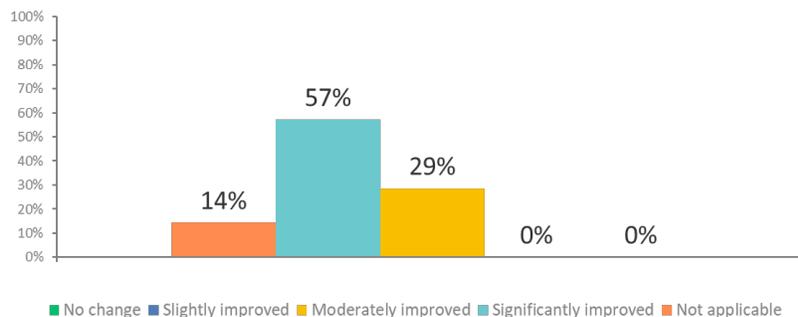
**How confident are you in your utility's ability to prepare an AWWA water audit after participating in the program?**



**How confident are you in your utility's ability to engage in a water audit validation after participating in the program?**

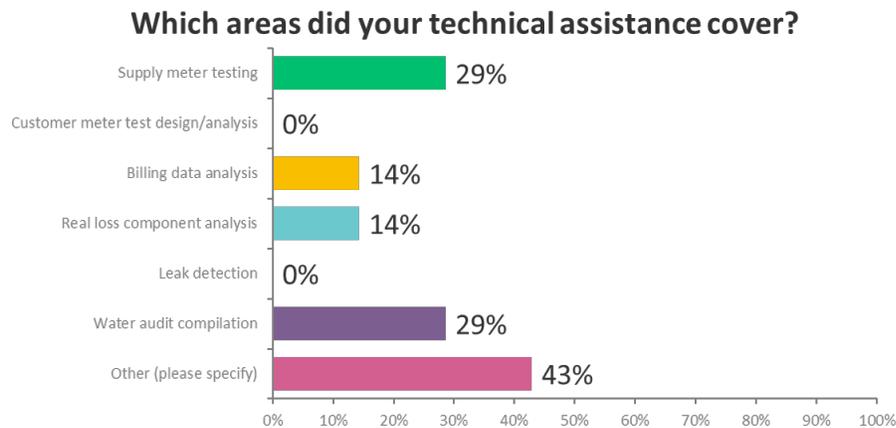


**To what extent has your staff's understanding of the AWWA M36 methodology improved?**



## Technical Assistance

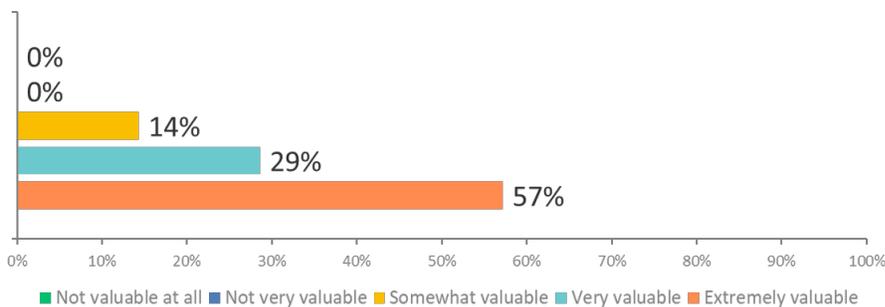
Direct technical assistance was received by 71% of respondents, with the most common areas being supply meter testing, water audit compilation, and other customized support. The assistance was rated highly valuable, with 86% finding it 'Very' or 'Extremely Valuable.'



### Other

- Awareness that our municipality allottees are using the services
- Data accuracy and volume accounting/categorizing
- Have not received assistance YET, but will soon

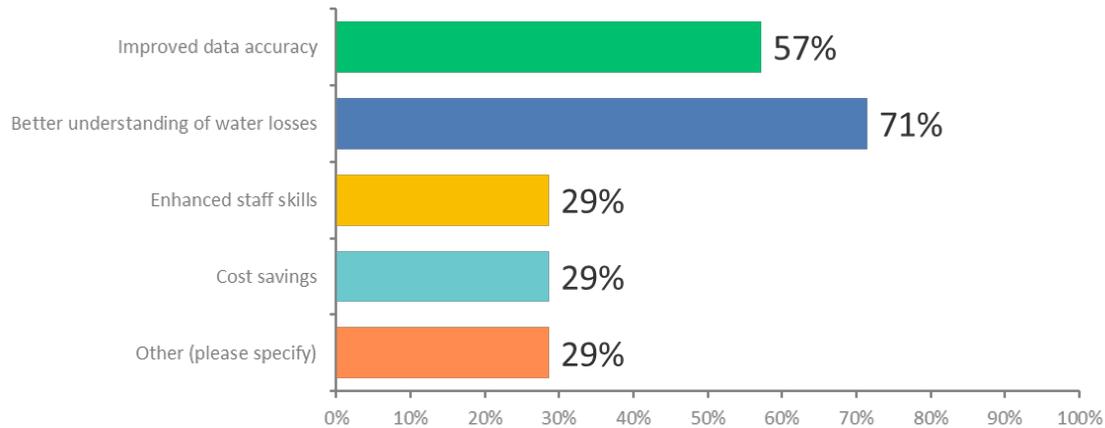
**How valuable was the technical assistance in helping your utility identify and address water loss issues?**



### Program Benefits

The most frequently cited benefits included a better understanding of water losses (71%) and improved data accuracy (57%). Some utilities also reported enhanced staff skills, cost savings, and other unique gains.

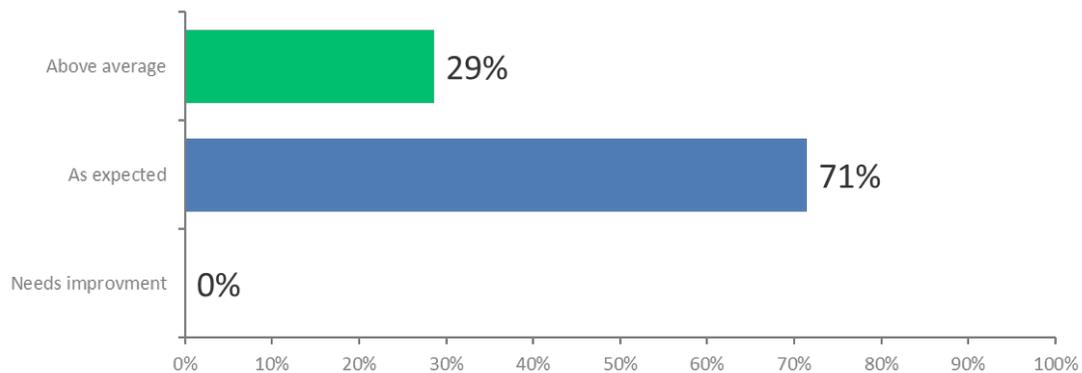
#### What benefits has your utility experienced from participating in the program?



### Communication & Recommendation

Communication from the program team was rated positively, with 86% describing it as 'Above Average' in responsiveness and frequency. Clarity of next steps was also well-rated. Importantly, 100% of participants said they would recommend the program to other utilities.

#### How would you rate information communicated through the program in terms of clarity of next steps?



## 4 RECOMMENDATIONS

Based on the program's achievements, feedback, and new regulations in the state of Colorado, it is recommended that the CWCB continue offering water loss management training and technical assistance through Phase III of the program. This program should continue to be available to all Colorado water providers.

As new regulations require certain water providers to submit a water audit, and given the demonstrated benefits of an L1V program, Phase III should also provide a validator training program. This initiative will ensure that the water audits submitted to the CWCB comply with L1V standard guidance.

### Lessons learned

Throughout the over 6 years of CWLI, the team has learned several lessons and made adjustments that were necessary for the success of the program. The main general consideration is that the program was not linear as initially conceived. The initial concept had Utility A participating in New Learner Workshops, moving on to Level 1 Validation, Advanced Workshops, and then to Technical Assistance. The reality was that many systems did not follow that linear path. They either restarted at the basics after being advanced or many repeated Level 1 Validations, as is recommended.

Here are the main observations:

**Contact management is a crucial on-going activity.** The list of contacts must be updated frequently as staff changes at the water providers are common. The main person that was leading the water loss effort may or may not be replaced, needing the CWLI Team to either establish contact with the new staff or to engage the utility to identify a new leader for the initiative. In some cases, utilities paused participation for months or years until a new staff picked up the effort.

**Utilities will benefit from having a main Lead or Champion of water loss management.** Having an identified champion for water loss management will help the utility progress with time and not lose acquired knowledge and experience on this topic. This program will show water providers that the CWCB is fully committed to water loss management and will also aid with the training of this staff.

**Basics and advanced training continue to be needed.** The need for the new learner training was constant for a few reasons. Systems participating for the first time were still joining the program after more than 5 years. Also, utility staff that participated in the past wanted to get a refresher on the basic concepts. Or additional and new staff at a participating utility would need to get up to speed on water loss knowledge. Although the basic workshops were originally planned for the initial part of the program, these workshops were still being conducted at the end of Phase 2.

**Water Audit Compilation and Level 1 Validations should be an annual practice.** The best way to understand changing water loss performance is to conduct annual water audits with Level 1 Validations. Several participants understood this and requested the validation of multiple audits throughout the program. The more updated audit can also assist in determining the next best step for improving water loss performance.

**Some of the Technical Assistance offerings were not feasible for some water providers.** Different types of Technical Assistance have different requirements. Some of the analyses have data requirements and some of the field activities have requirements on the infrastructure setting. The program can assist utilities understand what changes may be necessary for some of the best practices.

### Regulation

The CWCB revised its guidelines for reporting water use and conservation data by covered entities, which were adopted by the CWCB in May 2022. This revision was made to comply with the Act Concerning Additional Information Regarding Covered Entities' Water Efficiency Plans. The Act mandates that the Board establish guidelines for the reporting of water use and conservation data by covered entities. One of the requirements is the Annual Audit Report based on the AWWA M36 Manual.

The continuation of the CWLI can continue educating water providers in the M36 Methodology and help them understand the water loss management and how to manage the date for submittal to the CWCB and compliance.

### CWLI Phase 3

Phase 3 of the program will build on the successes of the previous phases and adopt the improvements that have been implemented to ensure the program continues to provide valuable training and assistance to Colorado water providers.

Additionally, there is an added water loss audit validator training curriculum task that will increase the pool of certified individuals in the state to perform Level 1 Water Audit Validations to keep up with the demand for this service. More water audit validations will drive more widespread adoption of accurate water loss audits.

Water loss control has been identified by the drinking water industry as a top priority. With multiple states providing statewide water loss control training and having identified the AWWA M36 methodology in

Colorado's Water Plan, the time is right to continue statewide training on the industry standard for water loss control and move on to prioritized interventions.

The following tasks are recommended for Phase 3 of the CWLI:

## **Task 1: Program Administration and Communications**

### **1.1. Program Management**

Consultant, with CWCB staff assistance, will provide ongoing management of the Initiative, including the development of a program management plan and associated schedule, regular team coordination calls for program management and documentation, internal progress tracking, internal task assignments and accountability, program management plan amendments, and course corrections as warranted.

#### Deliverables:

- Program Management Plan
- Monthly meetings
- Monthly progress reports

### **1.2. Participant Management**

Consultant, with CWCB staff assistance, will manage water system recruitment and retention for the Initiative. The objective of recruitment and retention will be the recruitment of new or inactive participants and as complete as possible continued involvement of previous participants in the Initiative. This will include development of a recruitment and retention plan, development of all communication materials in support of the recruitment plan, conducting regular coordination calls with the CWCB to manage execution of the outreach plan, and conducting direct outreach to all previous CWLI registrants.

As part of the recruitment and retention plan, CWCB staff and Consultant will assess the level of M36 Water Loss Control methodology implementation in Colorado.

Deliverables:

- Outreach, Recruitment and Retention Plan
- Plan Execution and Communication materials
- Monthly progress reports

### **1.3. Final Report and Post-Program Survey**

Consultant will conduct a post-program survey to each of the participant systems, to assess and compile data on the satisfaction of participant experience in the program, program effectiveness, program improvements needed and follow-up on training and technical assistance needs.

- Training: Including providing summary statistics on utility participation in each phase of the project

- Learning progression: By reviewing and analyzing the final water audit submissions of the “101” group and comparing to where the “101” group began the process in terms of knowledge base and awareness of the M36 methodology
- Audit results: several scales such as by the entire group or by river basin or by utility size
- Opportunities: greatest need/opportunity for real and apparent loss control was observed and suggest some recommended next steps utilities could implement to reduce losses as described in AWWA’s M36.
- Survey: summary of the post-program survey results.

Deliverables:

- Post-Program Survey
- Summary of Survey Results
- Final Report

**Task 2: Core Colorado Water Loss Initiative Training Areas**

This task will serve as an ongoing entry point for new learners just entering the training program and an ongoing skill building curriculum for past participants. Local water provider staff turnover has sharply increased since the inception of the CWLI and CWCB will be responsive to water provider needs for training new staff. The goal of this task is to implement an ongoing base knowledge curriculum that will introduce all necessary content for utilities that did not participate in previous phases, including Level 1 validation, while teaching more advanced topics for knowledge growth. Additionally, it will introduce participants to the most updated AWWA software (v.6 or latest version available).

Core training areas consist of:

Base Knowledge (all basic 101 knowledge plus assistance with compiling data for Level 1 audit), Level 1 Validation, 201 and 301 knowledge-including but not limited to Supply Meter Testing, Billing Data Analysis, Customer Meter Test – Design, Real Loss Component Analysis, Leak Detection.

**2.1- Water Audit Workshops**

This task will teach foundational water audit concepts and tools, provide a review of the AWWA Free Water Audit Software and its functions, and review data validity scoring. These workshops are geared towards providing the new utilities with a basic understanding of the water audit process and the AWWA Free Water Audit Software. Common mistakes in water audit preparation will be discussed with the workshop participants and tips and guidance will be provided for the preparation of their own water audits. Participating utilities will go through the Level 1 Validation process annually for the duration of the program (See Task 3). The Consultant will schedule 1 virtual workshop per quarter for the duration of the program (or as budget allows) and continuously assess new enrollments and demand for more or less workshop events.

Deliverables:

- 1 scheduled workshop per quarter; more or less depending on demand

- Workshop materials

### **2.2- Advanced Validation Workshops**

This task will focus on more advanced techniques and build off of the Level 1 Water Audit Validations in Task 2.1. These direct technical assistance tasks will include water audit compilation, supply meter testing, customer meter test design/test data analysis, billing data analysis, real loss component analysis, and leak detection among other techniques. In order to equip utilities to take advantage of the most appropriate direct technical assistance type, the Consultant will conduct virtual workshops quarterly as demand dictates from utilities that have successfully completed a Level 1 Validation or would like a refresher workshop. These workshops will cover a detailed review of the direct technical assistance types and processes. Consultant with assistance from CWCB staff will provide workshop administration including coordination, registration setup and management, and Contact Hours (CH) coordination. Consultant will provide all associated technical materials development, including curriculum development, workshop presentation content, practical exercises content, and utility participant workbook content.

#### Deliverables:

- 1 scheduled workshop per quarter, depending on demand
- Workshop materials

### **Task 3: Direct Technical Assistance**

New Learners and Advanced CWLI participants will have the opportunity to receive individualized technical assistance, such as: source meter testing, billing data analysis, customer meter accuracy testing support, real loss component analysis, and leak detection. Other analyses may be determined appropriately on a case-by-case basis. In order to take advantage of these direct technical assistance types, participating utilities must go through the Level 1 Validation process for the most recent complete water audit Calendar Reporting Year.

#### **3.1 Level 1 Water Audit Validation**

One of the goals of the program is to assist utilities to establish and maintain a baseline of annual validated water audit data. Direct Technical Assistance must meet the pre-requisite of annual water audit validation. For example, to take advantage of Direct Technical Assistance in Calendar Year 2025, the Calendar Year 2024 water audit must be validated. The Consultant will:

- Make contact with each utility participant to achieve the following:
- Confirm scheduling for the Level 1 Validation
- Review utility supporting documentation
- Conduct the remote Level 1 Validation session
- Document the Level 1 Validation results and provide recommendations to the utility

#### **3.2 Direct Technical Assistance Recommendation & Feasibility**

The first step in this task is to identify and prioritize the best hands-on direct technical assistance (DTA) area for each participating utility based on the results of the most recent Level 1 validated water audit. The team will then meet with participants to go over the recommendations and discuss data and/or infrastructure needs to determine the feasibility of this DTA for the utility. Once the feasibility has been confirmed, the team will proceed with performing the DTA. If the DTA is currently not feasible for the utility, the team will provide recommendations for the feasibility of the DTA and may offer an alternate DTA.

Deliverables:

- Direct Technical Assistance Recommendation
- Feasibility Evaluation of Direct Technical Assistance

**3.3 Direct Technical Assistance Performance Summary Report**

Consultant will perform the recommended DTA and provide a summary report of the results.

Deliverables:

- Direct Technical Assistance Performance and Summary Report

**Task 4: Validator Training**

Consultant will develop a program to train and certify independent third-party validators to perform Level 1 validations of water audit prepared by water providers. The task will include a feasibility investigation, research validation efforts for water loss reporting across the country, developing the curriculum, and providing the training.

**4.1 Research validation efforts across the country**

Consultant will research third party validation efforts for water loss reporting across the country focusing on benefits, challenges, and potential solutions to those challenges. The information gathered will be used to investigate feasibility of requiring third party water audit validation in water loss reporting in Colorado.

Deliverables:

- Final Report

**4.2 Develop Validator Training Program**

Consultant will develop the training and certification program for independent third-party validators based on the latest validation guidance developed by AWWA, WRF, and other validator training programs across the country. The program development may include defining training requirements, types of examinations, rigor of program instructional content, examination, reoccurring certification and credential renewal, quality control of the program, reciprocal certifications (if warranted), among others.

*Deliverables:*

- Definition of the training program
- Develop training modules
- Develop exam and grading rubric

***4.3 Carry Out Training and Certification Program***

Consultant will offer the validator training, administer the exam, score exams, and certify those students that comply with all the program requirements to become a certified validator in Colorado. Several training opportunities will be offered.

*Deliverables:*

- Providing training and examination
- Certify passing students

Appendix A: Workshop Participation

| Utility  | Workshop Participants |                |
|--|-----------------------|----------------|
|  | New Learner           | Advanced Group |
| Alameda  | 1                     |                |
| Alamosa  | 2                     |                |
| Arapahoe County Water & Wastewater Authority       | 1                     | 1              |
| Arvada   | 4                     |                |
| Aspen  | 3                     | 1              |
| Aurora   | 1                     | 1              |
| Baca   | 1                     |                |
| Baca Grande Water and Sanitation District          |                       | 1              |
| Bancroft-Clover                                    | 2                     |                |
| Berthoud   | 3                     |                |
| Boulder  | 1                     | 1              |
| Burlington   |                       | 1              |
| Canon City   |                       | 2              |
| Castle Pines                                       | 1                     |                |
| Castle Rock  |                       | 2              |
| Centennial Water & Sanitation District             |                       | 1              |
| Central Weld County Water District                 | 1                     |                |
| Cherry Creek Valley                                | 2                     |                |
| Colorado Springs Utilities                         |                       | 2              |
| Consolidated Mutual Water Company                  | 1                     |                |
| Copper Mountain Metropolitan Consolidated District | 1                     | 1              |
| Cortez   | 1                     | 1              |
| Crestview  | 1                     |                |
| Dallas Creek Water Company                         |                       | 1              |
| Denver Water                                       | 2                     |                |
| Eagle River Water & Sanitation District            |                       | 2              |
| East River & Sanitation District                   | 3                     |                |
| Edgewater  | 2                     |                |
| Englewood  | 3                     | 2              |
| Erie   |                       | 1              |
| Evan   | 1                     |                |
| Evans  | 1                     |                |
| Fort Collins                                       |                       | 4              |
| Fort Collins-Loveland                              | 1                     |                |
| Fountain   | 2                     | 1              |

| Utility                                  | Workshop Participants |                |
|--|-----------------------|----------------|
|  | New Learner           | Advanced Group |
| Fraser                                   | 1                     |                |
| Frederick                                |                       | 1              |
| Frisco                                   | 3                     | 2              |
| Glenwood Springs                         | 2                     |                |
| Golden                                   |                       | 1              |
| Green Mountain                           | 1                     |                |
| Gunnison                                 |                       | 1              |
| Gunnison County Sewer and Water District | 2                     |                |
| Highlands Ranch                          | 4                     |                |
| Ken Caryl Ranch                          | 2                     |                |
| Lafayette                                | 3                     |                |
| Lakehurst                                | 1                     |                |
| Lakewood                                 | 1                     |                |
| Las Animas                               |                       | 2              |
| Little Thompson Water District           |                       | 2              |
| Longmont                                 | 1                     |                |
| Louviers                                 | 3                     | 1              |
| Loveland                                 | 1                     | 3              |
| Mount Werner Water & Sanitation District |                       | 1              |
| Nucla                                    | 3                     | 1              |
| Paonia                                   | 1                     | 2              |
| Parker Water & Sanitation District       | 2                     |                |
| Platte Canyon                            | 2                     |                |
| Pueblo Board of Water Works              | 1                     | 1              |
| Pueblo West Metropolitan District        |                       | 2              |
| Security Water District                  | 1                     |                |
| Snowmass Water & Sanitation District     | 1                     |                |
| Sterling                                 | 1                     | 2              |
| Telluride                                | 2                     | 1              |
| Tri-County Water Conservancy District    | 2                     |                |
| Willow                                   | 1                     |                |
| Non-Utility                              | 3                     |                |
| <b>Total Participants</b>                | <b>87</b>             | <b>49</b>      |

**Appendix B: Level 1 Validations Conducted in Phase 2**

| Utility                                      | Year |
|--|------|
| Alameda                                      | 2023 |
| Alamosa                                      | 2023 |
| Arapahoe County Water & Wastewater Authority | 2023 |
| Arvada                                       | 2023 |
| Bancroft-Clover Water & Sewer District       | 2022 |
| Bancroft-Clover Water & Sewer District       | 2023 |
| Bellyache Ridge                              | 2022 |
| Berthoud                                     | 2023 |
| Berthoud                                     | 2024 |
| Boulder                                      | 2021 |
| Canon City                                   | 2021 |
| Cherry Creek Valley                          | 2023 |
| Cherry Creek Valley                          | 2024 |
| Copper Mountain                              | 2021 |
| Eagle River Water & Sanitation District      | 2023 |
| Englewood                                    | 2021 |
| Estes Park                                   | 2022 |
| Evans  | 2021 |
| Evans  | 2023 |
| Evans  | 2024 |
| Fort Collins                                 | 2022 |
| Fort Collins                                 | 2023 |
| Fort Collins-Loveland Water District         | 2024 |
| Fountain                                     | 2021 |
| Fountain                                     | 2024 |
| Frederick                                    | 2022 |
| Frisco                                       | 2021 |
| Glenwood Springs                             | 2023 |
| Glenwood Springs                             | 2024 |
| Golden                                       | 2023 |
| Golden                                       | 2024 |
| Greeley                                      | 2021 |
| Greeley                                      | 2023 |
| Gunnison                                     | 2021 |
| Lakehurst                                    | 2023 |
| Lakewood                                     | 2023 |



| Utility                                  | Year |
|--|------|
| Las Animas                               | 2021 |
| Longmont                                 | 2022 |
| Longmont                                 | 2023 |
| Longmont                                 | 2024 |
| Louviers                                 | 2021 |
| Morrison                                 | 2022 |
| Mount Werner Water & Sanitation District | 2023 |
| Paonia                                   | 2021 |
| Parker Water & Sanitation District       | 2022 |
| Parker Water & Sanitation District       | 2023 |
| Parker Water & Sanitation District       | 2024 |
| Pueblo Board of Water Works              | 2021 |
| Telluride                                | 2024 |
| Tri-County Water Conservancy District    | 2023 |
| Tri-County Water Conservancy District    | 2024 |

**Appendix C: Technical Assistance Summary and Reports**

| Utility          | Technical Assistance         | Year |
|------------------|------------------------------|------|
| Aurora           | Supply Meter Testing         | 2022 |
| Aurora           | Supply Meter Testing         | 2024 |
| Baca Grande      | Supply Meter Testing         | 2022 |
| Boulder          | Supply Meter Testing         | 2025 |
| Breckenridge     | Supply Meter Testing         | 2022 |
| Castle Rock      | Supply Meter Testing         | 2022 |
| Eagle river      | Supply Meter Testing         | 2025 |
| Fountain         | Supply Meter Testing         | 2024 |
| Frederick        | Supply Meter Testing         | 2025 |
| Frisco           | Supply Meter Testing         | 2023 |
| Loveland         | Supply Meter Testing         | 2022 |
| Mount Werner     | Supply Meter Testing         | 2022 |
| Pueblo           | Supply Meter Testing         | 2023 |
| Pueblo           | Supply Meter Testing         | 2024 |
| Golden           | Billing Data Analysis        | 2025 |
| Frederick        | Billing Data Analysis        | 2023 |
| Fountain         | Billing Data Analysis        | 2023 |
| Fort Collins     | Billing Data Analysis        | 2023 |
| Pueblo West      | Billing Data Analysis        | 2023 |
| Arapahoe         | Customer Meter Test Design   | 2020 |
| Aspen            | Water Audit Compilation      | 2022 |
| Aspen            | Water Audit Compilation      | 2023 |
| Aspen            | Water Audit Compilation      | 2024 |
| Mount Werner     | Real Loss Component Analysis | 2024 |
| Colorado Springs | Leak Detection               | 2023 |
| Loveland         | Leak Detection               | 2023 |



**Appendix D: Source Meter Test Reports**

# Production Meter Test Results

City of Aurora

*December 2022*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |  |    |
|-------|--|----|
| 1     | Executive Summary.....                       | 1  |
| 2     | Background .....                             | 2  |
| 2.1   | Site Description .....                       | 2  |
| 2.2   | Site Infrastructure .....                    | 2  |
| 2.2.1 | Wemlinger WTP .....                          | 2  |
| 2.2.2 | Griswold WTP.....                            | 5  |
| 2.2.3 | Binney WTP .....                             | 5  |
| 3     | Methods.....                                 | 6  |
| 3.1   | Drawdown Test Procedure .....                | 6  |
| 3.1.1 | Determination of Tank Dimensions .....       | 6  |
| 3.1.2 | Tank Level Measurement.....                  | 7  |
| 3.1.3 | Quantification of Uncertainty .....          | 7  |
| 3.2   | Insertion Meter Test Procedure.....          | 8  |
| 4     | Results.....                                 | 10 |
| 5     | Summary of findings and recommendations..... | 11 |

## List of Figures

|  |   |
|--|---|
| Figure 1: Wemlinger Zone 3 Flowmeter ..... | 3 |
| Figure 2: Wemlinger Zone 4 Flowmeter ..... | 3 |
| Figure 3: Wemlinger Zone 5 Flowmeter ..... | 4 |
| Figure 4: Wemlinger Clearwell Hatch .....  | 4 |
| Figure 5: Binney Flowmeter .....           | 5 |
| Figure 6: Binney WTP Velocity Profile..... | 9 |

## List of Tables

|                             |    |
|-----------------------------|----|
| Table 1: Test Results ..... | 1  |
| Table 2: Test Results ..... | 10 |

## 1 Executive Summary

The City of Aurora produces water at three Water Treatment Plants – Binney, Griswold, and Wemlinger – and flow to the distribution system is measured by a total of six finished water meters. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meters using the most appropriate test method. E Source and Aurora determined a tank drawdown test would be the most appropriate method for the Wemlinger and Griswold WTP’s and a comparative meter test was most appropriate for Binney WTP.

E Source completed drawdown tests for each meter at Wemlinger and Griswold WTP’s and an insertion test for the meter at Binney WTP. This report describes the test method and result. Table 1 below summarizes the result of the test. More detail on how the test result was derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name        | Test Flow Rate (MGD) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|------------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Wemlinger Zone 3 | 8.3                  | 989,050                | 1,009,410                    | <b>102.1%</b>                | <b>2.1%</b>                  |
| Wemlinger Zone 4 | 9.9                  | 1,040,563              | 1,027,010                    | <b>98.7%</b>                 | <b>2.0%</b>                  |
| Wemlinger Zone 5 | 5.0                  | 1,040,563              | 1,030,990                    | <b>99.1%</b>                 | <b>2.0%</b>                  |
| Binney           | 15.5                 | 646,350                | 648,786                      | <b>100.4%</b>                | <b>3.7%</b>                  |
| Griswold Zone 3  | 15.5                 | 1,938,300              | 1,898,661                    | <b>98.0%</b>                 | <b>3.1%</b>                  |
| Griswold Zone 4  | 14.5                 | 1,415,560              | 1,402,644                    | <b>99.1%</b>                 | <b>4.0%</b>                  |

The test result shows that all meters tested are accurately measuring flow within the test margin of error. The Wemlinger Zone 3 meter showed over-registration equal to the test margin of error. The total uncertainty of the volumetric tests is between +/- 2.0% and +/-4.0% for all tests, taking into consideration uncertainty associated with meter totalizer resolution and reference volume calculation. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth. Through the 2-year program, the CWLI will provide individualized technical support and training workshops on water loss control best practices to urban water utilities.

Participants of the CWLI will have the chance to undergo, at a minimum, a Level 1 validation of their water audits. Levels of water audit validation are defined in the Water Research Foundation Report 4639B Utility Water Audit Validation: Principles and Programs. Validation efforts range from Level 1, which examines summary data for evident errors and correct application of the M36 Methodology; to Level 3, which includes field tests. Participants who completed a Level 1 validation through the CWLI program will have the opportunity to participate in more advanced validation of their water audit data through direct technical assistance.

Aurora completed a Level 1 validation through CWLI. Based on the results of the water audit and conversations with CWLI, Aurora selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy tests performed for Aurora.

### 2.1 Site Description

Aurora produces water at three Water Treatment Plants – Wemlinger, Griswold and Binney. There are three production meters at Wemlinger, two production meters at Griswold and one at Binney. In total, six finished water meters were tested.

### 2.2 Site Infrastructure

#### 2.2.1 Wemlinger WTP

**Wemlinger Zone 3 Meter:** Aurora has installed a Rosemount electromagnetic flowmeter on the 36" discharge line as shown in Figure 1. The meter is installed with 5 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream, which meets manufacturer requirements. The meter is connected to SCADA which was used to collect the start and end reads.



**Figure 1: Wemlinger Zone 3 Flowmeter**

**Wemlinger Zone 4 Meter:** Aurora has installed a BIF Venturi meter on the 36" discharge line as shown in Figure 2. The meter installation conditions could not be verified on site. The meter is connected to SCADA which was used to collect the start and end reads.



**Figure 2: Wemlinger Zone 4 Flowmeter**

**Wemlinger Zone 5 Meter:** Aurora has installed a BIF Venturi meter on the 24" discharge line as shown in Figure 3: . The meter installation conditions could not be verified on site. The meter is connected to SCADA which was used to collect the start and end reads.



**Figure 3: Wemlinger Zone 5 Flowmeter**

**Wemlinger Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume. There is a hatch on top of the clearwell that was opened to measure the water level inside as shown below in Figure 4.



**Figure 4: Wemlinger Clearwell Hatch**

### 2.2.2 Griswold WTP

**Griswold Zone 3 Flow Meter:** E Source did not visit the Griswold Zone 3 Flow Meter. The meter is connected to SCADA which was used to collect the start and end reads.

**Griswold Zone 4 Flow Meter:** E Source did not visit the Griswold Zone 3 Flow Meter. The meter is connected to SCADA which was used to collect the start and end reads.

**Griswold Clearwell:** On-site at the treatment plant is a clearwell which was used to determine the test reference volume.

### 2.2.3 Binney WTP

**Binney Flow Meter:** Aurora has installed an Endress & Hauser electromagnetic flowmeter on the 24" discharge line as shown in Figure 5. The meter is connected to SCADA which was used to collect the start and end reads.



Figure 5: Binney Flowmeter

## 3 Methods

Between November 9<sup>th</sup> and 15<sup>th</sup>, E Source and Aurora carried out a volumetric test at a single flow rate for the Wemlinger and Griswold meters and a comparative insertion test on the Binney meter. The drawdown tests were performed by drawing a reference volume through each meter at a specific flow rate out of the clearwell onsite. By comparing the volume change in the tank to the volume registered by the meter, Aurora and E Source determined each meter's accuracy to within a target margin of error.

### 3.1 Drawdown Test Procedure

The meter tests were performed by E Source and Aurora as follows:

1. **Shut down WTP:** All treatment processes were halted so no water was entering the clearwell
2. **Turn off Pumps:** Turn off all pumps so that no water is exiting the clearwell
3. **Begin Static Test:** Review clearwell SCADA data to ensure all valves are holding and no water is entering or exiting the clearwell.
4. **Collect starting reads:** The starting totalizer read was collected on SCADA. The water level of the tank was measured and taken from SCADA.
5. **Turn on Pumps:** Turn on the pumps to move water through the meter to be tested.
6. **Observe Level Change:** Flow continued through the meter until desired level change was observed in the clearwell.
7. **Turn off Pumps:** Turn off all pumps so that no water is exiting the clearwell
8. **Collect ending reads:** The end totalizer reads were collected from SCADA and the water level of the clearwell was measured.
9. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
10. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the clearwell.
11. **Compare reference volume and the metered volume:** The difference between the volume metered by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

#### 3.1.1 Determination of Tank Dimensions

The volume of water sent from the tank during the test was referred to as the “reference volume”. At the end of the test, the totalizer read out was compared to this reference volume to determine the meter's accuracy. To ensure confidence in this testing methodology, the dimensions of the tank needed to be determined.

To determine the volume of the tank, E Source used a data provided by the utility. Aurora provided clearwell drawings for all WTP's which E Source used to calculate the clearwell volumes. The Griswold clearwell is trapezoidal shaped, so the volume per foot of level change changes based on the water level. Therefore, E Source used a clearwell volume table provided by Aurora.

### 3.1.2 Tank Level Measurement

In addition to knowing the dimensions of the clearwells, it was also necessary to measure the level of water in the clearwell to a high degree of confidence for each test. E Source used a level sounder to measure and record the water level in the clearwell during each test as well as SCADA data provided by Aurora.

The level sounder was fed through a hatch on top of each clearwell until it contacted the surface of the water, at which point it emitted a noise. At that point, the line was marked so it could be measured and recorded. The difference between the starting length and ending length indicated the level change after the test was performed. It was assumed that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.1.3 Quantification of Uncertainty

There is uncertainty associated with conducting a drop test due to potential measurement errors and test equipment precision. This section discusses the sources of uncertainty and how the uncertainty was calculated.

#### 3.1.3.1 Totalizer Uncertainty

There is uncertainty associated with the meter totalizer registration because the meter will only record and display volumes to a certain interval. The Wemlinger meters had a resolution of 10 gallons. The Griswold and Binney meters used SCADA data which had a resolution of less than 1 gallon. Therefore, the volume of uncertainty from the totalizer reading is negligible.

#### 3.1.3.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a level sounder which was believed to be accurate within 0.25". The Griswold WTP has a trapezoidal reservoir, which can cause additional uncertainty due to the non-uniform shape. Therefore, in addition to knowing the relative level change, it is also required to know the absolute water level. To account for this uncertainty, E Source relied on the Aurora SCADA system to determine the absolute starting and ending levels. E Source assumed this SCADA level is also accurate within 0.25".

#### 3.1.3.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the test, E Source considered the margin of error volumes obtained from the level measurements and additionally considered the SCADA level uncertainty at the Griswold WTP.

#### 3.1.3.4 Griswold Uncertainty Calculation

During the Griswold Zone 3 test, the level in the tank began at 20.689' and ended at 18.069'. Based on the data provided by Aurora, when the tank level is 20.7' the volume is 11.651MG and when the tank level is 20.6' the volume is 11.574MG. Therefore, for every 0.1' change in level, there is a volume difference of 0.077MG for the starting level. When the tank level is 18.1' the volume is 9.725MG and

when the tank level is 18.0' the volume is 9.658MG. Therefore, for every 0.1' change in level, there is a volume difference of 0.067MG for the ending level.

To calculate the test uncertainty, E Source used +/-0.25" accuracy for the level measurement uncertain and +/- 0.25" for the SCADA level uncertainty at the beginning and ending readings for the test. Therefore, the uncertainty volume associated with the test is:

$$Uncertainty = 2 * (.077 * 10) * \frac{.25}{12} + 2 * (.067 * 10) * \frac{.25}{12} = 0.60MG$$

To calculate the uncertainty as a percentage, the uncertainty is divided by the reference volume calculated for the test:

$$Uncertainty \% = \frac{0.6}{1.938}MG = 3.1\%$$

A similar calculation was used for the Zone 4 test which had a test uncertainty of 4.0%.

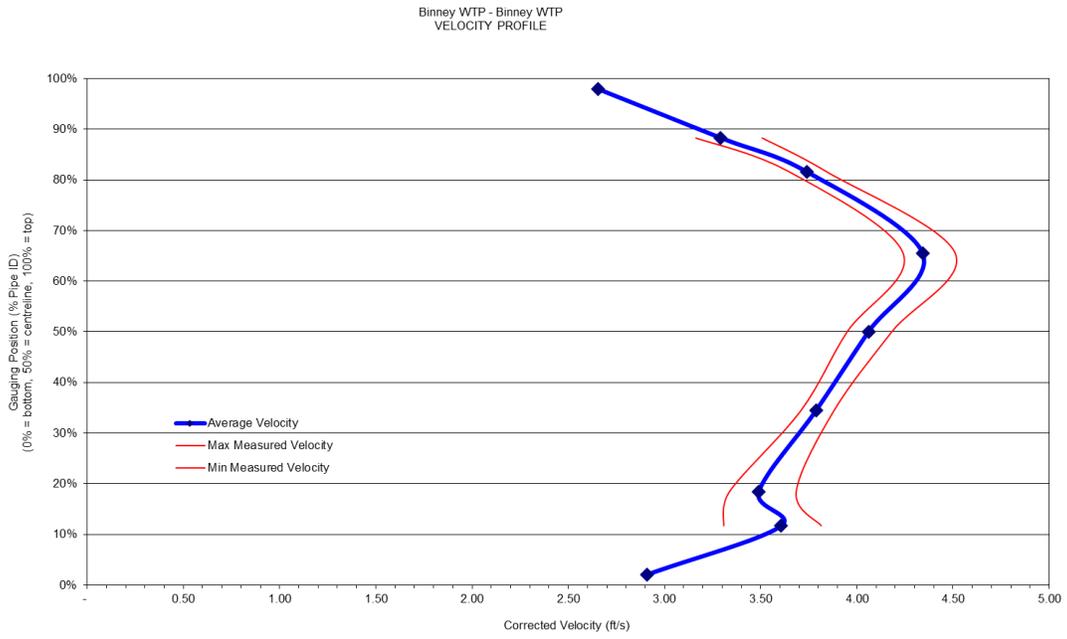
### 3.2 Insertion Meter Test Procedure

Comparative meter tests use a temporarily installed 'reference' meter of known accuracy to provide a reference measurement against which the in-situ meter can be compared. The reference meter used was an electromagnetic insertion flow meter.

The comparative test using an insertion meter is typically done by installing the reference meter at an appropriate location either upstream or downstream of the meter to be tested. If properly located, the insertion meter will produce a pulse output that is proportional to fluid velocity at the point of measurement. The result is a true and linear output signal with respect to the fluid velocity. A data logger records the number of pulses produced by the flow meter using a 1-minute logging interval.

Key influences on the test point measurement accuracy are the intrinsic accuracy of the measurement device and the stability of the Mean-Velocity (Vm) / Centerline-Velocity (Vc) relationship over normally encountered flow rates. To investigate these factors, a velocity profile test was undertaken at the test point. E Source used previously collected data to determine the internal diameter of the pipe.

The insertion meter used by E Source has a stated measurement accuracy for recorded velocity of +/- 2%. Then, using the pipe diameter and the Vm/Vc ratio measured, the velocity is converted to a flow rate. The uncertainty of the Vm/Vc ratio is dependant on the stability of the velocity profile measurement. At Binney WTP, the test margin of error was calculated to be +/-3.7% including both sources of uncertainty. The measured velocity profile is shown below in Figure 6.



**Figure 6: Binney WTP Velocity Profile**

## 4 Results

The production meter tests were conducted at a single flow rate based on the typical flow rate passing through each meter. The results presented in the table below show a comparison between calculated reference volume and the metered volumes based on data from the Aurora SCADA data.

**Table 2: Test Results**

| Test Name        | Test Flow Rate (MGD) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|------------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Wemlinger Zone 3 | 8.3                  | 989,050                | 1,009,410                    | <b>102.1%</b>                | <b>2.1%</b>                  |
| Wemlinger Zone 4 | 9.9                  | 1,040,563              | 1,027,010                    | <b>98.7%</b>                 | <b>2.0%</b>                  |
| Wemlinger Zone 5 | 5.0                  | 1,040,563              | 1,030,990                    | <b>99.1%</b>                 | <b>2.0%</b>                  |
| Binney           | 15.5                 | 646,350                | 648,786                      | <b>100.4%</b>                | <b>3.7%</b>                  |
| Griswold Zone 3  | 15.5                 | 1,938,300              | 1,898,661                    | <b>98.0%</b>                 | <b>3.1%</b>                  |
| Griswold Zone 4  | 14.5                 | 1,415,560              | 1,402,644                    | <b>99.1%</b>                 | <b>4.0%</b>                  |

The test result shows that all meters tested are accurately measuring flow within the test margin of error. The Wemlinger Zone 3 meter showed over-registration equal to the test margin of error. The total uncertainty of the volumetric tests is between +/- 2.0% and +/-4.0% for all tests, taking into consideration uncertainty associated with meter totalizer resolution and reference volume calculation.

## 5 Summary of findings and recommendations

Production Meter Tests were performed for six finished water flow meters between November 9<sup>th</sup> and 15<sup>th</sup>, 2022 using a representative flow rate for each meter.

- All flow meters are operating within the test margin of error
- E Source recommends that Aurora follow the test procedure described to confirm the accuracy of all production meters on at least an annual basis.
- E Source recommends that Aurora perform electronic calibration of all meters annually as part of an ongoing meter maintenance program.

# Production Meter Test Results

City of Aurora

*December 2024*



## Meter Test Summary

The City of Aurora produces water at three Water Treatment Plants – Binney, Griswold, and Wemlinger – and flow to the distribution system is measured by a total of six finished water meters. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meters using the most appropriate test method. E Source and Aurora determined a tank drawdown test would be the most appropriate method for the Wemlinger and Griswold WTP’s and a comparative meter test was most appropriate for Binney WTP.

E Source completed drawdown tests for two meters at Wemlinger and an insertion meter test for the meter at Binney WTP. E Source provided test procedure guidance to Aurora for the remaining meters and compiled results for the Wemlinger Zone 5, Griswold Zone 3 and Griswold Zone 4 tests. Table 1 below summarizes the result of the test. More detail on how the test result was derived can be found in the 2022 report.

**Table 1: Test Results**

| Test Name        | Test Flow Rate (MGD) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Uncertainty (+/- %) |
|------------------|----------------------|------------------------|------------------------------|------------------------------|--------------------------|
| Wemlinger Zone 3 | 7.5                  | 1,137,407              | 1,138,030                    | <b>100.1%</b>                | <b>2.7%</b>              |
| Wemlinger Zone 4 | 18.7                 | 1,025,557              | 1,000,320                    | <b>97.5%</b>                 | <b>5.7%</b>              |
| Wemlinger Zone 5 | 6.0                  | 1,027,128              | 1,000,750                    | <b>97.4%</b>                 | <b>3.1%</b>              |
| Binney           | 14.4                 | 600,199                | 594,359                      | <b>99.0%</b>                 | <b>3.3%</b>              |
| Griswold Zone 3  | 2.5                  | 1,103,300              | 1,150,000                    | <b>104.2%</b>                | <b>5.8%</b>              |
| Griswold Zone 4  | 14.1                 | 2,060,800              | 2,005,062                    | <b>97.3%</b>                 | <b>3.0%</b>              |

The test results show all meters accurately measuring flow within the test margin of error. The total uncertainty of the tests is between +/-2.7% and +/-5.8%. Griswold Zone 3 had a higher than typical test uncertainty due to additional uncertainty from the trapezoidal reservoir and Wemlinger Zone 4 had a higher uncertainty due to accounting for filter influent flow into the reservoir during the test.

E Source recommends that Aurora follow the test procedures provided to confirm the accuracy of all meters on an annual basis. Based on the results of the accuracy tests, no changes are required for any of the production meters.

# Production Meter Test Results

Baca Grande Water and Sanitation District

*October 2022*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |  |   |
|-------|--|---|
| 1     | Executive Summary.....                       | 1 |
| 2     | Background .....                             | 2 |
| 2.1   | Site Description .....                       | 2 |
| 2.2   | Site Infrastructure .....                    | 2 |
| 3     | Methods.....                                 | 4 |
| 3.1   | Flow Rate Selection.....                     | 4 |
| 3.2   | General Test Procedure .....                 | 4 |
| 3.3   | Determination of Tank Dimensions .....       | 5 |
| 3.4   | Tank Level Measurement.....                  | 5 |
| 3.5   | Quantification of Uncertainty .....          | 6 |
| 3.5.1 | Tank Size Uncertainty.....                   | 6 |
| 3.5.2 | Level Measurement Uncertainty .....          | 6 |
| 3.5.3 | Calculation of Uncertainty .....             | 6 |
| 4     | Results.....                                 | 7 |
| 5     | Summary of findings and recommendations..... | 7 |

## List of Figures

|                                      |   |
|--------------------------------------|---|
| Figure 1: Well 18 Flowmeter.....     | 3 |
| Figure 2: Well 18 Meter Display..... | 3 |
| Figure 3: Well 18 Tank Opening.....  | 4 |

## List of Tables

|                             |   |
|-----------------------------|---|
| Table 1: Test Results ..... | 1 |
| Table 2: Test Results ..... | 7 |

## 1 Executive Summary

Baca Grande Water produces water at two well sites that pump into the Well 18 Tank. This tank discharges through a 4" line that is equipped with a mag meter which is used to determine the volume of water provided to the distribution system. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meter using the most appropriate test method. E Source and Baca Grande determined a tank drawdown test would be the most appropriate.

E Source completed a drawdown test at a single flow rate for 1 hour 9 minutes. This report describes the test method and result. Table 1 below summarizes the result of the test. More detail on how the test result was derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name    | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|--------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Well 18 Tank | 208                  | 14,289                 | 14,011                       | 98.5%                        | 2.0%                         |

The test result shows that the meter is accurately recording the volume of water passing through at the test flow rate. The total uncertainty of the volumetric test is +/- 2.0%, taking into consideration uncertainty associated with meter totalizer resolution and tank reference volume calculation. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to Phase 1 participants.

Baca Grande Water and Sanitation District completed a Level 1 validation through Phase 1 of CWLI. Based on the results of the water audit validation and conversations with CWLI, Baca Grande selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy test performed for Baca Grande.

### 2.1 Site Description

Baca Grande Water produces water at two well sites that pump into the Well 18 Tank. This tank discharges through a 4" line that is equipped with a mag meter which is used to determine the volume of water provided to the distribution system.

### 2.2 Site Infrastructure

**Well 18 Meter:** Baca Grande has installed a 4" Endress & Hauser Promag flowmeter to measure water flowing out of the storage tank. This meter is used for to determine the volume of water supplied to the distribution system. The meter is connected to SCADA and has a visible display as shown on the following page in Figure 2.



Figure 1: Well 18 Flowmeter



Figure 2: Well 18 Meter Display

**Well 18 tank:** Near the meter is a 46,000 gallon capacity tank. There is a hatch on top of the tank that was opened to measure the water level inside as shown below in Figure 3.



**Figure 3: Well 18 Tank Opening**

### 3 Methods

E Source and Baca Grande carried out a volumetric test on the water meter at a single flow rate on August 22, 2022. The test was performed by drawing a reference volume through the meter at a specific flow rate out of the tank onsite. By comparing the volume change in the tank to the volume registered by the meter, the City and E Source determined the meter's accuracy to within a target margin of error.

#### 3.1 Flow Rate Selection

To determine the accuracy of a source meter, it is best practice to conduct the test at the full range of flowrates that the meter will typically experience. After reviewing historic flow data, E Source and the City concluded that only one flow rate was necessary, as the flow typically has minimal variation. The recommended flow for the test was 200 gpm.

#### 3.2 General Test Procedure

The meter test was performed by E Source and Baca Grande as follows:

1. **Switch Pumps to Manual Operation:** The pumps for the groundwater wells and the discharge line were switched to manual operation and moved to the off position to ensure no water would be entering the tank during the test.
2. **Begin Static Test:** A 15-minute static test was completed with all pumps off to ensure that all valves were operating as expected and no water was entering or exiting the tank.
3. **Collect starting reads:** The starting totalizer read was collected for the meter and the water level of the tank was measured.
4. **Turn on Discharge Pump:** The pump was turned on to begin flow through the meter
5. **Observe Level Change:** Flow continued through the meter until 6 feet of level change was observed in the tank.
6. **Turn off Pump:** The pump was turned off to stop flow through the meter
7. **Collect ending reads:** The end totalizer read was collected from the meter and the water level of the tank was measured.
8. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
9. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the tank.
10. **Compare reference volume and the metered volume:** The difference between the volume metered by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.3 Determination of Tank Dimensions

The volume of water sent from the tank during the test was referred to as the “reference volume”. At the end of the test, the totalizer read out was compared to this reference volume to determine the meter’s accuracy. To ensure confidence in this testing methodology, the dimensions of the tank needed to be determined.

To determine the volume of the tank, E Source used a data provided by the utility. Baca Grande provided a tank dimension table that had tank measurements and capacity listed. E Source attempted to validate the measurements while on-site by taking measurements of the tank diameter and wall thickness on top of the tank to ensure they matched the drawing dimensions provided. Using the tank dimensions, E Source calculated a volumetric change of 2,350 gallons per foot of level change.

### 3.4 Tank Level Measurement

In addition to knowing the dimensions of the tank, it was also necessary to measure the level of water in the tank to a high degree of confidence. E Source used a level sounder to measure and record the water level in the tank during the test.

The level sounder was placed on the roof of the tank, where a weighted line was fed through an opening until it contacted the surface of the water, at which point it emitted a noise. At that point, the line was marked so it could be measured and recorded. The difference between the starting length and ending

length indicated the level change after the test was performed. It was estimated that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.5 Quantification of Uncertainty

There is uncertainty associated with conducting a drop test due to potential measurement errors and test equipment precision.

#### 3.5.1 Tank Size Uncertainty

The Well 18 Tank used to calculate the reference volume has a liner on the inside of the tank which reduces the interior volume of the tank. Since the liner could not be measured, E Source estimated that it reduced the tank radius by  $\frac{1}{4}$ " with an uncertainty of  $\pm 1$ ". This uncertainty in the tank's dimension corresponded to an uncertainty of  $\pm 237$  gallons.

#### 3.5.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a level sounder which was believed to be accurate within 0.25". A measurement uncertainty of  $\pm .25$ " corresponds to a measurement uncertainty of approximately  $\pm 49$  gallons.

#### 3.5.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the test, E Source considered the tank size as well as the margin of error obtained from the level measurement. E Source calculated the total test uncertainty to be  $\pm 2.0\%$

## 4 Results

The volumetric test was conducted at a single flow rate based on the typical flow rate passing through the meter. The results presented in the table below show a comparison between the volume change in the tank based on calculations made using measured level change and the metered volume based on photos taken of the meter totalizer before and after the test.

**Table 2: Test Results**

| Test Name     | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal)* | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|---------------|----------------------|------------------------|-------------------------------|------------------------------|------------------------------|
| Well 18 Meter | 206                  | 14,230                 | 14,011                        | 98.5%                        | 2.0%                         |

Based on the differences between the tank reference volumes and the meter totalizer volumes, it appears that the meter is accurately measuring flow within the limits of accuracy of the test.

## 5 Summary of findings and recommendations

The Well 18 meter was tested at a single flow rate on August 22, 2022. Below the main findings of the test:

- The volumetric change for the tank was determined to be 2,350 gallons/foot using tank dimensions provided
- The Well 18 meter is operating at 98.5% accuracy with a margin of error of 2.0% at the test flow rate
- The meter is accurately recording flow and no volumetric adjustments are required.
- E Source recommends that Baca Grande follow the test procedure described to confirm the accuracy of the Well 18 meter on at least an annual basis.

# Production Meter Test Results

City of Boulder

*January 2025*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |                                       |   |
|-------|---------------------------------------|---|
| 1     | Executive Summary .....               | 1 |
| 2     | Background.....                       | 2 |
| 3     | Methods.....                          | 3 |
| 3.1   | Flow Rate Selection .....             | 3 |
| 3.2   | General Test Procedure .....          | 3 |
| 3.3   | Determination of Tank Dimensions..... | 4 |
| 3.4   | Tank Level Measurement .....          | 4 |
| 3.5   | Quantification of Uncertainty .....   | 4 |
| 3.5.1 | Totalizer Uncertainty .....           | 4 |
| 3.5.2 | Level Measurement Uncertainty.....    | 4 |
| 3.5.3 | Calculation of Uncertainty.....       | 5 |
| 4     | Results.....                          | 6 |

## List of Tables

|          |                    |   |
|----------|--------------------|---|
| Table 1: | Test Results ..... | 1 |
| Table 2: | Test Results ..... | 6 |

# 1 Executive Summary

The City of Boulder produces water at the 63<sup>rd</sup> St. and Betasso Water Treatment Plants. Water is discharged through one flowmeter at the 63<sup>rd</sup> St. plant and two flowmeters at the Betasso plant to determine the volume of water supplied to the distribution system. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meters using the most appropriate test method. E Source and Boulder determined a tank drawdown test would be the most appropriate for all flowmeters.

E Source completed a drawdown test for each flowmeter. This report describes the test method and result. Table 1 below summarizes the result of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name               | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal)* | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|-------------------------|----------------------|------------------------|-------------------------------|------------------------------|------------------------------|
| 63 <sup>rd</sup> St WTP | 3,401                | 306,117                | 300,900                       | <b>98.3%</b>                 | <b>1.9%</b>                  |
| Betasso 20"             | 2,758                | 330,965                | 330,000                       | <b>99.2%</b>                 | <b>1.8%</b>                  |
| Betasso 30"             | 2,716                | 312,298                | 310,000                       | <b>100.9%</b>                | <b>1.9%</b>                  |

The test results show that all meters are accurately registering flow within the test margin of error. The total uncertainty of the volumetric test is +/- 1.9% for the 63<sup>rd</sup> St test, +/- 1.8% for the Betasso 20" test and +/-1.9% for the Betasso 30" test, taking into consideration uncertainty associated with meter totalizer resolution and tank reference volume calculation. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program continues offering water audit validations, but also goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to CWLI participants.

City of Boulder completed a Level 1 validation through CWLI and selected source meter testing for additional direct technical assistance. This report summarizes the methodology and results of the accuracy tests.

## 3 Methods

E Source and Boulder carried out a volumetric test on each finished water meter at a single flow rate on December 17<sup>th</sup> and 18<sup>th</sup>, 2024. The tests were performed by drawing a reference volume through the meter at a specific flow rate out of the tank onsite. By comparing the volumetric change in the tank to the volume registered by the meter, Boulder and E Source determined the meter's accuracy to within a target margin of error.

### 3.1 Flow Rate Selection

To determine the accuracy of a source meter, it is best practice to conduct the test at the full range of flowrates that the meter will typically experience. The flow rate through the meter is dependent on demand in the distribution system. E Source and Boulder had limited operational flexibility and performed the test based on system demand at the time of the test.

### 3.2 General Test Procedure

The meter tests were performed by E Source and Boulder as follows:

1. **Shut down WTP:** All treatment processes and filter pumps were halted so no water was entering the clearwell
2. **Operate valves:** Close valves as needed to ensure water can flow out of the tank through one meter at a time and no water is entering the clearwell
3. **Collect starting reads:** The starting totalizer read was collected on SCADA for the meter and the water level of the tank was measured.
4. **Observe Level Change:** Flow continued through the meter until desired level change was observed in the tank.
5. **Collect ending reads:** The end totalizer read was collected from SCADA for the meter and the water level of the tank was measured.
6. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
7. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the tank.
8. **Compare reference volume and the metered volume:** The difference between the volume metered by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.3 Determination of Tank Dimensions

The volume of water sent from the tank during the test was referred to as the “reference volume”. At the end of the test, the totalizer read out was compared to this reference volume to determine the meter’s accuracy. To ensure confidence in this testing methodology, the dimensions of the tank needed to be determined.

To determine the volume of the tank, E Source used a data provided by the utility. Boulder provided tank drawings which E Source used to calculate the tank volume. Using the tank dimensions, E Source calculated a volumetric change of 118,880 gallons per foot of level change at the 63<sup>rd</sup> St WTP, and 118,679 gallons per foot of level change for the combined Betasso Tanks 1 & 2.

### 3.4 Tank Level Measurement

In addition to knowing the dimensions of the tank, it was also necessary to measure the level of water in the tank to a high degree of confidence. E Source used a laser measurement tool with a disc that floats on the water surface to measure and record the water level in the tank during the test.

The disc was fed through an opening until it floated on the surface of the water. At that point, the laser measurement tool was used to measure the distance from the top of the tank to the floating disc. The difference between the starting measurement and ending measurement indicated the level change after the test was performed. It was assumed that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.5 Quantification of Uncertainty

There is uncertainty associated with conducting a drop test due to potential measurement errors and test equipment precision. This section discusses the sources of uncertainty and how the uncertainty was calculated.

#### 3.5.1 Totalizer Uncertainty

There is uncertainty associated with the meter totalizer registration because the meter will only record and display volumes to a certain interval. The 63<sup>rd</sup> St. Meter test used SCADA which had a resolution of 1,000 gallons, while the Betasso Meters used a calculation based on the minute-by-minute flowrate.

#### 3.5.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a laser tool which was believed to be accurate within 0.25”. A measurement uncertainty of +/- .25” corresponds to a measurement uncertainty of approximately +/- 2,477 gallons for 63<sup>rd</sup> St. and 2,472 gallons for Betasso.

### 3.5.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the test, E Source considered the resolution of the meter totalizer as well as the margin of error volumes obtained from the level measurement. E Source calculated the total test uncertainty to be +/- 1.9% for the 63<sup>rd</sup> St test, +/- 1.8% for the Betasso 20" test and +/-1.9% for the Betasso 30" test.

## 4 Results

The volumetric tests were conducted at a single flow rate based on the typical flow rate passing through each meter. The results presented in the table below show a comparison between the volumetric changes in the tank based on calculations made using measured level changes and the metered volumes based on data from SCADA.

**Table 2: Test Results**

| Test Name               | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal)* | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|-------------------------|----------------------|------------------------|-------------------------------|------------------------------|------------------------------|
| 63 <sup>rd</sup> St WTP | 3,401                | 306,117                | 300,900                       | <b>98.3%</b>                 | <b>1.9%</b>                  |
| Betasso 20"             | 2,758                | 330,965                | 330,000                       | <b>99.2%</b>                 | <b>1.8%</b>                  |
| Betasso 30"             | 2,716                | 312,298                | 310,000                       | <b>100.9%</b>                | <b>1.9%</b>                  |

The test results show that all meters are accurately registering flow within the test margin of error. The total uncertainty of the volumetric test is +/- 1.9% for the 63<sup>rd</sup> St test, +/- 1.8% for the Betasso 20" test and +/-1.9% for the Betasso 30" test, taking into consideration uncertainty associated with meter totalizer resolution and tank reference volume calculation.

# Production Meter Test Results

Town of Breckenridge

*December 2022*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |  |   |
|-------|--|---|
| 1     | Executive Summary.....                       | 1 |
| 2     | Background .....                             | 2 |
| 2.1   | Site Description .....                       | 2 |
| 2.2   | Site Infrastructure .....                    | 2 |
| 2.2.1 | Gary Roberts WTP.....                        | 2 |
| 2.2.2 | North WTP.....                               | 3 |
| 3     | Methods.....                                 | 5 |
| 3.1   | General Test Procedure .....                 | 5 |
| 3.2   | Determination of Tank Dimensions .....       | 5 |
| 3.3   | Tank Level Measurement.....                  | 6 |
| 3.4   | Quantification of Uncertainty .....          | 6 |
| 3.4.1 | Totalizer Uncertainty .....                  | 6 |
| 3.4.2 | Level Measurement Uncertainty .....          | 6 |
| 3.4.3 | Calculation of Uncertainty .....             | 6 |
| 4     | Results.....                                 | 7 |
| 5     | Summary of findings and recommendations..... | 8 |

## List of Figures

|                                       |   |
|---------------------------------------|---|
| Figure 1: Gary Roberts Flowmeter..... | 3 |
| Figure 2: North WTP Flowmeter .....   | 4 |

## List of Tables

|                             |   |
|-----------------------------|---|
| Table 1: Test Results ..... | 1 |
| Table 2: Test Results ..... | 7 |

## 1 Executive Summary

The Town of Breckenridge produces water at two Water Treatment Plants – Gary Roberts WTP and North WTP – each equipped with one finished water meter. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the production meters using the most appropriate test method. E Source and Breckenridge determined a clearwell drawdown test would be the most appropriate and could be performed for both meters.

E Source completed a drawdown test for each flowmeter. This report describes the test method and results. Table 1 below summarizes the results of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name        | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|------------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Gary Roberts WTP | 700                  | 58,489                 | 64,993                       | <b>111.1%</b>                | <b>1.6%</b>                  |
| North WTP        | 1,600                | 100,702                | 103,000                      | <b>102.3%</b>                | <b>2.0%</b>                  |

The test results shows that the Gary Roberts WTP is over-registering flow by 11.1% with a test margin of error of +/-1.6% and the North WTP meter is over-registering flow by 2.3% with a test margin of error of +/- 2.0% and is therefore accurate within AWWA guidelines. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado’s projected growth. Through the 2-year program, the CWLI will provide individualized technical support and training workshops on water loss control best practices to urban water utilities.

Participants of the CWLI will have the chance to undergo, at a minimum, a Level 1 validation of their water audits. Levels of water audit validation are defined in the Water Research Foundation Report 4639B Utility Water Audit Validation: Principles and Programs. Validation efforts range from Level 1, which examines summary data for evident errors and correct application of the M36 Methodology; to Level 3, which includes field tests. Participants who completed a Level 1 validation through the CWLI program will have the opportunity to participate in more advanced validation of their water audit data through direct technical assistance.

Breckenridge completed a Level 1 validation through CWLI. Based on the results of the water audit and conversations with CWLI, Breckenridge selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy tests performed for Breckenridge.

### 2.1 Site Description

Breckenridge produces water at two Water Treatment Plants – Gary Roberts WTP and the North WTP. Each Water Treatment Plant has one finished discharge meter that was considered for testing.

### 2.2 Site Infrastructure

#### 2.2.1 Gary Roberts WTP

**Gary Roberts Flow Meter:** Breckenridge has installed an ultrasonic flowmeter to measure water flowing out of the clearwell as shown in Figure 1. The meter is connected to SCADA and has a visible display.

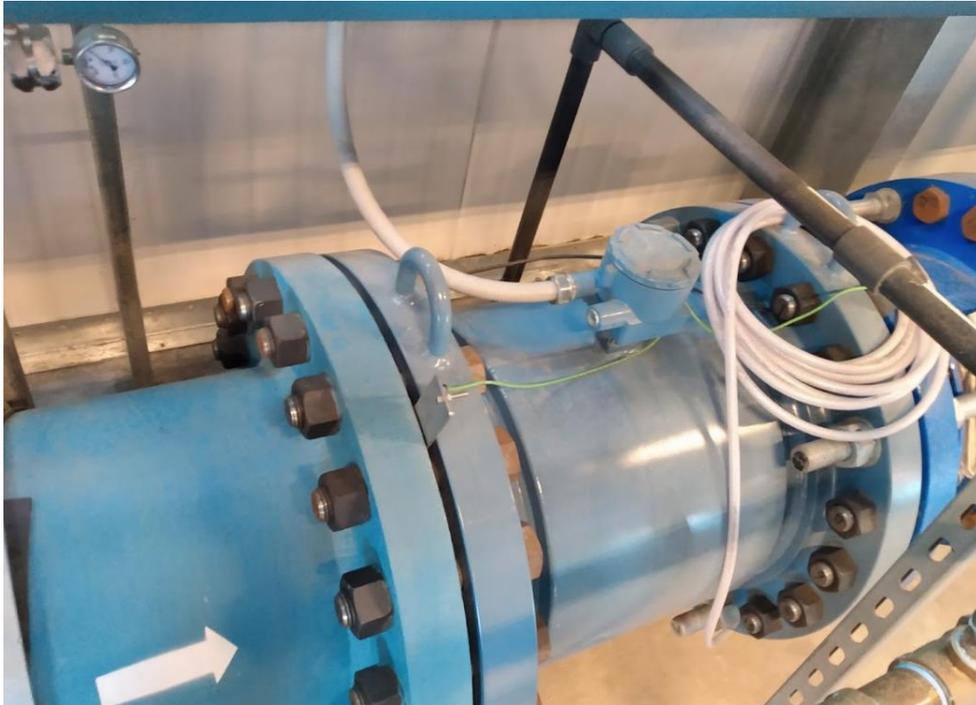


**Figure 1: Gary Roberts Flowmeter**

**Gary Roberts Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume.

### 2.2.2 North WTP

**North Flow Meter:** Breckenridge has installed an electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 2. The meter is connected to SCADA which was used to collect the start and end reads.



**Figure 2: North WTP Flowmeter**

**North WTP Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume. There is a hatch on top of the tank that was opened to measure the water level inside.

## 3 Methods

E Source and Breckenridge carried out a volumetric test at a single flow rate for the North WTP Meter on October 17<sup>th</sup>, 2022, and a test for the Gary Roberts WTP meter on November 14<sup>th</sup>. The tests were performed by drawing a reference volume through each meter at a specific flow rate out of the clearwell onsite. By comparing the volume change in the tank to the volume registered by the meter, Breckenridge and E Source determined each meter's accuracy to within a target margin of error.

### 3.1 General Test Procedure

The meter tests were performed by E Source and Breckenridge as follows:

1. **Shut down WTP:** All treatment processes and filter pumps were halted so no water was entering the clearwell
2. **Begin Static Test:** If possible, begin a 15-minute static test with all pumps off to ensure all valves are holding and no water is entering or exiting the clearwell.
3. **Collect starting reads:** The starting totalizer read was collected on SCADA. The water level of the tank was measured by E Source and taken from SCADA.
4. **Observe Level Change:** Flow continued through the meter until desired level change was observed in the clearwell.
5. **Collect ending reads:** The end totalizer reads were collected from SCADA, and the water level of the clearwell was measured.
6. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
7. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the clearwell.
8. **Compare reference volume and the metered volume:** The difference between the volume metered by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.2 Determination of Tank Dimensions

The volume of water sent from the tank during the test was referred to as the "reference volume". At the end of the test, the totalizer read out was compared to this reference volume to determine the meter's accuracy. To ensure confidence in this testing methodology, the dimensions of the tank needed to be determined.

To determine the volume of the tank, E Source used clearwell drawings provided by the utility Breckenridge. Using the clearwell drawings, E Source calculated the following volumes per foot of level change:

- Gary Roberts WTP: 12,878 gal/ft
- North WTP: 23,351 gal/ft

### 3.3 Tank Level Measurement

In addition to knowing the dimensions of the clearwells, it was also necessary to measure the level of water in the clearwell to a high degree of confidence for each test. E Source used a level sounder to measure and record the water level in the clearwell during each test.

The level sounder was fed through a hatch on top of each clearwell until it contacted the surface of the water, at which point it emitted a noise. At that point, the line was marked so it could be measured and recorded. The difference between the starting length and ending length indicated the level change after the test was performed. It was assumed that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.4 Quantification of Uncertainty

There is uncertainty associated with conducting a drawdown test due to potential measurement errors and test equipment precision. This section discusses the sources of uncertainty and how the uncertainty was calculated.

#### 3.4.1 Totalizer Uncertainty

There is uncertainty associated with the meter totalizer registration because the meter will only record and display volumes to a certain interval. All meters had a resolution of 1,000 gallons. Therefore, the volume of uncertainty from the totalizer reading is 1,000 gallons for all tests.

#### 3.4.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a level sounder which was believed to be accurate within 0.25". A measurement uncertainty of +/- .25" corresponds to 1/48<sup>th</sup> of the previously listed volume per foot for each clearwell.

#### 3.4.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the test, E Source considered the resolution of the meter totalizer as well as the margin of error volumes obtained from the level measurement. E Source calculated the following test uncertainties:

- Gary Roberts WTP: +/- 1.6%
- North WTP: +/- 2.0%

## 4 Results

The volumetric tests were conducted at a single flow rate based on the typical flow rate passing through each meter. The results presented in the table below show a comparison between the volume changes in the clearwell based on calculations made using measured level changes and the metered volumes based on data from the physical meter register.

**Table 2: Test Results**

| Test Name        | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|------------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Gary Roberts WTP | 700                  | 58,489                 | 64,993                       | <b>111.1%</b>                | <b>1.6%</b>                  |
| North WTP        | 1,600                | 100,702                | 103,000                      | <b>102.3%</b>                | <b>2.0%</b>                  |

The test results shows that the Gary Roberts WTP is over-registering flow by 11.1% with a test margin of error of +/-1.6% and the North WTP meter is over-registering flow by 2.3% with a test margin of error of +/- 2.0% and is therefore accurate within AWWA guidelines.

## 5 Summary of findings and recommendations

Volumetric Tests were performed for two finished water flow meters between October 17<sup>th</sup> and November 14<sup>th</sup>, 2022, using a representative flow rate for each meter and using the clearwell at the respective treatment plant to determine the reference volumes

- The volumetric change for the clearwells were determined to be as follows using the drawings provided:
  - Gary Roberts WTP: 12,878 gal/ft
  - North WTP: 23,351 gal/ft
- The Gary Roberts WTP meter is operating at 111.1% accuracy with a margin of error of 1.6% at the test flow rate
- The North WTP meter is operating at 102.3% accuracy with a margin of error of 2.0% at the test flow rate
- E Source recommends that Breckenridge follow the test procedure described to confirm the accuracy of both meters on at least an annual basis.
- E Source recommends that Breckenridge perform electronic calibration of all meters annually as part of an ongoing meter maintenance program.

# Production Meter Test Results

Town of Castle Rock

*December 2022*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |   |    |
|-------|---|----|
| 1     | Executive Summary .....                       | 1  |
| 2     | Background.....                               | 2  |
| 2.1   | Site Description.....                         | 2  |
| 2.2   | Site Infrastructure .....                     | 2  |
| 2.2.1 | Founders WTP .....                            | 2  |
| 2.2.2 | Miller WTP .....                              | 4  |
| 2.2.3 | Plum Creek WTP.....                           | 5  |
| 2.2.4 | Ray Waterman WTP.....                         | 6  |
| 2.2.5 | Meadows WTP .....                             | 8  |
| 3     | Methods.....                                  | 10 |
| 3.1   | General Test Procedure .....                  | 10 |
| 3.2   | Determination of Tank Dimensions .....        | 10 |
| 3.3   | Tank Level Measurement .....                  | 11 |
| 3.4   | Quantification of Uncertainty .....           | 11 |
| 3.4.1 | Totalizer Uncertainty .....                   | 11 |
| 3.4.2 | Level Measurement Uncertainty.....            | 11 |
| 3.4.3 | Calculation of Uncertainty.....               | 11 |
| 4     | Results.....                                  | 13 |
| 5     | Summary of findings and recommendations ..... | 14 |

## List of Figures

|   |   |
|---|---|
| Figure 1: Founders Flowmeter .....        | 3 |
| Figure 2: Founders Clearwell Opening..... | 3 |
| Figure 3: Founders Flowmeter .....        | 4 |
| Figure 4: Miller Clearwell Opening .....  | 5 |
| Figure 5: Prairie Hawk Flowmeter .....    | 5 |
| Figure 6: South Flowmeter .....           | 6 |
| Figure 7: Green Flowmeter.....            | 7 |
| Figure 8: Red Flowmeter .....             | 7 |

Figure 9: Meadows Flowmeter .....8  
Figure 10: Meadows Clearwell Opening .....9

## List of Tables

Table 1: Test Results .....1  
Table 2: Test Results .....13

# 1 Executive Summary

The Town of Castle Rock produces water at five Water Treatment Plants – Founders, Meadows, Miller, Plum Creek, and Ray Waterman – and flow to the distribution system is measured by a total of seven finished water meters. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meters using the most appropriate test method. E Source and Castle Rock determined a tank drawdown test would be the most appropriate and could be performed for all meters.

E Source completed a drawdown test for each flowmeter. This report describes the test method and results. Table 1 below summarizes the results of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name                 | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|---------------------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Founders                  | 1,300                | 29,688                 | 29,353                       | 98.9%                        | 1.6%                         |
| Miller                    | 600                  | 27,410                 | 27,694                       | 101.1%                       | 1.3%                         |
| Plum Creek – Prairie Hawk | 2,400                | 25,391                 | 25,485                       | 100.4%                       | 1.3%                         |
| Plum Creek - South        | 2,300                | 24,979                 | 25,315                       | 101.3%                       | 1.3%                         |
| Ray Waterman - Green      | 2,500                | 123,900                | 123,768                      | 99.8%                        | 1.4%                         |
| Ray Waterman – Red        | 2,300                | 121,380                | 123,641                      | 101.7%                       | 1.4%                         |
| Meadows WTP               | 1,400                | 67,244                 | 66,954                       | 99.6%                        | 2.0%                         |

The test results shows that all meters tested are accurately measuring flow. The Ray Waterman Red line meter was the only test to be outside of the margin of error, but still was within +/-2%. The total uncertainty of the volumetric tests is between +/- 1.3% and +/-2.0% for all tests, taking into consideration uncertainty associated with meter totalizer resolution and tank reference volume calculation. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado’s projected growth. Through the 2-year program, the CWLI will provide individualized technical support and training workshops on water loss control best practices to urban water utilities.

Participants of the CWLI will have the chance to undergo, at a minimum, a Level 1 validation of their water audits. Levels of water audit validation are defined in the Water Research Foundation Report 4639B Utility Water Audit Validation: Principles and Programs. Validation efforts range from Level 1, which examines summary data for evident errors and correct application of the M36 Methodology; to Level 3, which includes field tests. Participants who completed a Level 1 validation through the CWLI program will have the opportunity to participate in more advanced validation of their water audit data through direct technical assistance.

Castle Rock completed a Level 1 validation through CWLI. Based on the results of the water audit and conversations with CWLI, Castle Rock selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy tests performed for Castle Rock.

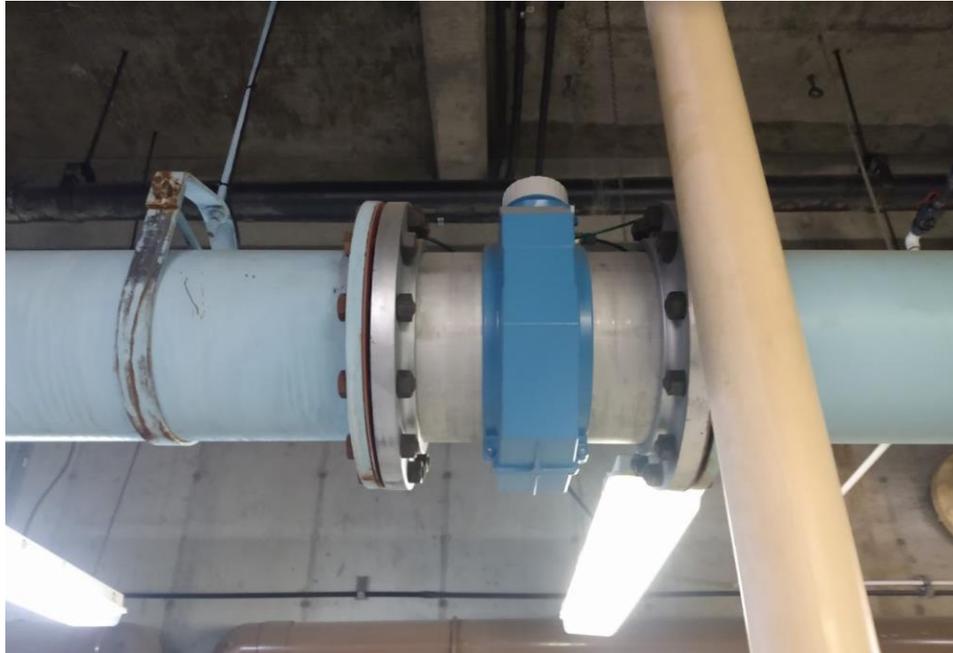
### 2.1 Site Description

Castle Rock produces water at five Water Treatment Plants – Founders, Miller, Plum Creek, Ray Waterman, and Meadows. The Plum Creek and Ray Waterman Treatment Plants each have two finished discharge meters and all other treatment plants have one, for a total of seven finished water meters that were included in testing.

### 2.2 Site Infrastructure

#### 2.2.1 Founders WTP

**Founders Flow Meter:** Castle Rock has installed an Endress & Hauser electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 1. The meter is connected to SCADA and has a visible display used to collect the start and end reads.



**Figure 1: Founders Flowmeter**

**Founders Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume. There is a hatch on top of the clearwell that was opened to measure the water level inside as shown below in Figure 2.



**Figure 2: Founders Clearwell Opening**

### 2.2.2 Miller WTP

**Miller Flow Meter:** Castle Rock has installed an Endress & Hauser electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 3. The meter is connected to SCADA and has a visible display used to collect the start and end reads.



**Figure 3: Founders Flowmeter**

**Miller Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume. There is a hatch on top of the tank that was opened to measure the water level inside as shown below in Figure 4.



Figure 4: Miller Clearwell Opening

### 2.2.3 Plum Creek WTP

**Prairie Hawk Flow Meter:** Castle Rock has installed an Endress & Hauser electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 5. The meter is connected to SCADA and has a visible display used to collect the start and end reads.



Figure 5: Prairie Hawk Flowmeter

**South Flow Meter:** Castle Rock has installed an Endress & Hauser electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 6. The meter is connected to SCADA and has a visible display used to collect the start and end reads.



**Figure 6: South Flowmeter**

**Plum Creek Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume.

#### 2.2.4 Ray Waterman WTP

**Green Flow Meter:** Castle Rock has installed an Endress & Hauser electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 7. The meter is connected to SCADA and has a visible display used to collect the start and end reads.



Figure 7: Green Flowmeter

**Red Flow Meter:** Castle Rock has installed an Endress & Hauser electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 8. The meter is connected to SCADA and has a visible display used to collect the start and end reads.



Figure 8: Red Flowmeter

**Ray Waterman Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume.

### 2.2.5 Meadows WTP

**Meadows Flowmeter** Castle Rock has installed an Endress & Hauser electromagnetic flowmeter to measure water flowing out of the clearwell as shown in Figure 9.



**Figure 9: Meadows Flowmeter**

**Meadows Clearwell:** On-site at the Treatment Plant is a clearwell which was used to determine the test reference volume. There is a hatch on top of the tank that was opened to measure the water level inside as shown in Figure 10.



Figure 10: Meadows Clearwell Opening

## 3 Methods

E Source and Castle Rock carried out a volumetric test at a single flow rate for each meter on October 12<sup>th</sup> and 13<sup>th</sup>, 2022. The tests were performed by drawing a reference volume through each meter at a specific flow rate out of the clearwell onsite. By comparing the volume change in the tank to the volume registered by the meter, Castle Rock and E Source determined each meter’s accuracy to within a target margin of error.

### 3.1 General Test Procedure

The meter tests were performed by E Source and Castle Rock as follows:

1. **Shut down WTP:** All treatment processes and filter pumps were halted so no water was entering the clearwell
2. **Begin Static Test:** If possible, begin a 15-minute static test with all pumps off to ensure all valves are holding and no water is entering or exiting the clearwell.
3. **Collect starting reads:** The starting totalizer read was collected on SCADA and at the meter face. The water level of the tank was measured and taken from SCADA.
4. **Observe Level Change:** Flow continued through the meter until desired level change was observed in the clearwell.
5. **Collect ending reads:** The end totalizer reads were collected from SCADA, the meter face, and the water level of the clearwell was measured.
6. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
7. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the clearwell.
8. **Compare reference volume and the metered volume:** The difference between the volume metered by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.2 Determination of Tank Dimensions

The volume of water sent from the tank during the test was referred to as the “reference volume”. At the end of the test, the totalizer read out was compared to this reference volume to determine the meter’s accuracy. To ensure confidence in this testing methodology, the dimensions of the tank needed to be determined.

To determine the volume of the tank, E Source used a data provided by the utility. Castle Rock provided clearwell drawings for all WTP’s which E Source used to calculate the clearwell volumes. Using the clearwell dimensions, E Source calculated the following volumes per foot of level change:

- Founders WTP: 11,310 gal/ft
- Miller WTP: 8,860 gal/ft
- Plum Creek WTP: 7,914 gal/ft
- Ray Waterman WTP: 40,320 gal/ft
- Meadows WTP: 32,358 gal/ft

### 3.3 Tank Level Measurement

In addition to knowing the dimensions of the clearwells, it was also necessary to measure the level of water in the clearwell to a high degree of confidence for each test. E Source used a level sounder to measure and record the water level in the clearwell during each test.

The level sounder was fed through a hatch on top of each clearwell until it contacted the surface of the water, at which point it emitted a noise. At that point, the line was marked so it could be measured and recorded. The difference between the starting length and ending length indicated the level change after the test was performed. It was assumed that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.4 Quantification of Uncertainty

There is uncertainty associated with conducting a drawdown test due to potential measurement errors and test equipment precision. This section discusses the sources of uncertainty and how the uncertainty was calculated.

#### 3.4.1 Totalizer Uncertainty

There is uncertainty associated with the meter totalizer registration because the meter will only record and display volumes to a certain interval. All meters had a resolution of 1 gallon. Therefore, the volume of uncertainty from the totalizer reading is 1 gallon for all tests.

#### 3.4.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a level sounder which was believed to be accurate within 0.25". A measurement uncertainty of +/- .25" corresponds to 1/48<sup>th</sup> of the previously listed volume per foot for each clearwell.

#### 3.4.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the test, E Source considered the resolution of the meter totalizer as well as the margin of error volumes obtained from the level measurement. E Source calculated the following test uncertainties:

- Founders WTP: +/- 1.6%
- Miller WTP: +/- 1.3%
- Plum Creek WTP: +/- 1.3%
- Ray Waterman WTP: +/- 1.4%
- Meadows WTP: +/- 2.0%

## 4 Results

The volumetric tests were conducted at a single flow rate based on the typical flow rate passing through each meter. The results presented in the table below show a comparison between the volume changes in the clearwell based on calculations made using measured level changes and the metered volumes based on data from the physical meter register.

**Table 2: Test Results**

| Test Name                 | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|---------------------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Founders                  | 1,300                | 29,688                 | 29,353                       | 98.9%                        | 1.6%                         |
| Miller                    | 600                  | 27,410                 | 27,694                       | 101.1%                       | 1.3%                         |
| Plum Creek – Prairie Hawk | 2,400                | 25,391                 | 25,485                       | 100.4%                       | 1.3%                         |
| Plum Creek - South        | 2,300                | 24,979                 | 25,315                       | 101.3%                       | 1.3%                         |
| Ray Waterman - Green      | 2,500                | 123,900                | 123,768                      | 99.8%                        | 1.4%                         |
| Ray Waterman – Red        | 2,300                | 121,380                | 123,641                      | 101.7%                       | 1.4%                         |
| Meadows WTP               | 1,400                | 67,244                 | 66,954                       | 99.6%                        | 2.0%                         |

The test result shows that all meters tested are accurately measuring flow. The Ray Waterman Red line meter was the only test to be outside of the margin of error, but still was within +/-2%.

## 5 Summary of findings and recommendations

Volumetric Tests were performed for seven finished water flow meters between October 12<sup>th</sup> and 13<sup>th</sup>, 2022 using a representative flow rate for each meter and using the clearwell at the respective treatment plant to determine the reference volumes

- The volumetric change for the clearwells were determined to be as follows using the drawings provided:
  - Founders WTP: 11,310 gal/ft
  - Miller WTP: 8,860 gal/ft
  - Plum Creek WTP: 7,914 gal/ft
  - Ray Waterman WTP: 40,320 gal/ft
  - Meadows WTP: 32,358 gal/ft
- The Ray Waterman Red line meter is operating at 100.7% accuracy with a margin of error of 1.4% at the test flow rate
- All other flow meters are operating within the test margin of error
- E Source recommends that Castle Rock follow the test procedure described to confirm the accuracy of both meters on at least an annual basis.
- E Source recommends that Castle Rock perform electronic calibration of all meters annually as part of an ongoing meter maintenance program.

# Production Meter Test Results

Eagle River Water & Sanitation District

*June 2025*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |  |    |
|-------|--|----|
| 1     | Executive Summary.....                       | 1  |
| 2     | Background .....                             | 2  |
| 2.1   | Site Description.....                        | 2  |
| 2.2   | Site Infrastructure.....                     | 2  |
| 2.2.1 | Vail R2.....                                 | 2  |
| 2.2.2 | Vail R4.....                                 | 4  |
| 2.2.3 | Vail R6.....                                 | 6  |
| 2.2.4 | Vail R7.....                                 | 8  |
| 2.2.5 | Berry Creek 1.....                           | 9  |
| 2.2.6 | Berry Creek 2.....                           | 10 |
| 2.2.7 | Berry Creek 3.....                           | 11 |
| 3     | Methods.....                                 | 13 |
| 3.1   | Insertion Meter Test Procedure .....         | 13 |
| 4     | Results.....                                 | 17 |
| 5     | Summary of findings and recommendations..... | 18 |

## List of Figures

|  |    |
|--|----|
| Figure 1: Vail R2 Flowmeter .....        | 3  |
| Figure 2: Vail R2 Tap Location.....      | 3  |
| Figure 3: Vail R4 Flowmeter.....         | 4  |
| Figure 4: Vail R4 FPI Meter.....         | 5  |
| Figure 5: Vail R4 Tap Location.....      | 6  |
| Figure 6: Vail R6 Flowmeter .....        | 7  |
| Figure 7: Vail R6 Tap Location.....      | 7  |
| Figure 8: Vail R7 Flowmeters .....       | 8  |
| Figure 9: Vail R7 Tap Location.....      | 9  |
| Figure 10: Berry Creek 1 Flowmeter ..... | 10 |
| Figure 11: Berry Creek Tap Location..... | 10 |
| Figure 12: Berry Creek 2 Flowmeter ..... | 11 |

|  |    |
|--|----|
| Figure 13: Berry Creek 3 Flowmeter .....           | 12 |
| Figure 14: Vail R2 Velocity Profile .....          | 14 |
| Figure 15: Vail R4 Velocity Profile .....          | 14 |
| Figure 16: Vail R6 Velocity Profile .....          | 15 |
| Figure 17: Vail R7 Velocity Profile .....          | 15 |
| Figure 18: Berry Creek 1 & 2 Velocity Profile..... | 16 |
| Figure 19 Berry Creek 3 Velocity Profile .....     | 16 |

## List of Tables

|                             |    |
|-----------------------------|----|
| Table 1: Test Results ..... | 1  |
| Table 2: Test Results ..... | 17 |

## 1 Executive Summary

Eagle River produces water at multiple well sites and operates the service area as discreet zones. Eagle River had a particular interest in testing the well meters related to the Vail Zone of the system. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the well meters using the most appropriate test method. E Source and Eagle River determined a comparative meter test was most appropriate for all site locations.

E Source completed comparative meter tests using an insertion mag meter. This report describes the test methods and results. Table 1 below summarizes the result of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name     | Reference Flow (GPM) | Meter Flow (GPM) | Meter Accuracy (%) | Test Margin of Error (+/- %) | Pass/Fail |
|---------------|----------------------|------------------|--------------------|------------------------------|-----------|
| Vail R2       | 1,997                | 1,953            | 97.8%              | +/-3.1%                      | Pass      |
| Vail R4       | 1,070                | 834              | 77.9%              | +/-6.4%                      | n/a*      |
| Vail R6       | 638                  | 630              | 98.8%              | +/-2.8%                      | Pass      |
| Vail R7       | 1,864                | 1,828            | 98.0%              | +/-10.6%                     | n/a*      |
| Berry Creek 1 | 224                  | 218              | 97.1%              | +/-3.2%                      | Pass      |
| Berry Creek 2 | 423                  | 359              | 85.0%              | +/-3.2%                      | Fail      |
| Berry Creek 3 | 740                  | 728              | 98.4%              | +/-3.1%                      | Pass      |

\*Vail R4 and Vail R7 had tap locations that were not suitable for testing, resulting in very high test uncertainties.

The test result shows that the Vail R2, Vail R6, Berry Creek 1 and Berry Creek 3 meters are accurately measuring flow within the test margin of error. The Berry Creek 2 meter appeared to be under-registering flow by approximately 15%. Vail R4 and Vail R7 did not have sufficient lengths of straight pipe for comparative meter testing. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth. Through the 2-year program, the CWLI will provide individualized technical support and training workshops on water loss control best practices to urban water utilities.

Participants of the CWLI will have the chance to undergo, at a minimum, a Level 1 validation of their water audits. Levels of water audit validation are defined in the Water Research Foundation Report 4639B Utility Water Audit Validation: Principles and Programs. Validation efforts range from Level 1, which examines summary data for evident errors and correct application of the M36 Methodology; to Level 3, which includes field tests. Participants who completed a Level 1 validation through the CWLI program will have the opportunity to participate in more advanced validation of their water audit data through direct technical assistance.

Eagle River completed a Level 1 validation through CWLI. Based on the results of the water audit and conversations with CWLI, Aurora selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy tests performed for Eagle River.

### 2.1 Site Description

Eagle River produces water at multiple well sites and operates the service area as discreet zones. Eagle River had a particular interest in testing the well meters related to the Vail Zone of the system.

### 2.2 Site Infrastructure

#### 2.2.1 Vail R2

**Vail R2 Meter:** Eagle River has installed a Rosemount electromagnetic flowmeter on the 12" discharge line as shown in the figure below. The Rosemount meter is installed with 5 pipe diameters of straight pipe upstream and 1 pipe diameter of straight pipe downstream, which does not meet manufacturer requirements. The meter has a physical display which was used to collect the flow data.



**Figure 1: Vail R2 Flowmeter**

**Vail R2 Tap Location:** Eagle River has installed a tap with 4 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream as shown in the figure below. This is less than recommended, but the measurement did not appear to be significantly impacted.



**Figure 2: Vail R2 Tap Location**

### 2.2.2 Vail R4

**Vail R4 Meters:** Eagle River has installed a Rosemount electromagnetic flowmeter and an FPI insertion meter on the 10" discharge line as shown in the figures below. The Rosemount meter installation conditions could not be verified. The FPI meter is installed with approximately 5 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream. Installation requirements for this meter are unknown. The meters have a physical display which was used to collect the flow data.



**Figure 3: Vail R4 Flowmeter**



**Figure 4: Vail R4 FPI Meter**

**Vail R4 Tap Location:** Eagle River has installed a tap with 3 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream as shown in the figure below. This is not suitable for a comparative meter test.



**Figure 5: Vail R4 Tap Location**

### 2.2.3 Vail R6

**Vail R6 Meter:** Eagle River has installed a Rosemount electromagnetic flowmeter on the 12" discharge line as shown in the figure below. The Rosemount meter is installed with 5 pipe diameters of straight pipe upstream and 1 pipe diameter of straight pipe downstream, which does not meet manufacturer requirements. The meter has a physical display which was used to collect the flow data.



**Figure 6: Vail R6 Flowmeter**

**Vail R6 Tap Location:** Eagle River has installed a tap with 4 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream as shown in the figure below. This is less than recommended, but the measurement did not appear to be significantly impacted.



**Figure 7: Vail R6 Tap Location**

#### 2.2.4 Vail R7

**Vail R7 Meters:** Eagle River has installed a Rosemount electromagnetic flowmeter and an FPI insertion meter on the 10" discharge line as shown in the figure below. The Rosemount meter is installed with 5 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream, which meets manufacturer requirements. The FPI meter is installed with 9 pipe diameters of straight pipe upstream and 9 pipe diameters of straight pipe downstream. Installation requirements for this meter are unknown. The meters have a physical display which was used to collect the flow data.



**Figure 8: Vail R7 Flowmeters**

**Vail R7 Tap Location:** Eagle River has installed a tap with 0.5 pipe diameters of straight pipe upstream and 1 pipe diameter of straight pipe downstream as shown in the figure below. This is not sufficient for a comparative meter test.



**Figure 9: Vail R7 Tap Location**

### 2.2.5 Berry Creek 1

**Berry Creek 1 Meter:** Eagle River has installed a Rosemount electromagnetic flowmeter on the 6" discharge line as shown in the figure below. The Rosemount meter is installed with 4 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream, which does not meet manufacturer requirements. The meter has a physical display which was used to collect the flow data.



**Figure 10: Berry Creek 1 Flowmeter**

**Berry Creek Tap Location:** Eagle River has installed a tap with 10 pipe diameters of straight pipe upstream and 1 pipe diameters of straight pipe downstream as shown in the figure below. This is less than recommended, but the measurement did not appear to be significantly impacted.



**Figure 11: Berry Creek Tap Location**

### 2.2.6 Berry Creek 2

**Berry Creek 2 Meter:** Eagle River has installed a Rosemount electromagnetic flowmeter on the 6" discharge line as shown in the figure below. The Rosemount meter is installed with 4 pipe diameters of straight pipe upstream and 2 pipe diameters of straight pipe downstream, which does not meet manufacturer requirements. The meter has a physical display which was used to collect the flow data.



**Figure 12: Berry Creek 2 Flowmeter**

**Berry Creek 2 Tap Location:** The same tap location was used as in the Berry Creek 1 test.

### 2.2.7 Berry Creek 3

**Berry Creek 3 Meter:** Eagle River has installed a Rosemount electromagnetic flowmeter on the 8" discharge line as shown in the figure below. The Rosemount meter is installed with 4 pipe diameters of straight pipe upstream and 1 pipe diameter of straight pipe downstream, which does not meet manufacturer requirements. The meter has a physical display which was used to collect the flow data.



**Figure 13: Berry Creek 3 Flowmeter**

**Berry Creek 3 Tap Location:** The same tap location was used as in the Berry Creek 1 test.

## 3 Methods

Between April 29<sup>th</sup> and 30<sup>th</sup>, E Source and Eagle River carried out comparative insertion tests on the Vail R2, R4, R6, R7 well meters and the Berry Creek 1, 2 and 3 meters.

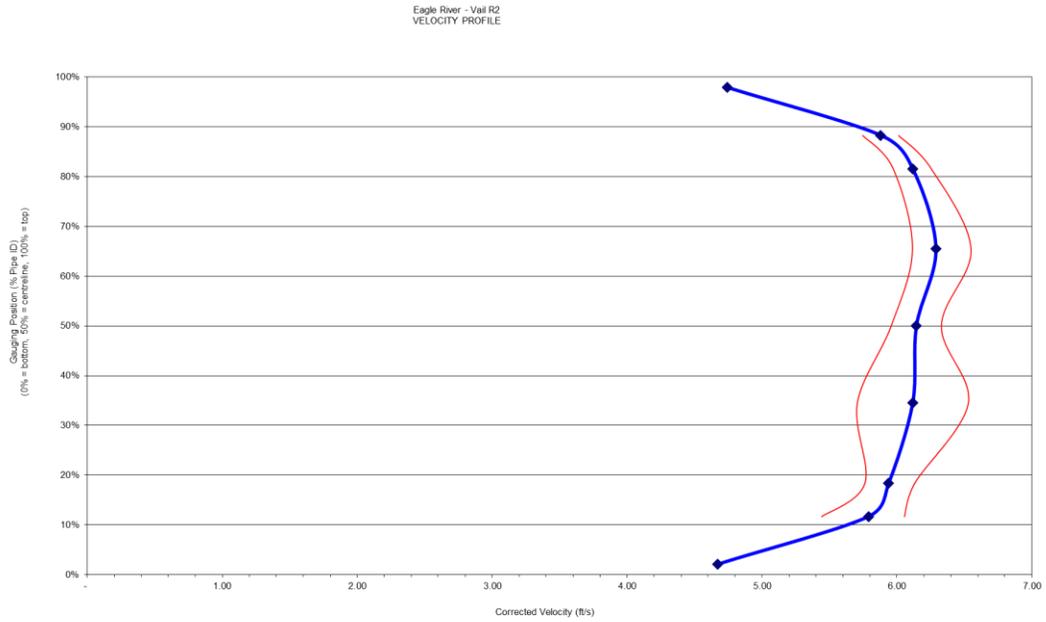
### 3.1 Insertion Meter Test Procedure

Comparative meter tests use a temporarily installed 'reference' meter of known accuracy to provide a reference measurement against which the in-situ meter can be compared. The reference meter used was an electromagnetic insertion flow meter.

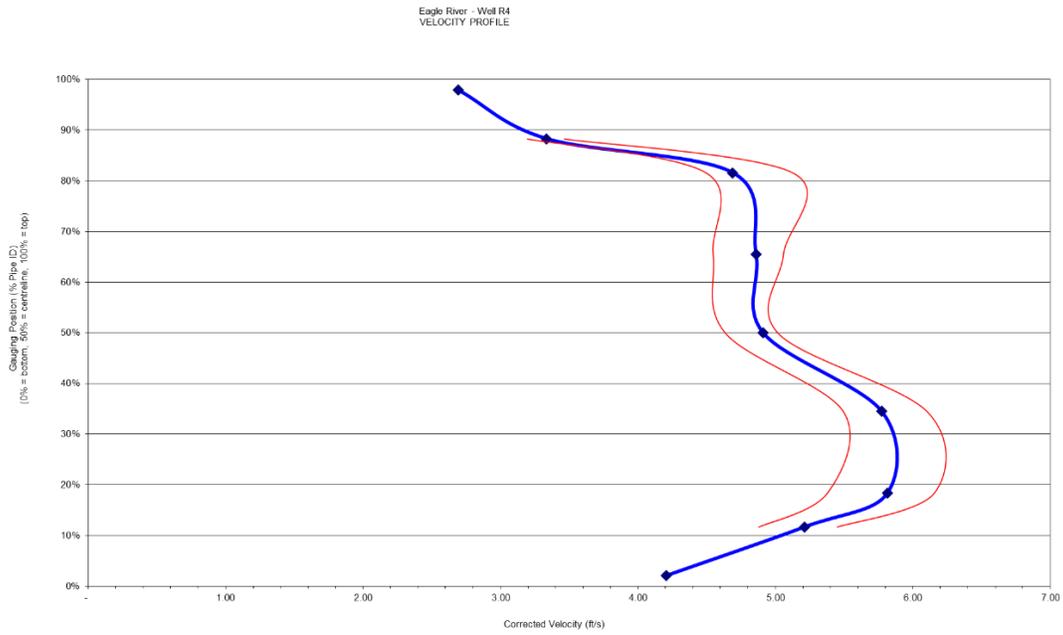
The comparative test using an insertion meter is typically done by installing the reference meter at an appropriate location either upstream or downstream of the meter to be tested. If properly located, the insertion meter will produce a pulse output that is proportional to fluid velocity at the point of measurement. The result is a true and linear output signal with respect to the fluid velocity. A data logger records the number of pulses produced by the flow meter using a 1-minute logging interval.

Key influences on the test point measurement accuracy are the intrinsic accuracy of the measurement device and the stability of the Mean-Velocity ( $V_m$ ) / Centerline-Velocity ( $V_c$ ) relationship over normally encountered flow rates. To investigate these factors, a velocity profile test was undertaken at the test point. E Source used previously collected data to determine the internal diameter of the pipe.

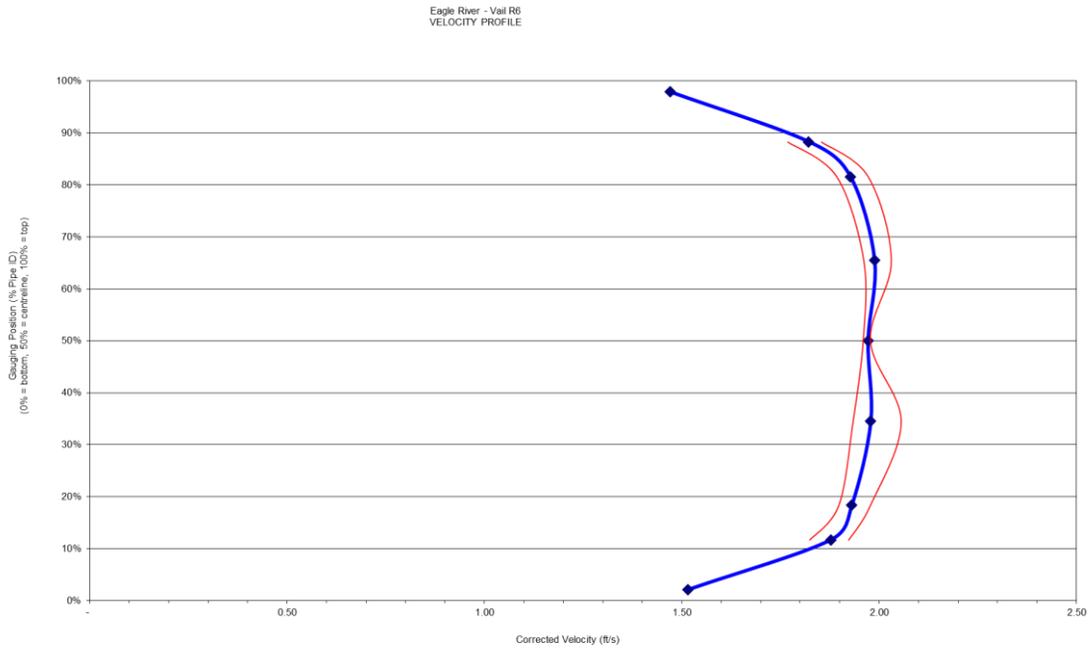
The insertion meter used by E Source has a stated measurement accuracy for recorded velocity of +/-2%. Then, using the pipe diameter and the  $V_m/V_c$  ratio measured, the velocity is converted to a flow rate. The uncertainty of the  $V_m/V_c$  ratio is dependant on the stability of the velocity profile measurement. The measured velocity profiles are shown below.



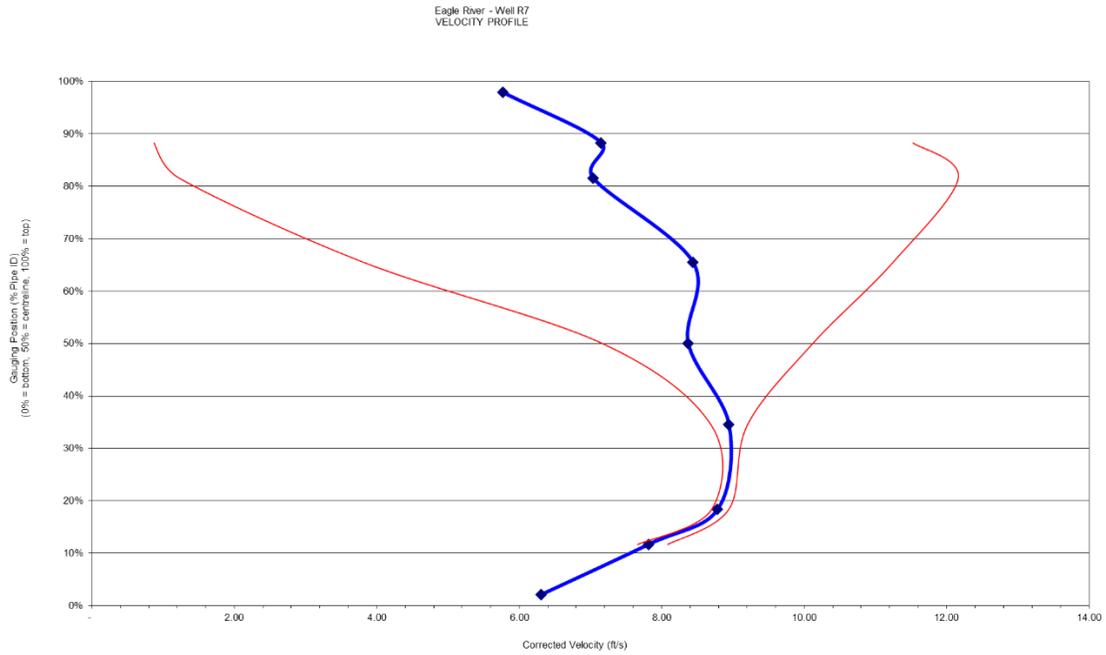
**Figure 14: Vail R2 Velocity Profile**



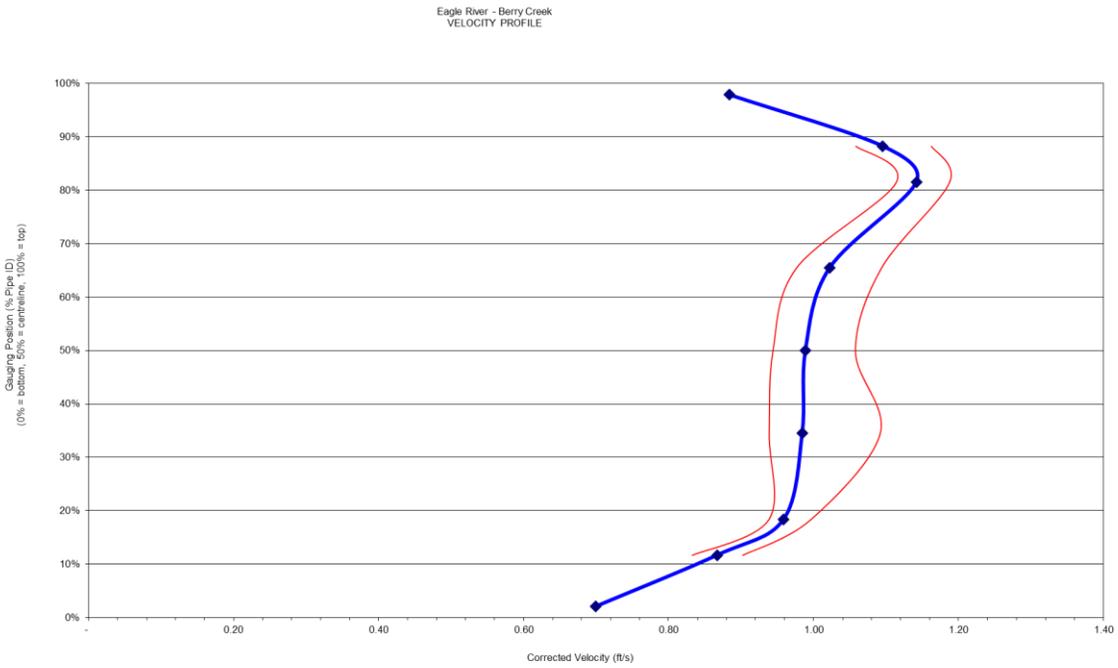
**Figure 15: Vail R4 Velocity Profile**



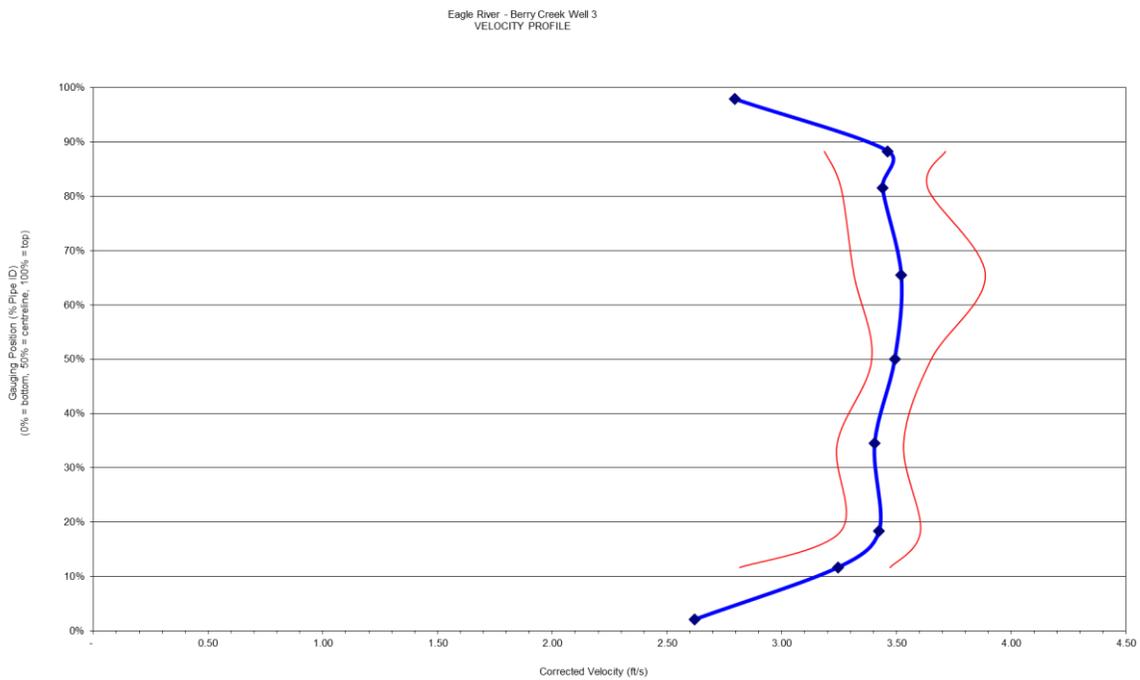
**Figure 16: Vail R6 Velocity Profile**



**Figure 17: Vail R7 Velocity Profile**



**Figure 18: Berry Creek 1 & 2 Velocity Profile**



**Figure 19 Berry Creek 3 Velocity Profile**

## 4 Results

The production meter tests were conducted at a single flow rate based on the typical flow rate passing through each meter. The results presented in the table below show a comparison between the reference meter and the Eagle River meters.

**Table 2: Test Results**

| Test Name     | Reference Flow (GPM) | Meter Flow (GPM) | Meter Accuracy (%) | Test Margin of Error (+/- %) | Pass/Fail   |
|---------------|----------------------|------------------|--------------------|------------------------------|-------------|
| Vail R2       | 1,997                | 1,953            | <b>97.8%</b>       | <b>+/-3.1%</b>               | <b>Pass</b> |
| Vail R4       | 1,070                | 834              | <b>77.9%</b>       | <b>+/-6.4%</b>               | <b>n/a*</b> |
| Vail R6       | 638                  | 630              | <b>98.8%</b>       | <b>+/-2.8%</b>               | <b>Pass</b> |
| Vail R7       | 1,864                | 1,828            | <b>98.0%</b>       | <b>+/-10.6%</b>              | <b>n/a*</b> |
| Berry Creek 1 | 224                  | 218              | <b>97.1%</b>       | <b>+/-3.2%</b>               | <b>Pass</b> |
| Berry Creek 2 | 423                  | 359              | <b>85.0%</b>       | <b>+/-3.2%</b>               | <b>Fail</b> |
| Berry Creek 3 | 740                  | 728              | <b>98.4%</b>       | <b>+/-3.1%</b>               | <b>Pass</b> |

\*Vail R4 and Vail R7 had tap locations that were not suitable for testing, resulting in very high test uncertainties.

The test result shows that the Vail R2, Vail R6, Berry Creek 1 and Berry Creek 3 meters are accurately measuring flow within the test margin of error. The Berry Creek 2 meter appeared to be under-registering flow by approximately 15%. Vail R4 and Vail R7 did not have sufficient lengths of straight pipe for comparative meter testing. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 5 Summary of findings and recommendations

Based on the test results, E Source provides the following summary and recommendations:

- Vail R2, Vail R6, Berry Creek 1 and Berry Creek 3 meters are operating within the test margin of error
- Berry Creek 2 meter appears to be under-registering flow by approximately 15%
- Vail R4 and Vail R7 results are not considered valid due to the high level of test uncertainty
- Vail R1 could not be tested due to a lack of a suitable tap
- The meters connecting the Vail system and Upper Eagle system are not installed according to manufacturer recommendations and have a high potential for meter error
- Only the Vail R7 meter is verified to be installed according to manufacturer recommendations. The Vail R4 conditions could not be verified, and the other meters are not installed according to manufacturer recommendations, leading to a higher probability of meter error
- E Source recommends that Eagle River perform electronic calibration of all meters annually as part of an ongoing meter maintenance program.

# Meter Test Results

City of Fountain

*January 2024*



## Contents

|       |  |   |
|-------|--|---|
| 1     | Executive Summary.....                 | 1 |
| 2     | Background .....                       | 2 |
| 2.1   | Site Description .....                 | 2 |
| 2.2   | Site Infrastructure .....              | 2 |
| 3     | Methods.....                           | 6 |
| 3.1   | General Test Procedures.....           | 6 |
| 3.2   | Determination of Tank Dimensions ..... | 6 |
| 3.3   | Tank Level Measurement.....            | 6 |
| 3.4   | Quantification of Uncertainty .....    | 7 |
| 3.4.1 | Meter Totalizer Uncertainty .....      | 7 |
| 3.4.2 | Level Measurement Uncertainty .....    | 7 |
| 3.4.3 | Static Test Uncertainty.....           | 7 |
| 3.4.4 | Calculation of Uncertainty .....       | 7 |
| 4     | Results.....                           | 8 |

## List of Figures

|   |   |
|---|---|
| Figure 1: Well 5 Flowmeter.....               | 3 |
| Figure 2: Southwest Water Storage Tank .....  | 4 |
| Figure 3: Fountain Terminal Tank Drawing..... | 5 |

## List of Tables

|                             |   |
|-----------------------------|---|
| Table 1: Test Results ..... | 1 |
| Table 2: Test Results ..... | 8 |

## 1 Executive Summary

The City of Fountain measures water entering the distribution system through three supply meters. One meter is located at the water treatment plant and two meters are at tank sites owned by Fountain Valley Authority (FVA). As part of the Colorado Water Loss Initiative, E Source and Fountain performed tests to determine the accuracy of both FVA meters.

E Source and Fountain completed tests of the Fountain North and Fountain South meters using the Southwest Water Storage Tank and Fountain Terminal Tank at the respective meter locations. This report describes the test methods and results. Table 1 below summarizes the results of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name | Target Flow Rate (GPM) | Reference Volume (kgal) | Meter Totalizer Volume (kgal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|-----------|------------------------|-------------------------|-------------------------------|------------------------------|------------------------------|
| South     | 1600                   | 290.3                   | 292.8                         | <b>100.9%</b>                | <b>2.6%</b>                  |
| North     | 1300                   | 120.7                   | 121.0                         | <b>100.2%</b>                | <b>2.0%</b>                  |

The test results show that both meters are accurately registering flow within the test margin of error. The South meter has a higher test uncertainty since the Southwest Water Tank seemed to have a valve that was not holding.

E Source recommends that both meters undergo calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to Phase 1 participants.

The City of Fountain completed a Level 1 validation through CWLI. Based on the results of the water audit validation and conversations with CWLI, Fountain selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy test performed for Fountain.

### 2.1 Site Description

The City of Fountain measures water at three supply meters which are summed to determine the total production for Fountain. One meter is located at the water treatment plant and two meters are at tank sites owned by FVA. Both meters at the tank sites were selected for testing. E Source reviewed the meter at the water treatment plant and the current testing procedures and determined no additional testing was needed.

### 2.2 Site Infrastructure

**Fountain South Meter:** Fountain has installed a 6" Endress Hauser Promag to measure water from the FVA tank. The meter is installed 7" downstream of a reducer and has a visible display as shown in Figure 1.



**Figure 1: Fountain South Flowmeter**

**Fountain North Meter:** During the test, the North meter was not visible so installation conditions could not be confirmed.

**Southwest Water Storage Tank:** The Southwest Storage Tank is a 3 MG tank with a hatch on top of the tank which was used to take physical level measurements. Fountain provided a drawing of the tank, which E Source used to determine the tank dimensions. The tank hatch with ESource measurement device is shown in Figure 2.



**Figure 2: Southwest Water Storage Tank**

**Fountain Terminal Tank:** The Fountain Terminal Tank is a 2.6 MG tank with a hatch on top of the tank which was used to take physical level measurements. Fountain provided a drawing of the tank, which E Source used to determine the tank dimensions. The tank drawing is shown in Figure 3.



## 3 Methods

E Source and Fountain completed tests of South and North meters using the tanks on site at each location. The meters were tested by isolating the tank and passing water from the tank through the meter to be tested. By comparing the volume change in the clearwell to the volume registered by the meter, E Source determined the meter's accuracy to within a defined margin of error.

### 3.1 General Test Procedures

The South and North meters were tested using the following procedure:

1. **Isolate the tank:** Valves were operated so that no water could enter or exit the tank except what is passing through the meter to be tested.
2. **Complete Static Level Test:** With the tank isolated and no water passing through the meter, the tank level was observed for at least 15 minutes to ensure the tank level remained steady.
3. **Collect starting reads:** The starting totalizer read was collected for the meter to be tested and the water level of the tank was measured.
4. **Turn on Pumps:** Pumps were operated to move water from the tank through the meter to be tested.
5. **Observe Level Change:** Flow continued through the meter until the desired level change was observed in the tank.
6. **Collect ending reads:** The end totalizer read was collected from the meter to be tested and the water level of the tank was measured.
7. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
8. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the tank.
9. **Compare reference volume and the metered volume:** The difference between the volume measured by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.2 Determination of Tank Dimensions

To determine the volume of the clearwell, E Source used drawings provided by Fountain. The Southwest Storage Tank was determined to have a volume of 77,699 gallons per foot of level change and The Fountain Terminal Tank was determined to have a volume of 58,752 gallons per foot of level change.

### 3.3 Tank Level Measurement

In addition to knowing the dimensions of the tank, it was also necessary to measure the level of water in the tank to a high degree of confidence. To measure the water level, E Source used a laser measurement tool with an object that would float on the water surface. The level was recorded at the beginning and

ending of each test to determine the level change over the test period. It was assumed that the level of accuracy of this device was within +/- 0.25 inches.

### 3.4 Quantification of Uncertainty

There is uncertainty in the results of any meter test. The uncertainty is due to potential measurement errors and test equipment precision. The uncertainties associated with the test are quantified to determine the margin of error of the test result.

#### 3.4.1 Meter Totalizer Uncertainty

The meter totalizer recorded flow in units of 100 gallons. Therefore, between 0-99 gallons could pass through the meter before the register would turn over, meaning the uncertainty associated with the meter totalizer is 100 gallons.

#### 3.4.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a laser measurement tool which was believed to be accurate within 0.25". Therefore, E Source calculated the uncertainty associated with +/- .25" from the beginning and ending reads. This equated to an uncertainty volume of 3,237 gallons for the Southwest Tank and 2,448 gallons for the Fountain Terminal Tank.

#### 3.4.3 Static Test Uncertainty

After isolating the Southwest Water Storage Tank, E Source and Fountain performed a static test which consisted of leaving all valves closed with no water passing through the meter to be tested for at least 15 minutes. During these 15 minutes, there was a detectable change in the water level, so E Source continued to monitor the water level for an additional 15 minutes. After 33 minutes in total, the water level had changed by 0.25' for an average rate of change of 0.45 ft/hr. This rate of change was assumed to remain steady for the full duration of the test, which contributed a total of 1.37 ft of level change during the test. Using the assumed measurement accuracy, this level change contributes an additional 4,262 gallons of uncertainty for the South Meter test.

#### 3.4.4 Calculation of Uncertainty

To calculate the total uncertainty associated with the tests, E Source added all sources of uncertainty. E Source calculated the total test uncertainty to be +/- 2.6% for the South Meter and +/- 2.0% for the North Meter.

## 4 Results

E Source and Fountain completed tests of the Fountain North and Fountain South meters using the Southwest Water Storage Tank and Fountain Terminal Tank at the respective meter locations. The test results are presented in the table below.

**Table 2: Test Results**

| Test Name | Target Flow Rate (GPM) | Reference Volume (kgal) | Meter Totalizer Volume (kgal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|-----------|------------------------|-------------------------|-------------------------------|------------------------------|------------------------------|
| South     | 1600                   | 290.3                   | 292.8                         | <b>100.9%</b>                | <b>2.6%</b>                  |
| North     | 1300                   | 120.7                   | 121.0                         | <b>100.2%</b>                | <b>2.0%</b>                  |

The test results show that both meters are accurately registering flow within the test margin of error. The South meter has a higher test uncertainty since the Southwest Water Tank seemed to have a valve that was not holding.

E Source recommends that both meters undergo calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters

# Production Meter Test Results

City of Frederick

*January 2025*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|     |   |    |
|-----|---|----|
| 1   | Executive Summary .....                 | 3  |
| 2   | Background.....                         | 5  |
| 3   | Meter Evaluation .....                  | 6  |
| 3.1 | Installation Conditions Evaluation..... | 6  |
| 3.2 | Meter Accuracy Tests.....               | 8  |
| 3.3 | Results Summary .....                   | 10 |

## List of Tables

|  |    |
|--|----|
| Table 1: Meter Evaluation Summary .....      | 4  |
| Table 2: Meter Installation Evaluation ..... | 7  |
| Table 3: Summary of Test Results .....       | 9  |
| Table 4: Meter Evaluation Summary .....      | 11 |

## List of Figures

|   |    |
|---|----|
| Figure 1: Source Meter Test Results Summary ..... | 10 |
| Figure 2: Raspberry Hill 6" .....                 | 12 |
| Figure 3: Raspberry Hill 4" .....                 | 12 |
| Figure 4: Del Camino 6" .....                     | 13 |
| Figure 5: Del Camino 4" .....                     | 13 |
| Figure 6: Cambian.....                            | 14 |
| Figure 7: The Farm 6" .....                       | 14 |
| Figure 8: The Farm 4" .....                       | 15 |
| Figure 9: Countryside 6" .....                    | 15 |
| Figure 10: Countryside 4" .....                   | 16 |
| Figure 11: Indian Peaks 6" .....                  | 16 |
| Figure 12: Indian Peaks 4" .....                  | 17 |

|                                    |    |
|------------------------------------|----|
| Figure 13: The School.....         | 17 |
| Figure 14: Eagle Crest 6” .....    | 18 |
| Figure 15: Eagle Crest 4” .....    | 18 |
| Figure 16: Summitview 4” .....     | 19 |
| Figure 17: No Name 6” .....        | 19 |
| Figure 18: No Name 4” .....        | 20 |
| Figure 19: Prairie Greens 6” ..... | 20 |
| Figure 20: Prairie Greens 4” ..... | 21 |

## Appendices

Appendix A: Individual Meter Test Results

## 1 Executive Summary

The Town of Frederick purchases water from Central Weld through multiple connections and was interested in verifying the accuracy of the flowmeters. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meters using the most appropriate test method. Due to limitations with piping configuration, all meters were tested with a clamp-on ultrasonic flowmeter.

E Source performed meter tests on 21 metered connections between Nov. 28 and Nov. 30. This report describes the test methods and results for each flow meter as well as an assessment of meter installation conditions based on data from the meter manufacturer. Table 1 below summarizes the results of the analyses. More detail on how the test results were derived can be found in the body of this report. During the testing, only 6 of the 21 meters had the required length of straight pipe available for the reference meter, so test results should be used with caution. The averaged test results showed 5 of the 21 meters were within +/-3% accuracy; 3 of the meters were between 3% and 6%; 3 meters were between 6% and 10%; and 9 of the meters were outside of +/-10% accuracy.

**Table 1: Meter Evaluation Summary**

| <b>Meter</b>      | <b>Meets Installation Requirements?</b> | <b>Test Flow Rate (GPM)</b> | <b>Meter Accuracy</b> | <b>Test Confidence</b> |
|-------------------|---|-----------------------------|-----------------------|------------------------|
| Raspberry Hill 6" | N                                       | 209                         | 115%                  | Low                    |
| Raspberry Hill 4" | Y                                       | 44                          | 98%                   | Medium                 |
| Del Camino 6"     | N                                       | 56                          | 102%                  | Low                    |
| Del Camino 4"     | Y                                       | 48                          | 96%                   | Medium                 |
| Cambian           | N                                       | 39                          | 113%                  | Low                    |
| The Farm 6"       | N                                       | 149                         | 109%                  | Low                    |
| The Farm 4"       | Y                                       | 60                          | 91%                   | High                   |
| Countryside 6"    | N                                       | 319                         | 102%                  | Low                    |
| Countryside 4"    | Y                                       | 426                         | 66%                   | High                   |
| Indian Peaks 6"   | N                                       | 263                         | 89%                   | Medium                 |
| Indian Peaks 4"   | Y                                       | 292                         | 70%                   | High                   |
| The School        | N                                       | 61                          | 103%                  | Low                    |
| Eagle Crest 6"    | N                                       | 190                         | 116%                  | Low                    |
| Eagle Crest 4"    | Y                                       | 105                         | 81%                   | Low                    |
| Summitview 6"     | N                                       | 150                         | 0%                    | Low                    |
| Summitview 4"     | Y                                       | 63                          | 94%                   | High                   |
| No Name 6"        | Y                                       | 127                         | 106%                  | Low                    |
| No Name 4"        | Y                                       | 142                         | 71%                   | High                   |
| Prairie Greens 6" | Y                                       | 156                         | 101%                  | Low                    |
| Prairie Greens 4" | N                                       | 186                         | 92%                   | High                   |
| Tank Site         | Y                                       | 118                         | n/a*                  | n/a*                   |

\* Tank Site flow meter totalizer records to the nearest 1,000 gallons, therefore the test results not valid

In place of providing a test measurement uncertainty, E Source generally categorizes tests as high, medium, or low confidence based on the conditions of the test location. High confidence corresponds to a metallic pipe in good condition with a suitable length of upstream and downstream straight pipe and no other factors that may impact the measurement. Moderate confidence is assigned for tests that do not meet one of those conditions and low confidence is assigned for tests that fail multiple of those conditions or have less than 60% of the required length of straight pipe.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program continues offering water audit validations, but also goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to CWLI participants.

City of Frederick completed a Level 1 validation through CWLI in 2023 and selected source meter testing for additional direct technical assistance. This report summarizes the methodology and results of the accuracy tests.

## 3 Meter Evaluation

### 3.1 Installation Conditions Evaluation

Improper meter installation is one of the primary causes of meter inaccuracy. Therefore, E Source evaluated the installation conditions for all meters during the source meter testing. Each meter has a recommended upstream and downstream length of straight pipe specified by the meter manufacturer. E Source compared the actual upstream and downstream lengths of straight pipe to the lengths required by the manufacturer to determine whether the meter is installed according to the manufacturer recommendations. In total, 9 of the 21 meters are installed according to manufacturer recommendations. Table 2 below details the results of this evaluation.

**Table 2: Meter Installation Evaluation**

| <b>Meter</b>      | <b>Upstream Length (in)</b> | <b>Downstream Length (in)</b> | <b>Required Upstream</b> | <b>Required Downstream</b> | <b>Meets Installation Requirements?</b> |
|-------------------|-----------------------------|-------------------------------|--------------------------|----------------------------|---|
| Raspberry Hill 6" | 12                          | 14                            | 60                       | 12                         | N                                       |
| Raspberry Hill 4" | 63                          | 51                            | 40                       | 8                          | Y                                       |
| Del Camino 6"     | 16                          | 0                             | 60                       | 12                         | N                                       |
| Del Camino 4"     | 60                          | 50                            | 20                       | 8                          | Y                                       |
| Cambian           | 30                          | 10                            | 60                       | 12                         | N                                       |
| The Farm 6"       | 29                          | 28                            | 60                       | 12                         | N                                       |
| The Farm 4"       | 90                          | 72                            | 40                       | 8                          | Y                                       |
| Countryside 6"    | 23                          | 20                            | 60                       | 12                         | N                                       |
| Countryside 4"    | 63                          | 62                            | 40                       | 8                          | Y                                       |
| Indian Peaks 6"   | 48                          | 66                            | 60                       | 12                         | N                                       |
| Indian Peaks 4"   | 70                          | 64                            | 40                       | 8                          | Y                                       |
| The School        | 30                          | 8                             | 60                       | 12                         | N                                       |
| Eagle Crest 6"    | 12                          | 18                            | 60                       | 12                         | N                                       |
| Eagle Crest 4"    | 34                          | 47                            | 20                       | 8                          | Y                                       |
| Summitview 6"     | 36                          | 0                             | 30                       | 12                         | N                                       |
| Summitview 4"     | 69                          | 37                            | 40                       | 8                          | Y                                       |
| No Name 6"        | 19                          | 18                            | 60                       | 12                         | Y                                       |
| No Name 4"        | 46                          | 78                            | 20                       | 8                          | Y                                       |
| Prairie Greens 6" | 49                          | 31                            | 60                       | 12                         | Y                                       |
| Prairie Greens 4" | 128                         | 17                            | 40                       | 8                          | N                                       |
| Tank Site         | 32                          | 42                            | 40                       | 16                         | Y                                       |

### 3.2 Meter Accuracy Tests

E Source and Frederick completed the comparative meter tests using a Flexim F601 ultrasonic flow meter. The tests were performed by installing the E Source reference meter in line with the Frederick flow meters and recording flow measurements from the reference meter and the Frederick flow meters. The volume recorded by the Frederick meter was then compared to the volume recorded by the E Source reference meter to determine the meter accuracy.

**Table 3: Summary of Test Results**

| <b>Meter</b>      | <b>Frederick Meter Flow Rate (GPM)</b> | <b>Reference Flow Rate (GPM)</b> | <b>Meter Accuracy</b> | <b>Test Confidence</b> |
|-------------------|--|----------------------------------|-----------------------|------------------------|
| Raspberry Hill 6" | 240                                    | 209                              | 115%                  | Low                    |
| Raspberry Hill 4" | 43                                     | 44                               | 98%                   | Medium                 |
| Del Camino 6"     | 57                                     | 56                               | 102%                  | Low                    |
| Del Camino 4"     | 46                                     | 48                               | 96%                   | Medium                 |
| Cambian           | 44                                     | 39                               | 113%                  | Low                    |
| The Farm 6"       | 162                                    | 149                              | 109%                  | Low                    |
| The Farm 4"       | 55                                     | 60                               | 91%                   | High                   |
| Countryside 6"    | 326                                    | 319                              | 102%                  | Low                    |
| Countryside 4"    | 282                                    | 426                              | 66%                   | High                   |
| Indian Peaks 6"   | 235                                    | 263                              | 89%                   | Medium                 |
| Indian Peaks 4"   | 204                                    | 292                              | 70%                   | High                   |
| The School        | 63                                     | 61                               | 103%                  | Low                    |
| Eagle Crest 6"    | 220                                    | 190                              | 116%                  | Low                    |
| Eagle Crest 4"    | 85                                     | 105                              | 81%                   | Low                    |
| Summitview 6"     | 0                                      | 150                              | 0%                    | Low                    |
| Summitview 4"     | 60                                     | 63                               | 94%                   | High                   |
| No Name 6"        | 135                                    | 127                              | 106%                  | Low                    |
| No Name 4"        | 100                                    | 142                              | 71%                   | High                   |
| Prairie Greens 6" | 158                                    | 156                              | 101%                  | Low                    |
| Prairie Greens 4" | 172                                    | 186                              | 92%                   | High                   |
| Tank Site         | 133                                    | 118                              | n/a*                  | n/a*                   |

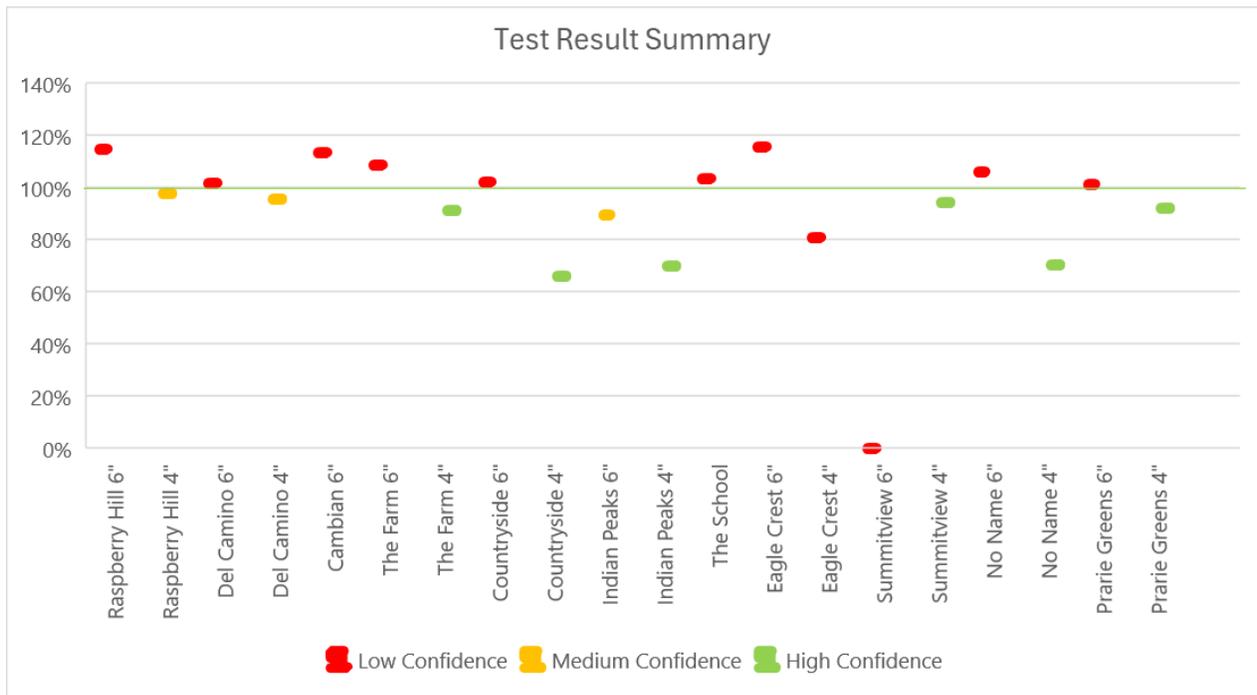
\* Tank Site flow meter totalizer records to the nearest 1,000 gallons, therefore the test results not valid

The ultrasonic flow meter that was used for testing has a requirement of 15 pipe diameters of straight pipe for an accurate measurement. During testing, 6 of the 21 test locations had the required length of straight pipe for the reference meter and thus the results are considered to have high confidence. Three of the test locations were between 60-100% of the required length of straight pipe and thus the test

results were considered having medium confidence. Twelve test locations had less than 60% of the required straight length and the results were considered having low confidence.

The averaged test results showed 5 of the 21 meters were within +/-3% accuracy; 3 of the meters were between 3% and 6%; 3 meters were between 6% and 10%; and 9 of the meters were outside of +/-10% accuracy. The meters overall were equally likely to show over-registration of flow as under-registration. Figure 1 shows the summary of the test results. Additional details for each meter are provided in Appendix A: Individual Meter Test Results.

**Figure 1: Source Meter Test Results Summary**



### 3.3 Results Summary

Table 4 on the following page summarizes the data collected by E Source including an evaluation of meter installation conditions and results of comparative meter testing performed on site. Additional details for each meter can be found in Appendix A.

After the site inspections, it was determined that 9 of the 21 meters evaluated were installed according to installation conditions.

During field testing, only six locations had the recommended length of straight pipe for the reference meter to result in high test confidence. Therefore, all other test results should be used with caution.

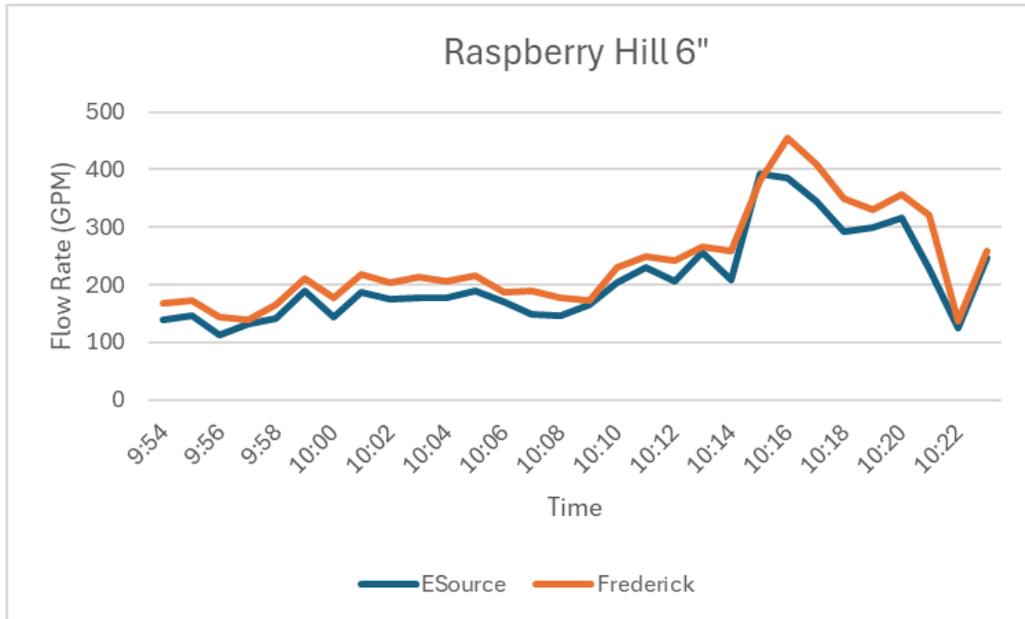
**Table 4: Meter Evaluation Summary**

| <b>Meter</b>      | <b>Meets Installation Requirements?</b> | <b>Test Flow Rate (GPM)</b> | <b>Meter Accuracy</b> | <b>Test Confidence</b> |
|-------------------|---|-----------------------------|-----------------------|------------------------|
| Raspberry Hill 6" | N                                       | 209                         | 115%                  | Low                    |
| Raspberry Hill 4" | Y                                       | 44                          | 98%                   | Medium                 |
| Del Camino 6"     | N                                       | 56                          | 102%                  | Low                    |
| Del Camino 4"     | Y                                       | 48                          | 96%                   | Medium                 |
| Cambian           | N                                       | 39                          | 113%                  | Low                    |
| The Farm 6"       | N                                       | 149                         | 109%                  | Low                    |
| The Farm 4"       | Y                                       | 60                          | 91%                   | High                   |
| Countryside 6"    | N                                       | 319                         | 102%                  | Low                    |
| Countryside 4"    | Y                                       | 426                         | 66%                   | High                   |
| Indian Peaks 6"   | N                                       | 263                         | 89%                   | Medium                 |
| Indian Peaks 4"   | Y                                       | 292                         | 70%                   | High                   |
| The School        | N                                       | 61                          | 103%                  | Low                    |
| Eagle Crest 6"    | N                                       | 190                         | 116%                  | Low                    |
| Eagle Crest 4"    | Y                                       | 105                         | 81%                   | Low                    |
| Summitview 6"     | N                                       | 150                         | 0%                    | Low                    |
| Summitview 4"     | Y                                       | 63                          | 94%                   | High                   |
| No Name 6"        | Y                                       | 127                         | 106%                  | Low                    |
| No Name 4"        | Y                                       | 142                         | 71%                   | High                   |
| Prairie Greens 6" | Y                                       | 156                         | 101%                  | Low                    |
| Prairie Greens 4" | N                                       | 186                         | 92%                   | High                   |
| Tank Site         | Y                                       | 118                         | n/a*                  | n/a*                   |

\* Tank Site flow meter totalizer records to the nearest 1,000 gallons, therefore the test results not valid

## Appendix A: Individual Meter Test Results

**Figure 2: Raspberry Hill 6"**



**Figure 3: Raspberry Hill 4"**

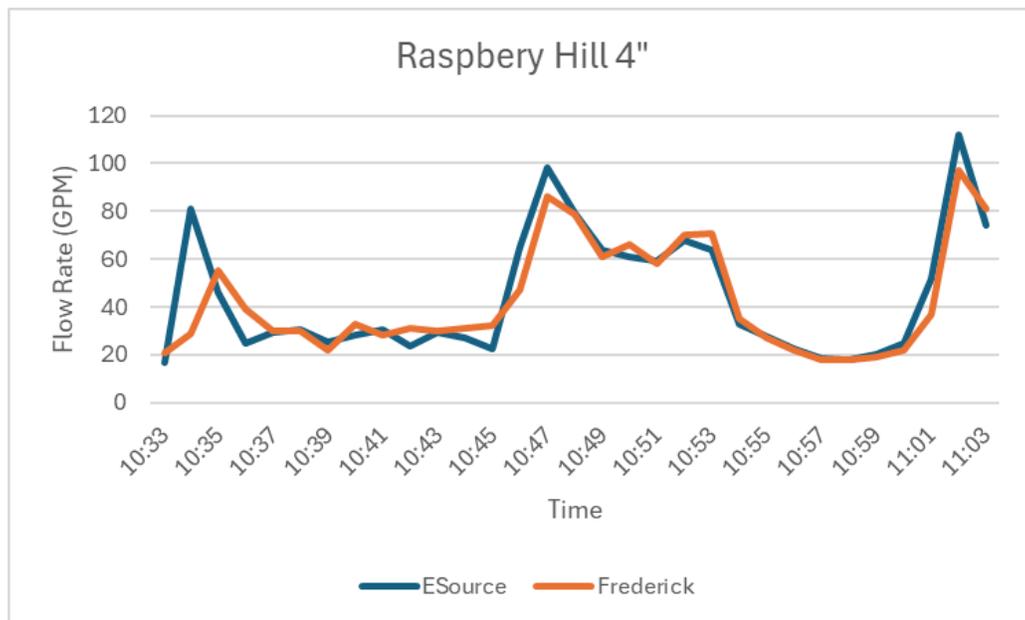


Figure 4: Del Camino 6"

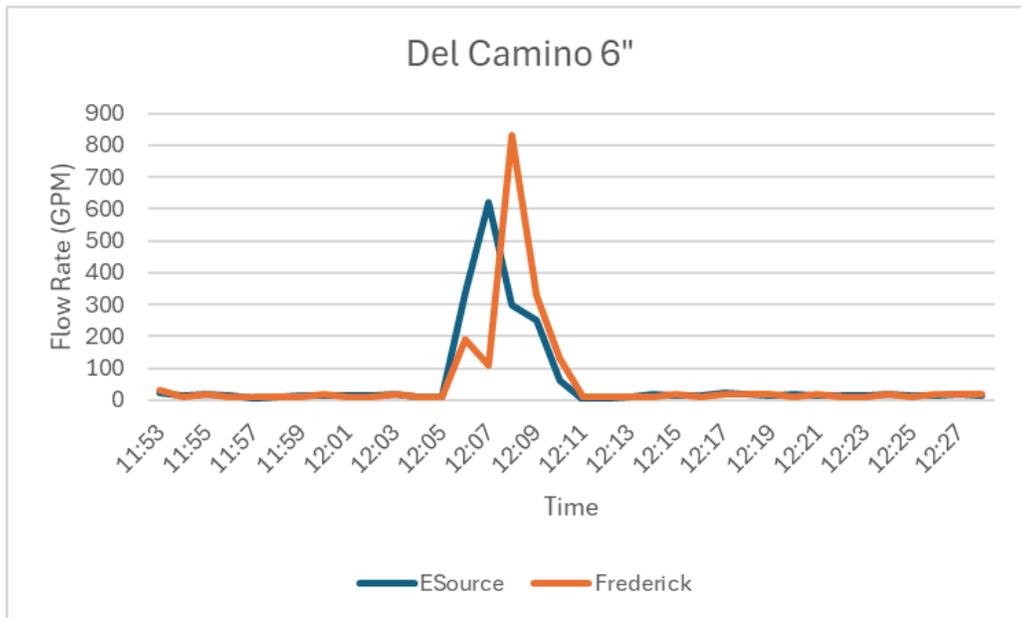


Figure 5: Del Camino 4"

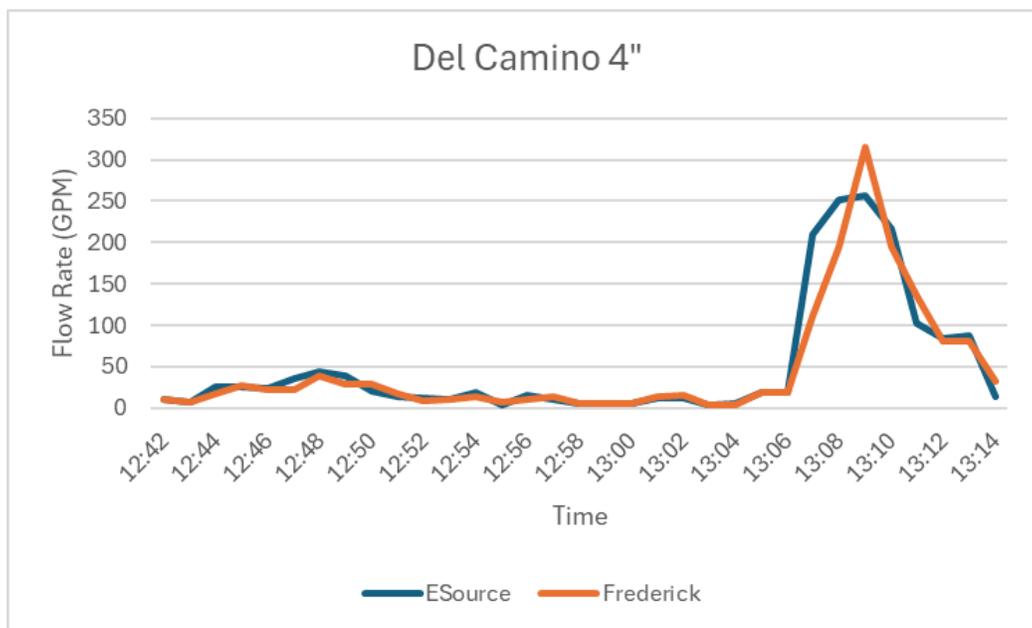


Figure 6: Cambian

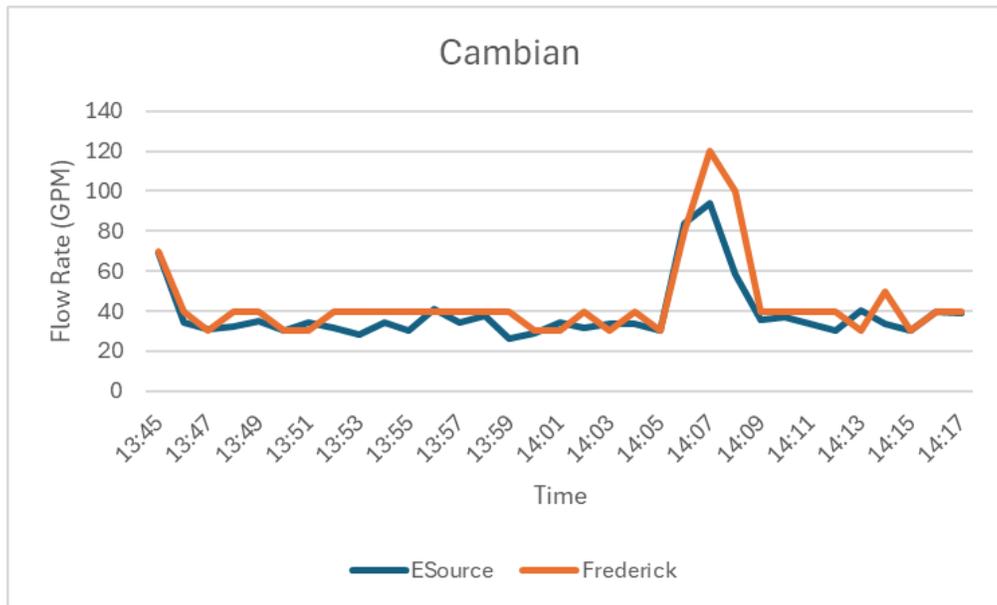
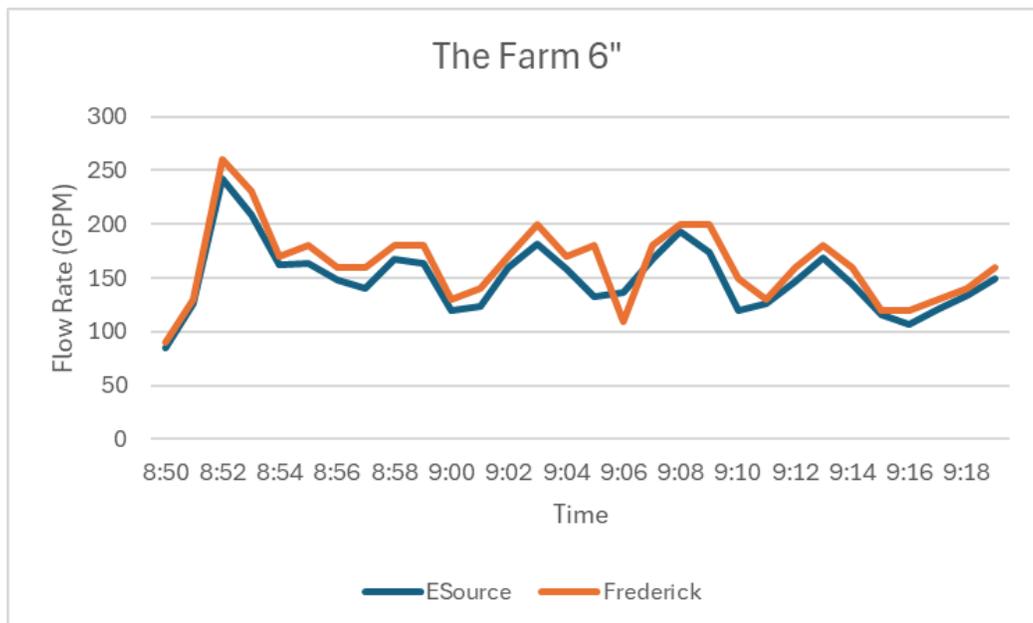
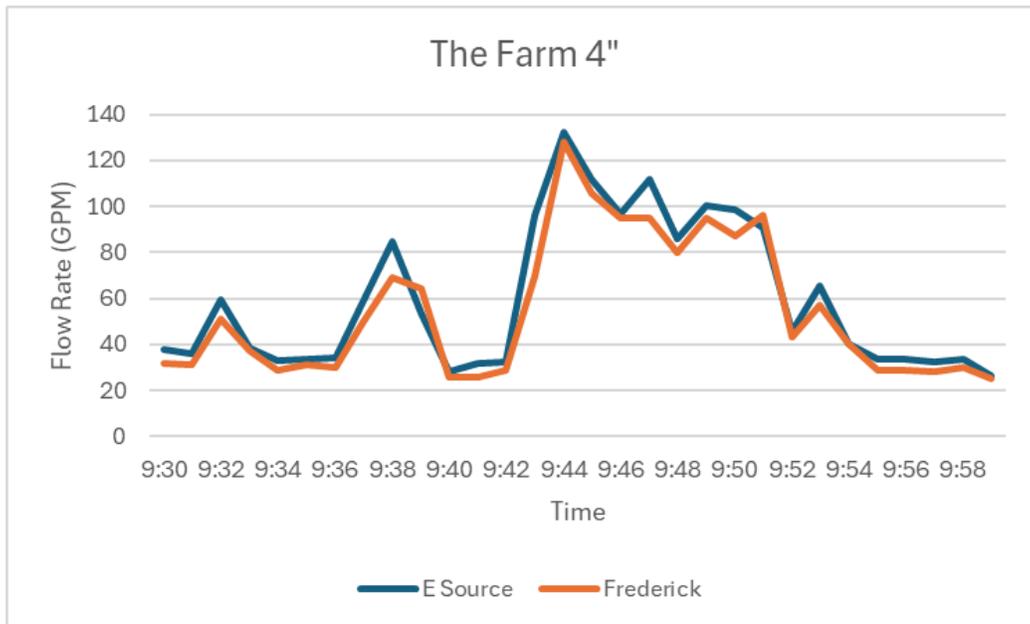


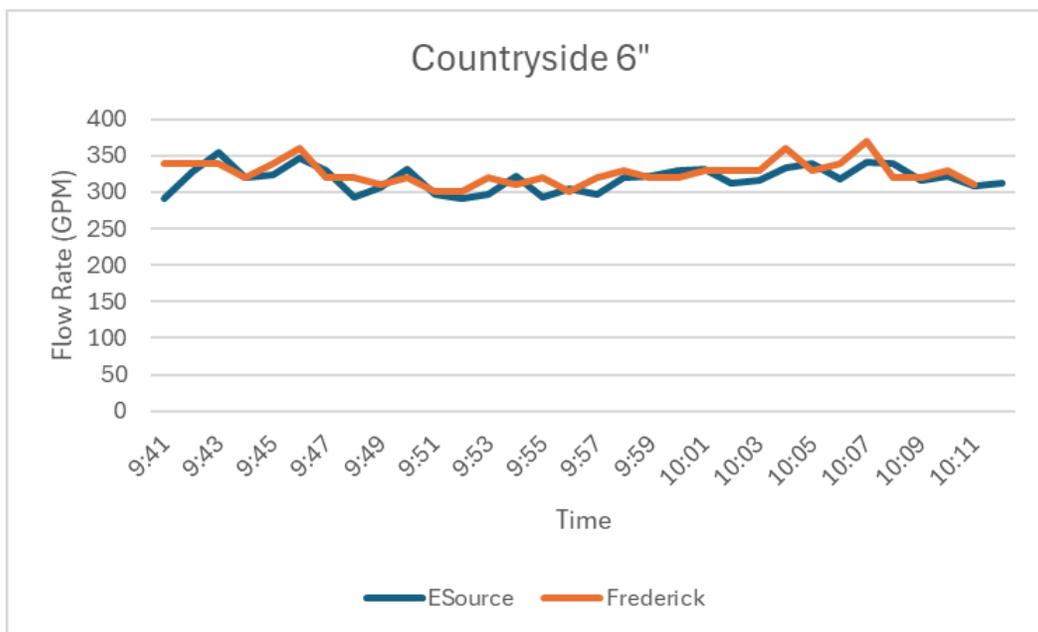
Figure 7: The Farm 6"



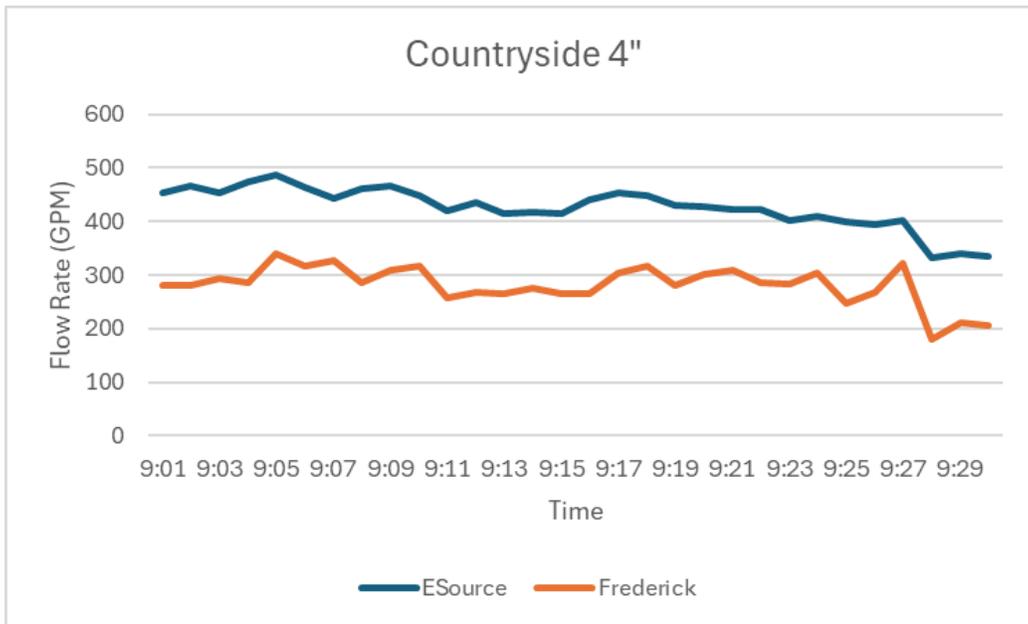
**Figure 8: The Farm 4"**



**Figure 9: Countryside 6"**



**Figure 10: Countryside 4"**



**Figure 11: Indian Peaks 6"**

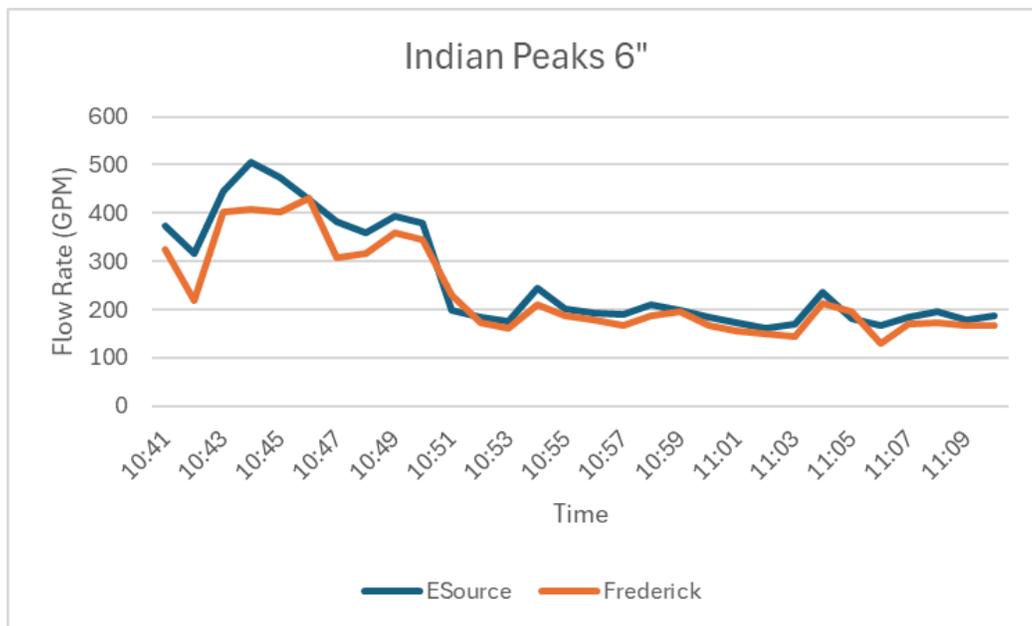


Figure 12: Indian Peaks 4"

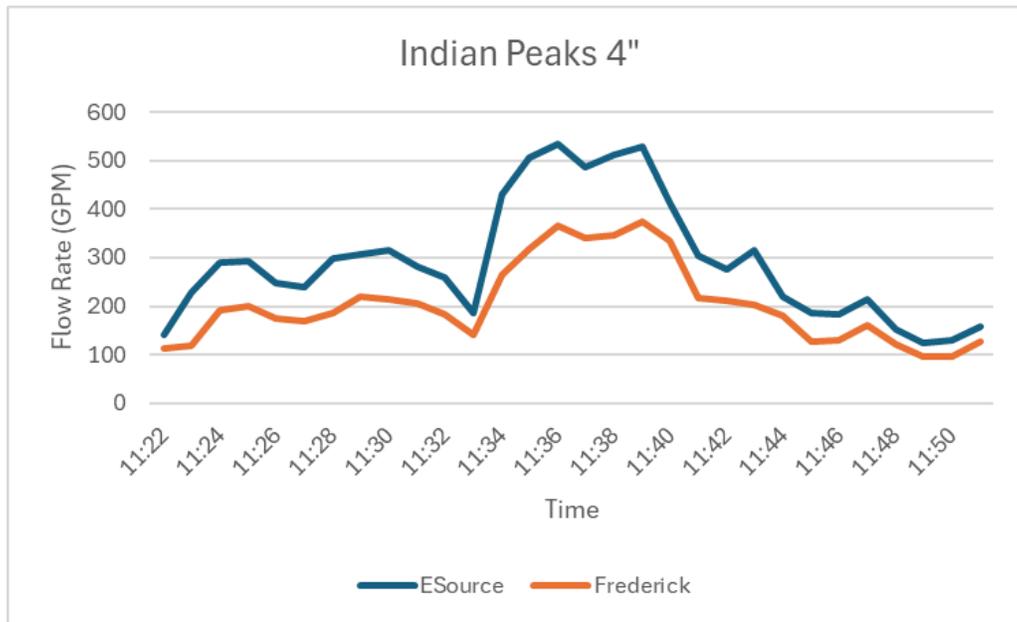
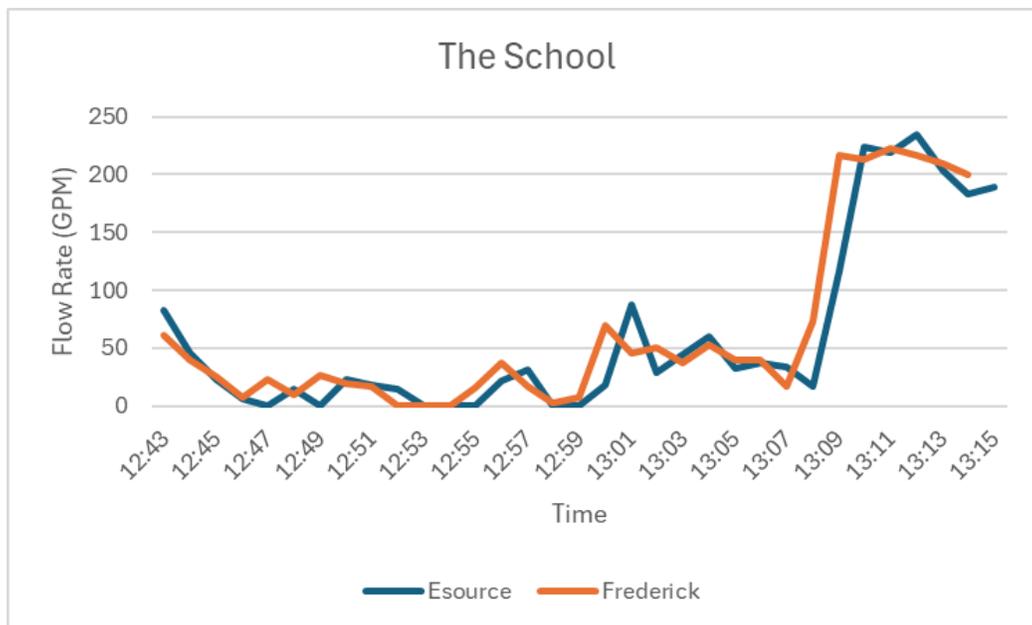
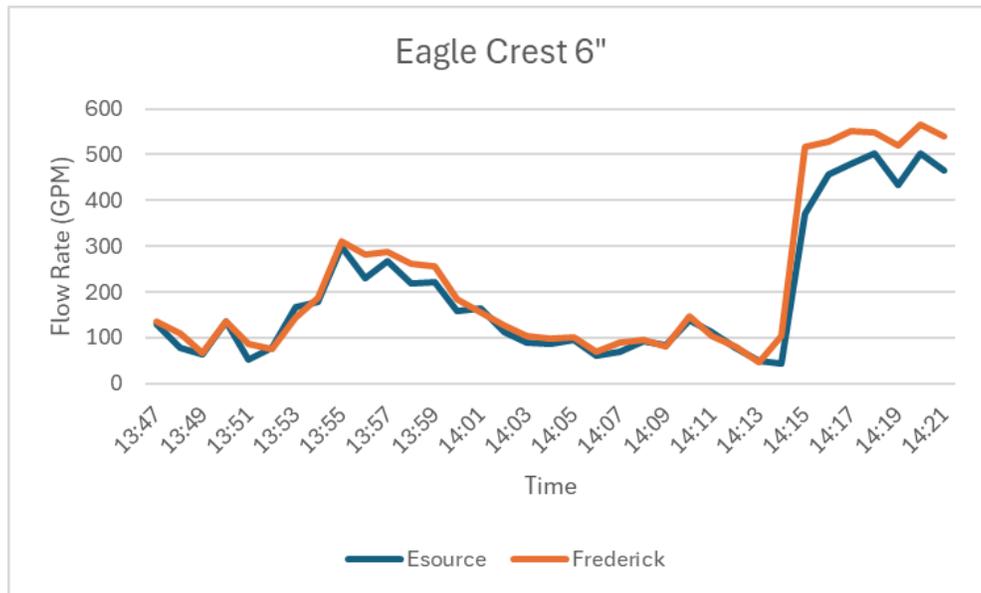


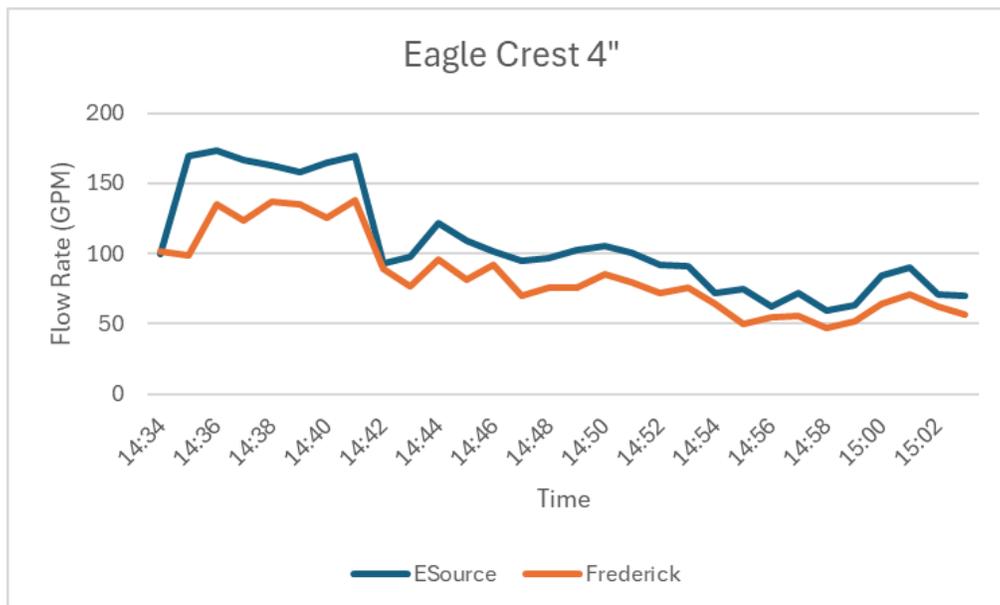
Figure 13: The School



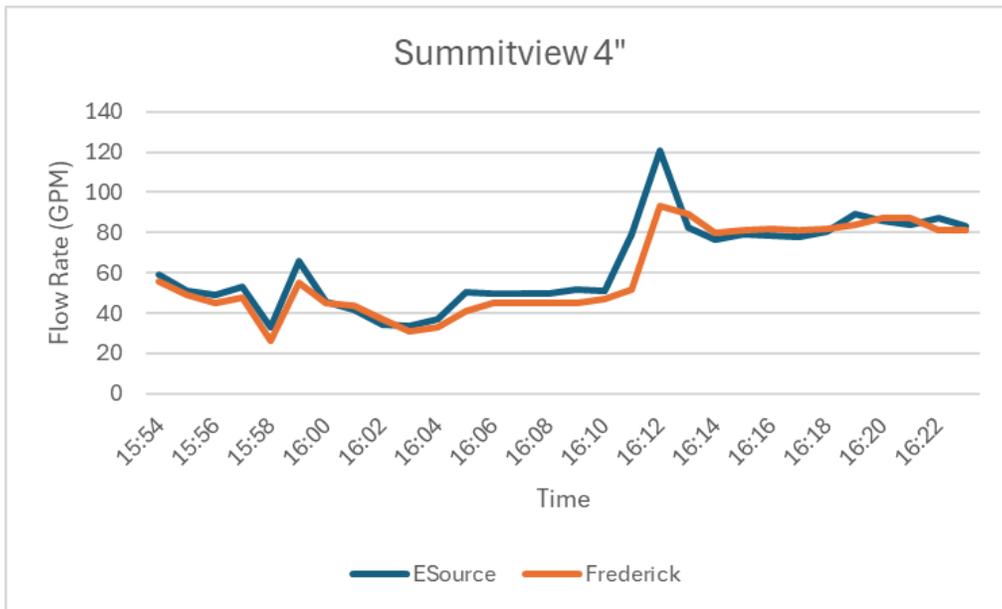
**Figure 14: Eagle Crest 6"**



**Figure 15: Eagle Crest 4"**



**Figure 16: Summitview 4"**



**Figure 17: No Name 6"**

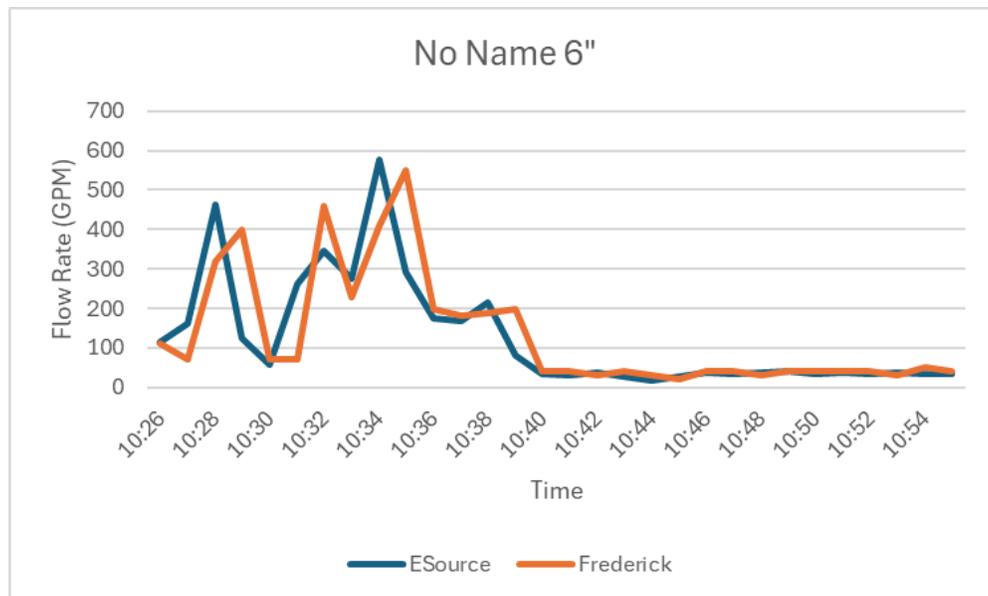


Figure 18: No Name 4"

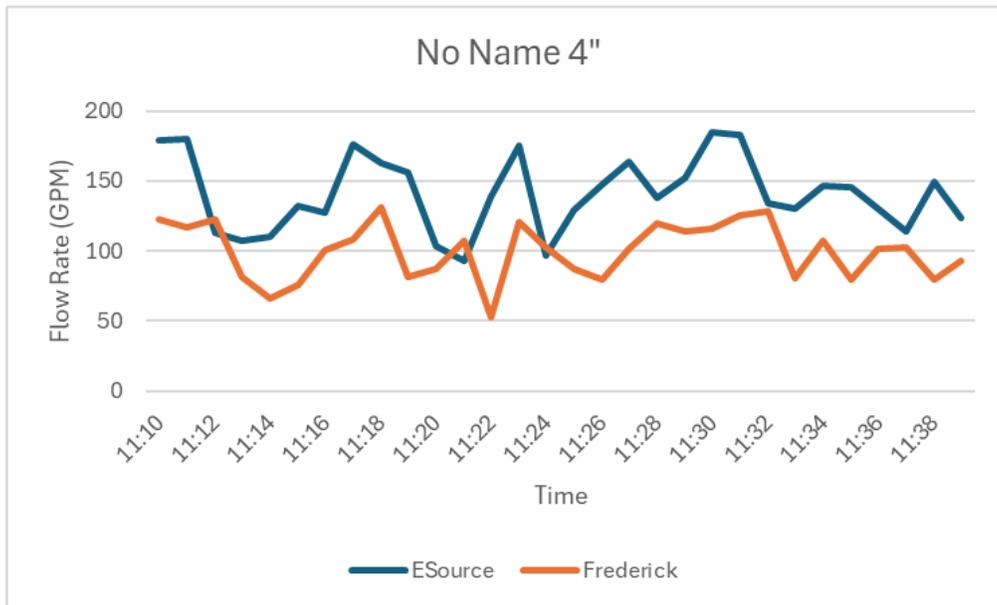


Figure 19: Prairie Greens 6"

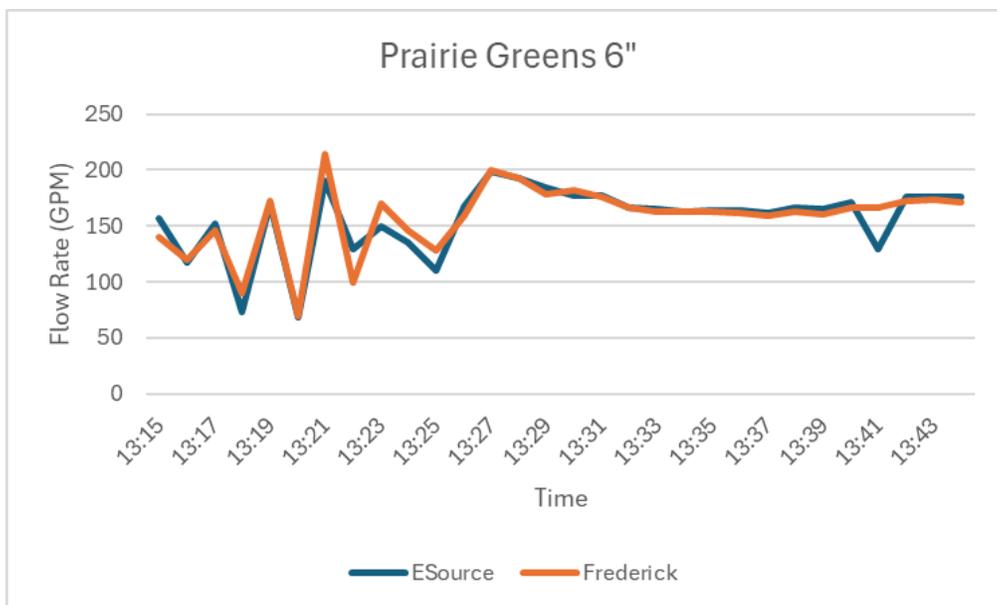
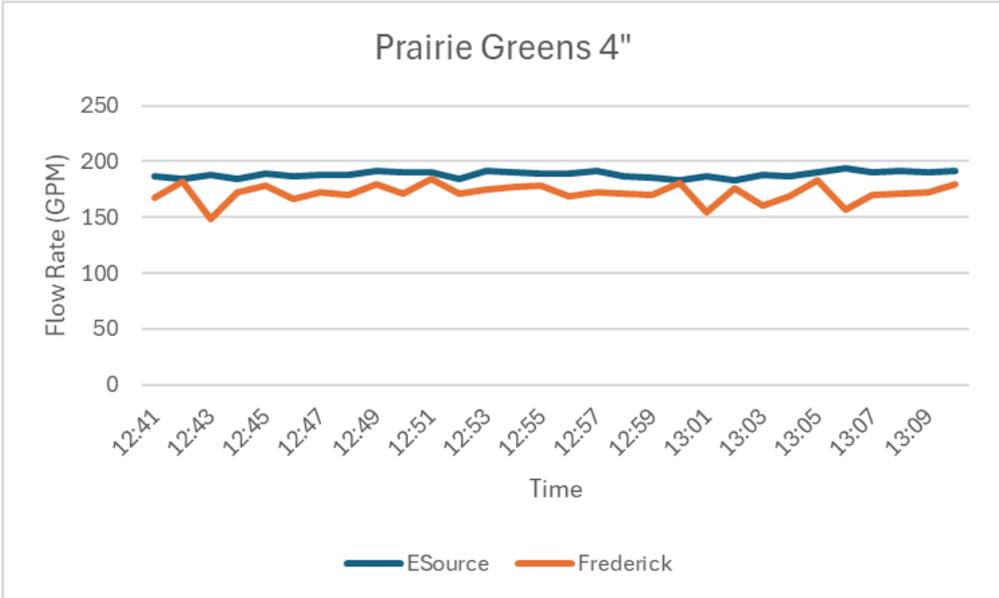


Figure 20: Prairie Greens 4"



# Meter Test Results

Town of Frisco

*December 2023*



## Contents

|       |  |    |
|-------|--|----|
| 1     | Executive Summary.....                       | 1  |
| 2     | Background .....                             | 2  |
| 2.1   | Site Description .....                       | 2  |
| 2.2   | Site Infrastructure .....                    | 2  |
| 3     | Methods.....                                 | 6  |
| 3.1   | Flow Rate Selection.....                     | 6  |
| 3.2   | General Test Procedures.....                 | 7  |
| 3.2.1 | Portable Test Procedure .....                | 7  |
| 3.2.2 | Clearwell Fill Test Procedure.....           | 7  |
| 3.3   | Determination of Tank Dimensions .....       | 8  |
| 3.4   | Tank Level Measurement.....                  | 8  |
| 3.5   | Quantification of Uncertainty .....          | 8  |
| 3.5.1 | Comparative Meter Uncertainty.....           | 8  |
| 3.5.2 | Level Measurement Uncertainty .....          | 8  |
| 3.5.3 | Calculation of Uncertainty .....             | 8  |
| 4     | Results.....                                 | 9  |
| 5     | Summary of findings and recommendations..... | 10 |

## List of Figures

|  |   |
|--|---|
| Figure 1: Well 5 Flowmeter.....              | 3 |
| Figure 2: Well 6 Meter .....                 | 4 |
| Figure 3: Skid A Flowmeter .....             | 5 |
| Figure 4: Skid B Flowmeter .....             | 5 |
| Figure 5: Frisco WTP Clearwell Opening ..... | 6 |

## List of Tables

|                             |   |
|-----------------------------|---|
| Table 1: Test Results ..... | 1 |
| Table 2: Test Results ..... | 9 |

# 1 Executive Summary

The town of Frisco produces water at three wells and one water treatment plant. As part of the Colorado Water Loss Initiative, E Source and Frisco performed tests to determine the accuracy of two well meters and two meters located at the water treatment plant.

E Source and Frisco completed tests of Well 5 and Well 6 using a Sensus OMNI Portable Meter Tester and completed tests of the WTP Skid A and Skid B meters using the clearwell on site. This report describes the test method and results. Table 1 below summarizes the results of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name | Target Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|-----------|------------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Well 5    | 350                    | 5001                   | 5180                         | <b>103.6%</b>                | <b>1.5%</b>                  |
| Well 6    | 350                    | 8219                   | 7920                         | <b>96.4%</b>                 | <b>1.5%</b>                  |
| Skid A    | 100                    | 7088                   | 7415                         | <b>104.6%</b>                | <b>2.0%</b>                  |
| Skid B    | 100                    | 7211                   | 7721                         | <b>107.1%</b>                | <b>2.0%</b>                  |

The test results show that the Well 5 meter is over registering by 3.6% while the Well 6 meter is under-registering by 3.6%. The test uncertainty is +/- 1.5% for both tests. The Skid A meter is over-registering by 4.6% and the Skid B meter is over-registering by 7.1% with a test uncertainty of +/-2.0% for each test. E Source further verified that there is no infiltration into the clearwell with a secondary measurement while all pumps were off to ensure the level was not changing.

E Source recommends that all 4 meters undergo calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters. E Source also recommends that Frisco use the stated accuracy of the test results to adjust the production volumes in the AWWA Water Audit Spreadsheet.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to Phase 1 participants.

The town of Frisco completed a Level 1 validation through Phase 1 of CWLI. Based on the results of the water audit validation and conversations with CWLI, Frisco selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy test performed for Frisco.

### 2.1 Site Description

The town of Frisco produces water at three wells and one water treatment plant. Each well has one meter and the water treatment plant has two independent skids that are summed to determine the production total. One of the three wells has been offline, but Well 5, Well 6 and Skid A & B at the water treatment plant were selected for testing.

### 2.2 Site Infrastructure

**Well 5 Meter:** Frisco has installed a 6" Sensus Omni Meter to measure water produced by Well 5. The meter is installed 7" downstream of a check-valve and does have a connection at the meter port. The meter has a visible display as shown in Figure 1.



**Figure 1: Well 5 Flowmeter**

**Well 6 Meter:** Frisco has installed a 6" Sensus Omni Meter to measure water produced by Well 6. The meter is installed 6" downstream of a Cla-valve and 14" upstream of a tee. The meter has a visible display as shown in Figure 2.



Figure 2: Well 6 Meter

**WTP Skid A:** Frisco has installed a 4" Rosemount Magnetic Flowtube meter to measure water flowing into the clearwell. The meter is installed 28" downstream of a bend and 20" upstream of a valve. The meter has a visible display as shown in Figure 3.



**Figure 3: Skid A Flowmeter**

**WTP Skid B:** Frisco has installed a 4" Rosemount Magnetic Flowtube meter to measure water flowing into the clearwell. The meter is installed 28" downstream of a bend and 20" upstream of a valve. The meter has a visible display as shown in Figure 4.



**Figure 4: Skid B Flowmeter**

**WTP Clearwell:** Downstream of the Skid A & B meters is a 30'x13' clearwell. There is a hatch on top of the clearwell that was opened to measure the water level inside, as shown in Figure 5.

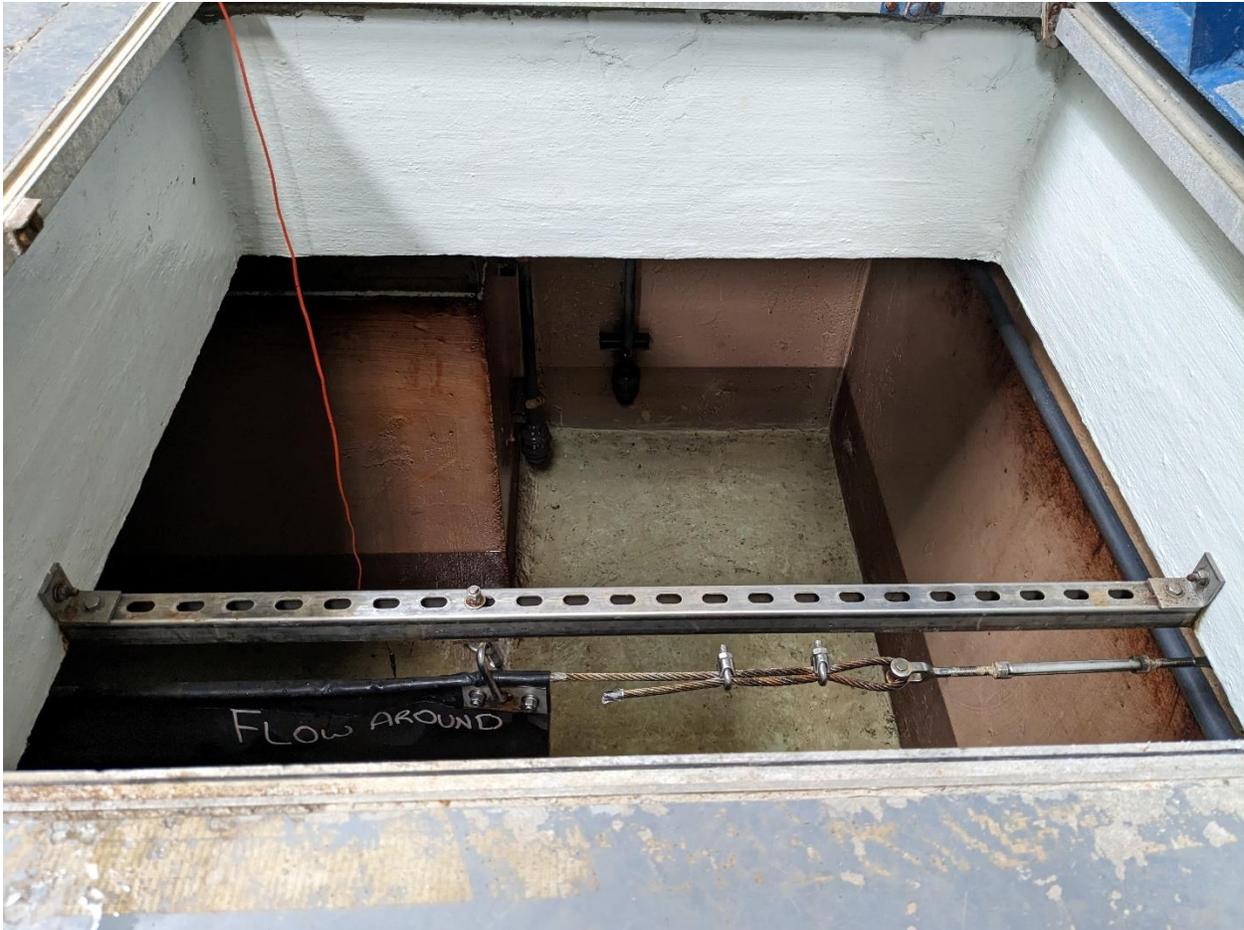


Figure 5: Frisco WTP Clearwell Opening

### 3 Methods

E Source and Frisco completed tests of Well 5 and Well 6 using a Sensus OMNI Portable Meter Tester and completed tests of the WTP Skid A and Skid B meters using the clearwell on site. The well tests were performed by closing a valve downstream of the well meter and pumping water through the well meter and through the portable test meter. The volume of water registered by each meter was compared to determine the accuracy of the meter. The WTP meters were tested by lowering the level of the clearwell and sending water through the meter to be tested into the clearwell. By comparing the volume change in the clearwell to the volume registered by the meter, E Source determined the meter's accuracy to within a defined margin of error.

#### 3.1 Flow Rate Selection

To determine the accuracy of a source meter, it is best practice to conduct the test at the full range of flowrates that the meter will typically experience. The portable meter tester has an upper limit of 350

GPM, which is the flow rate used to conduct the well meter tests. Based on conversations with, it was concluded that only one flow rate was necessary for the Skid A and Skid B meters, as the flow rate typically does not vary.

## 3.2 General Test Procedures

### 3.2.1 Portable Test Procedure

Well 5 and Well 6 were tested using the following procedure:

1. Connect fire hose from test fitting to test meter.
2. Connect hose from meter to test meter and open valves on test meter.
3. Turn on pump and adjust pump output to maintain desired flow rate.
4. Record start reading on the meter and on the test meter.
5. Allow flow to continue for approximately 15 minutes.
6. Record end reading on the meter and on the test meter.
7. Turn off well pump.
8. Remove all fittings.
9. Compare volume recorded by well meter to volume recorded by test meter to determine accuracy.

### 3.2.2 Clearwell Fill Test Procedure

Skid A and Skid B at the WTP were tested using the following procedure:

1. **Lower Clearwell level:** Water was released from the clearwell to ensure there was at least 3' to perform the meter test.
2. **Collect starting reads:** The starting totalizer read was collected for the meter to be tested and the water level of the tank was measured.
3. **Turn on Pump:** Pumps were operated to pass water through the meter to be tested and flowing into the clearwell.
4. **Observe Level Change:** Flow continued through the meter until at least 2.2 feet of level change was observed in the tank.
5. **Collect ending reads:** The end totalizer read was collected from the meter to be tested and the water level of the tank was measured.
6. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
7. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the tank.
8. **Compare reference volume and the metered volume:** The difference between the volume measured by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.3 Determination of Tank Dimensions

To determine the volume of the clearwell, E Source used a drawing provided by Frisco and took measurements on site using a laser measurement tool. Based on the drawing, the area of the tank varies near the bottom of the clearwell, so caution was taken to ensure that the water level stayed above the level at which the area is variable. The clearwell was determined to have a volume of 2,958 gallons per foot of level change.

### 3.4 Tank Level Measurement

In addition to knowing the dimensions of the tank, it was also necessary to measure the level of water in the tank to a high degree of confidence. To measure the water level, E Source measured the water level using a level sounder, which is a device that emits a noise once it contacts water. The level was recorded at the beginning and ending of each test to determine the level change over the test period. It was assumed that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.5 Quantification of Uncertainty

There is uncertainty in the results of any meter test. The uncertainty is due to potential measurement errors and test equipment precision. The uncertainties associated with the test are quantified to determine the margin of error of the test result.

#### 3.5.1 Comparative Meter Uncertainty

The Sensus OMNI Portable Test meter was recently calibrated and certified to measure within +/- 1.5% accuracy. Therefore, the test uncertainty for the Well 5 and Well 6 meter tests is assumed to be +/- 1.5%.

#### 3.5.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a level sounder which was believed to be accurate within 0.25". Therefore, E Source calculated the uncertainty from +/- .25" from the beginning and ending reads. Based on a volume of 2,958 gallons per foot, the level measurement uncertainty was 62 gallons.

#### 3.5.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the tests, E Source considered the comparative meter uncertainty or the level measurement uncertainty depending on the test. E Source calculated the total test uncertainty to be +/- 1.5% for the well meter tests and +/- 2.0% for the WTP clearwell tests.

## 4 Results

E Source completed a comparative meter test at a single flow rate for the Well 5 and Well 6 flowmeters and a volumetric meter test for the Skid A and Skid B flowmeters. The results presented in the table below show a comparison between the calculated reference volume and the volume recorded by the meter being tested.

**Table 2: Test Results**

| Test Name | Target Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|-----------|------------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Well 5    | 350                    | 5001                   | 5180                         | <b>103.6%</b>                | <b>1.5%</b>                  |
| Well 6    | 350                    | 8219                   | 7920                         | <b>96.4%</b>                 | <b>1.5%</b>                  |
| Skid A    | 100                    | 7088                   | 7415                         | <b>104.6%</b>                | <b>2.0%</b>                  |
| Skid B    | 100                    | 7211                   | 7721                         | <b>107.1%</b>                | <b>2.0%</b>                  |

The test results show that the Well 5 meter is over registering by 3.6% while the Well 6 meter is under-registering by 3.6%. The test uncertainty is +/- 1.5% for both tests. The Skid A meter is over-registering by 4.6% and the Skid B meter is over-registering by 7.1% with a test uncertainty of +/-2.0% for each test. E Source further verified that there is no infiltration into the clearwell with a secondary measurement while all pumps were off to ensure the level was not changing.

E Source recommends that all 4 meters undergo calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters. E Source also recommends that Frisco use the stated accuracy of the test results to adjust the production volumes in the AWWA Water Audit Spreadsheet.

## 5 Summary of findings and recommendations

E Source completed tests for the Well 5, Well 6, Skid A, and Skid B flow meters on November 4-5, 2023. Below are the main findings of the test and recommendations:

- The accuracy of the Well 5 meter was 103.6% with a margin of error of 1.5% at the test flow rate. It is recommended that this meter be calibrated and then tested on an annual basis.
- The accuracy of the Well 6 meter was 96.4% with a margin of error of 1.5% at the test flow rate. It is recommended that this meter be calibrated and then tested on an annual basis.
- The accuracy of the WTP Skid A meter was 104.6% with a margin of error of 2.0% at the test flow rate. It is recommended that this meter be calibrated and then tested on an annual basis.
- The accuracy of the WTP Skid B meter was 107.1% with a margin of error of 2.0% at the test flow rate. It is recommended that this meter be calibrated and then tested on an annual basis.
- E Source recommends that Frisco use the stated accuracy of the test results to adjust the production volumes in the AWWA Water Audit Spreadsheet.

# Production Meter Test Results

City of Loveland

*October 2022*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |  |   |
|-------|--|---|
| 1     | Executive Summary.....                       | 1 |
| 2     | Background .....                             | 2 |
| 2.1   | Site Description .....                       | 2 |
| 2.2   | Site Infrastructure .....                    | 2 |
| 3     | Methods.....                                 | 4 |
| 3.1   | Flow Rate Selection.....                     | 4 |
| 3.2   | General Test Procedure .....                 | 5 |
| 3.3   | Determination of Tank Dimensions .....       | 5 |
| 3.4   | Tank Level Measurement.....                  | 5 |
| 3.5   | Quantification of Uncertainty .....          | 6 |
| 3.5.1 | Totalizer Uncertainty .....                  | 6 |
| 3.5.2 | Level Measurement Uncertainty .....          | 6 |
| 3.5.3 | Calculation of Uncertainty .....             | 6 |
| 4     | Results.....                                 | 7 |
| 5     | Summary of findings and recommendations..... | 7 |

## List of Figures

|                                       |   |
|---------------------------------------|---|
| Figure 1: Discharge Flowmeter .....   | 3 |
| Figure 2: Flowmeter Display .....     | 3 |
| Figure 3: Chasteen Tank Opening ..... | 4 |

## List of Tables

|                             |   |
|-----------------------------|---|
| Table 1: Test Results ..... | 1 |
| Table 2: Test Results ..... | 7 |

## 1 Executive Summary

The City of Loveland produces water at the Chasteen’s Grove Water Treatment Plant. Water is discharged from the Chasteen Tank through a 30” mag meter to determine the volume of water supplied to the distribution system. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meter using the most appropriate test method. E Source and Loveland determined a tank drawdown test would be the most appropriate.

E Source completed a drawdown test at a single flow rate for 59 minutes. This report describes the test method and result. Table 1 below summarizes the result of the test. More detail on how the test result was derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name    | Test Flow Rate (MGD) | Reference Volume (gal) | Meter Totalizer Volume (gal) | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|--------------|----------------------|------------------------|------------------------------|------------------------------|------------------------------|
| Chasteen WTP | 23.0                 | 941,006                | 990,000                      | 105.2%                       | 2.1%                         |

The test result shows that the meter is over-registering the volume of water passing through by approximately 5% at the test flow rate. The total uncertainty of the volumetric test is +/- 2.1%, taking into consideration uncertainty associated with meter totalizer resolution and tank reference volume calculation. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth. Through the 2-year program, the CWLI will provide individualized technical support and training workshops on water loss control best practices to urban water utilities.

Participants of the CWLI will have the chance to undergo, at a minimum, a Level 1 validation of their water audits. Levels of water audit validation are defined in the Water Research Foundation Report 4639B Utility Water Audit Validation: Principles and Programs. Validation efforts range from Level 1, which examines summary data for evident errors and correct application of the M36 Methodology; to Level 3, which includes field tests. Participants who completed a Level 1 validation through the CWLI program will have the opportunity to participate in more advanced validation of their water audit data through direct technical assistance.

The City of Loveland completed a Level 1 validation through CWLI. Based on the results of the water audit and conversations with CWLI, Loveland selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy test performed for Loveland.

### 2.1 Site Description

The City of Loveland produces water at the Chasteen's Grove Water Treatment Plant. Water is discharged from the Chasteen Tank through a 48" outlet pipe. This pipe temporarily reduces to 30" and is equipped with a 30" magnetic flowmeter which is used to determine the volume of water provided to the distribution system.

### 2.2 Site Infrastructure

**30" Flowmeter:** The City of Loveland has installed a 30" Endress & Hauser Promag flowmeter to measure water flowing out of the Chasteen Tank. This meter is used for to determine the volume of water supplied to the distribution system. The meter is connected to SCADA and has a visible display as shown on the following page in Figure 2.



Figure 1: Discharge Flowmeter

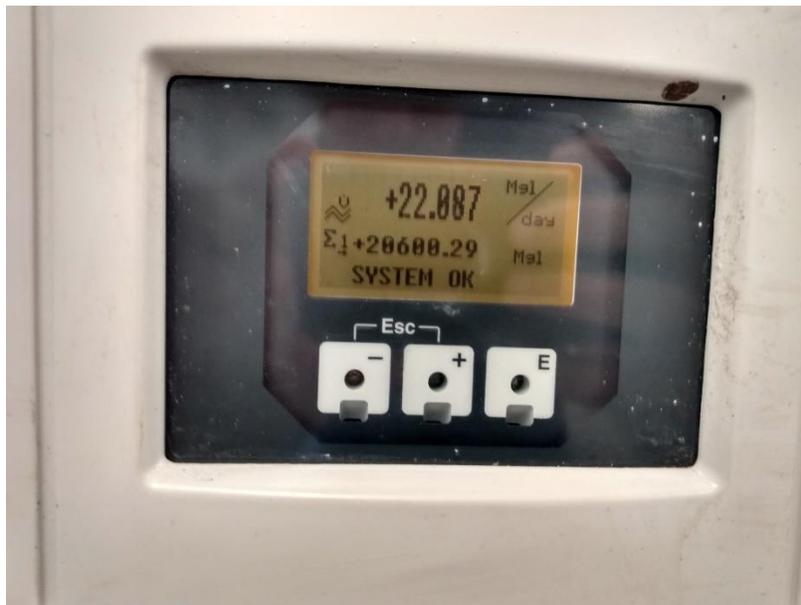


Figure 2: Flowmeter Display

**Chasteen Tank:** Near the meter is a 4 MG capacity tank. There is a hatch on top of the tank that was opened to measure the water level inside as shown below in Figure 3.



**Figure 3: Chasteen Tank Opening**

### 3 Methods

E Source and Loveland carried out a volumetric test on the water meter at a single flow rate on August 24, 2022. The test was performed by drawing a reference volume through the meter at a specific flow rate out of the tank onsite. By comparing the volume change in the tank to the volume registered by the meter, the City and E Source determined the meter's accuracy to within a target margin of error.

#### 3.1 Flow Rate Selection

To determine the accuracy of a source meter, it is best practice to conduct the test at the full range of flowrates that the meter will typically experience. The flow rate through the meter is dependent on demand in the distribution system. E Source and the City elected to conduct the test at the flow rate that was present during the test time without an attempt to alter the flow.

### 3.2 General Test Procedure

The meter test was performed by E Source and Loveland as follows:

1. **Collect starting reads:** The starting totalizer read was collected on SCADA for the meter and the water level of the tank was measured.
2. **Observe Level Change:** Flow continued through the meter until 4 feet of level change was observed in the tank.
3. **Collect ending reads:** The end totalizer read was collected from SCADA for the meter and the water level of the tank was measured.
4. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
5. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the tank.
6. **Compare reference volume and the metered volume:** The difference between the volume metered by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.3 Determination of Tank Dimensions

The volume of water sent from the tank during the test was referred to as the “reference volume”. At the end of the test, the totalizer read out was compared to this reference volume to determine the meter’s accuracy. To ensure confidence in this testing methodology, the dimensions of the tank needed to be determined.

To determine the volume of the tank, E Source used a data provided by the utility. Loveland provided a tank drawing which E Source used to calculate the tank volume. Using the tank dimensions, E Source calculated a volumetric change of 225,278 gallons per foot of level change.

### 3.4 Tank Level Measurement

In addition to knowing the dimensions of the tank, it was also necessary to measure the level of water in the tank to a high degree of confidence. E Source used a level sounder to measure and record the water level in the tank during the test.

The level sounder was placed on the roof of the tank, where a weighted line was fed through an opening until it contacted the surface of the water, at which point it emitted a noise. At that point, the line was marked so it could be measured and recorded. The difference between the starting length and ending length indicated the level change after the test was performed. It was assumed that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.5 Quantification of Uncertainty

There is uncertainty associated with conducting a drop test due to potential measurement errors and test equipment precision. This section discusses the sources of uncertainty and how the uncertainty was calculated.

#### 3.5.1 Totalizer Uncertainty

There is uncertainty associated with the meter totalizer registration because the meter will only record and display volumes to a certain interval. In this situation, the meter totalizer has a register resolution of 10,000 gallons. As an example, if the actual volume of water that has physically passed through that meter stands at 16,831 gallons, the totalizer would read 10,000. Therefore, the volume of uncertainty from the totalizer reading is 10,000 gallons.

#### 3.5.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a level sounder which was believed to be accurate within 0.25". A measurement uncertainty of +/- .25" corresponds to a measurement uncertainty of approximately +/- 4,693 gallons. This uncertainty volume is then multiplied by 2 because the measurement is taken twice, for a total level measurement uncertainty of 9,387 gallons.

#### 3.5.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the test, E Source considered the resolution of the meter totalizer as well as the margin of error volumes obtained from the level measurement. E Source calculated the total test uncertainty to be +/- 2.1%

## 4 Results

The volumetric test was conducted at a single flow rate based on the typical flow rate passing through the meter. The results presented in the table below show a comparison between the volume change in the tank based on calculations made using measured level change and the metered volume based on photos taken of the meter totalizer before and after the test.

**Table 2: Test Results**

| Test Name    | Test Flow Rate (MGD) | Reference Volume (gal) | Meter Totalizer Volume (gal)* | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|--------------|----------------------|------------------------|-------------------------------|------------------------------|------------------------------|
| Chasteen WTP | 23.0                 | 941,006                | 990,000                       | <b>105.2%</b>                | <b>2.1%</b>                  |

Based on the differences between the tank reference volumes and the meter totalizer volumes, it appears that the meter is over-registering flow by approximately 5%.

## 5 Summary of findings and recommendations

The Chasteen WTP meter was tested at a single flow rate on August 24, 2022. Below the main findings of the test:

- The volumetric change for the tank was determined to be 225,278 gallons/foot using tank dimensions provided
- The Chasteen WTP meter is operating at 105.2% accuracy with a margin of error of 2.1% at the test flow rate
- The meter is over-registering and recalibration is recommended.
- E Source recommends that Loveland follow the test procedure described to confirm the accuracy of the Chasteen WTP meter on at least an annual basis.

# Production Meter Test Results

Mount Werner Water District

*October 2022*



**COLORADO**

Colorado Water  
Conservation Board

Department of Natural Resources

## Contents

|       |  |   |
|-------|--|---|
| 1     | Executive Summary.....                       | 1 |
| 2     | Background .....                             | 2 |
| 2.1   | Site Description .....                       | 2 |
| 2.2   | Site Infrastructure .....                    | 2 |
| 3     | Methods.....                                 | 5 |
| 3.1   | Flow Rate Selection.....                     | 5 |
| 3.2   | General Test Procedure .....                 | 6 |
| 3.3   | Determination of Tank Dimensions .....       | 6 |
| 3.4   | Tank Level Measurement.....                  | 6 |
| 3.5   | Quantification of Uncertainty .....          | 7 |
| 3.5.1 | Totalizer Uncertainty .....                  | 7 |
| 3.5.2 | Level Measurement Uncertainty .....          | 7 |
| 3.5.3 | Calculation of Uncertainty .....             | 7 |
| 4     | Results.....                                 | 8 |
| 5     | Summary of findings and recommendations..... | 8 |

## List of Figures

|                                       |   |
|---------------------------------------|---|
| Figure 1: Discharge Flowmeter .....   | 3 |
| Figure 2: Flowmeter Display .....     | 3 |
| Figure 3: Chasteen Tank Opening ..... | 5 |

## List of Tables

|                             |   |
|-----------------------------|---|
| Table 1: Test Results ..... | 1 |
| Table 2: Test Results ..... | 8 |

## 1 Executive Summary

Mount Werner produces water at the Fish Creek Water Treatment Plant. Water is discharged from the treatment plant through 2 discharge lines equipped with ultrasonic flowmeters to determine the volume of water supplied to the distribution system. As part of the Colorado Water Loss Initiative (CWLI), E Source was selected to test the accuracy of the meters using the most appropriate test method. E Source and Mount Werner determined a tank drawdown test would be the most appropriate.

E Source completed a drawdown test for each flowmeter. This report describes the test method and result. Table 1 below summarizes the result of the test. More detail on how the test result was derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name      | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal)* | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|----------------|----------------------|------------------------|-------------------------------|------------------------------|------------------------------|
| City Meter     | 2,219                | 326,245                | 325,000                       | <b>99.6%</b>                 | <b>1.6%</b>                  |
| District Meter | 659                  | 98,180                 | 105,899                       | <b>107.9%</b>                | <b>4.2%</b>                  |

The test result shows that the “City” meter is accurately registering flow and the “District” meter is over-registering the volume of water passing through by approximately 8% at the test flow rate. The total uncertainty of the volumetric test is +/- 1.3% for the City test and +/-4.2% for the District test, taking into consideration uncertainty associated with meter totalizer resolution and tank reference volume calculation. More detail can be found in the body of this report that describes how the margin of error for the test was derived.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado’s projected growth. Through the 2-year program, the CWLI will provide individualized technical support and training workshops on water loss control best practices to urban water utilities.

Participants of the CWLI will have the chance to undergo, at a minimum, a Level 1 validation of their water audits. Levels of water audit validation are defined in the Water Research Foundation Report 4639B Utility Water Audit Validation: Principles and Programs. Validation efforts range from Level 1, which examines summary data for evident errors and correct application of the M36 Methodology; to Level 3, which includes field tests. Participants who completed a Level 1 validation through the CWLI program will have the opportunity to participate in more advanced validation of their water audit data through direct technical assistance.

Mount Werner completed a Level 1 validation through CWLI. Based on the results of the water audit and conversations with CWLI, Mount Werner selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy test performed for Mount Werner.

### 2.1 Site Description

Mount Werner produces water at the Fish Creek Water Treatment Plant. Water is discharged from the 2 MG Tank through 2 outlet pipes referred to as “City” and “District”. Both discharge lines are equipped with Endress & Hauser ultrasonic flowmeters.

### 2.2 Site Infrastructure

**City Flowmeter:** Mount Werner has installed an Endress & Hauser ultrasonic flowmeter to measure water flowing out of the 2 MG Tank through the “City” line. The meter is connected to SCADA and has a visible display as shown on the following page in Figure 2.

**District Flowmeter** Mount Werner has installed an Endress & Hauser ultrasonic flowmeter to measure water flowing out of the 2 MG Tank through the “District” line. The meter is connected to SCADA and has a visible display as shown on the following page in Figure 4.



Figure 1: City Flowmeter



Figure 2: City Meter Display



Figure 3: District Flowmeter



Figure 4: District Meter Display

**2 MG Tank:** Near the Treatment Plant is a 2 MG capacity tank. There is a hatch on top of the tank that was opened to measure the water level inside as shown below in Figure 5.



**Figure 5: 2 MG Tank Opening**

### 3 Methods

E Source and Mount Werner carried out a volumetric test on the water meter at a single flow rate for each meter on September 8<sup>th</sup> and 9<sup>th</sup>, 2022. The test was performed by drawing a reference volume through the meter at a specific flow rate out of the tank onsite. By comparing the volume change in the tank to the volume registered by the meter, Mount Werner and E Source determined the meter's accuracy to within a target margin of error.

#### 3.1 Flow Rate Selection

To determine the accuracy of a source meter, it is best practice to conduct the test at the full range of flowrates that the meter will typically experience. The flow rate through the meter is dependent on demand in the distribution system. E Source and Mount Werner had limited operational flexibility and performed the test based on demand at the time.

### 3.2 General Test Procedure

The meter test was performed by E Source and Mount Werner as follows:

1. **Shut down WTP:** All treatment processes and filter pumps were halted so no water was entering the clearwell
2. **Pump clearwell down:** Ensure water level in clearwell is below the level of the pipe feeding the 2-MG tank
3. **Operate valves:** Close valves to ensure water can flow out of the tank through 1 meter at a time
4. **Begin Static Test:** A 15-minute static test was completed with all pumps off and found that water was flowing from the distribution system into the clearwell. Valves further downstream were operated and the static test was repeated with no level change
5. **Collect starting reads:** The starting totalizer read was collected on SCADA for the meter and the water level of the tank was measured.
6. **Observe Level Change:** Flow continued through the meter until desired level change was observed in the tank.
7. **Collect ending reads:** The end totalizer read was collected from SCADA for the meter and the water level of the tank was measured.
8. **Calculate volume recorded by the meter:** The difference between the starting and ending totalizer reads at the meter was calculated to determine metered volume.
9. **Calculate reference volume:** E Source calculated the starting and finishing volume of water using the water level and the geometry of the tank.
10. **Compare reference volume and the metered volume:** The difference between the volume metered by the meter and the reference volume was calculated to determine the accuracy of the meter at the specified flow rate.

### 3.3 Determination of Tank Dimensions

The volume of water sent from the tank during the test was referred to as the “reference volume”. At the end of the test, the totalizer read out was compared to this reference volume to determine the meter’s accuracy. To ensure confidence in this testing methodology, the dimensions of the tank needed to be determined.

To determine the volume of the tank, E Source used a data provided by the utility. Mount Werner provided a tank drawing which E Source used to calculate the tank volume. Using the tank dimensions, E Source calculated a volumetric change of 98,180 gallons per foot of level change.

### 3.4 Tank Level Measurement

In addition to knowing the dimensions of the tank, it was also necessary to measure the level of water in the tank to a high degree of confidence. E Source used a level sounder to measure and record the water level in the tank during the test.

The level sounder was placed on the roof of the tank, where a weighted line was fed through an opening until it contacted the surface of the water, at which point it emitted a noise. At that point, the line was marked so it could be measured and recorded. The difference between the starting length and ending length indicated the level change after the test was performed. It was assumed that the level of accuracy of this device was approximately +/- 0.25 inches.

### 3.5 Quantification of Uncertainty

There is uncertainty associated with conducting a drop test due to potential measurement errors and test equipment precision. This section discusses the sources of uncertainty and how the uncertainty was calculated.

#### 3.5.1 Totalizer Uncertainty

There is uncertainty associated with the meter totalizer registration because the meter will only record and display volumes to a certain interval. The City Meter test used SCADA which had a resolution of 1,000 gallons, while the District Meter used a direct read method which had a resolution of 1 gallon. Therefore, the volume of uncertainty from the totalizer reading is 1,000 gallons for the City test and 1 gallon for the District test.

#### 3.5.2 Level Measurement Uncertainty

As stated previously, E Source measured the water with a level sounder which was believed to be accurate within 0.25". A measurement uncertainty of +/- .25" corresponds to a measurement uncertainty of approximately +/- 2,045 gallons. This uncertainty volume is then multiplied by 2 because the measurement is taken twice, for a total level measurement uncertainty of 4,092 gallons.

#### 3.5.3 Calculation of Uncertainty

To calculate the total uncertainty associated with the test, E Source considered the resolution of the meter totalizer as well as the margin of error volumes obtained from the level measurement. E Source calculated the total test uncertainty to be +/- 1.6% for the City Meter test and +/- 4.2% for the District Meter test.

## 4 Results

The volumetric tests were conducted at a single flow rate based on the typical flow rate passing through each meter. The results presented in the table below show a comparison between the volume changes in the tank based on calculations made using measured level changes and the metered volumes based on data from SCADA or the physical meter register.

**Table 2: Test Results**

| Test Name      | Test Flow Rate (GPM) | Reference Volume (gal) | Meter Totalizer Volume (gal)* | Meter Totalizer Accuracy (%) | Test Margin of Error (+/- %) |
|----------------|----------------------|------------------------|-------------------------------|------------------------------|------------------------------|
| City Meter     | 2,219                | 326,245                | 325,000                       | 99.6%                        | 1.6%                         |
| District Meter | 659                  | 98,180                 | 105,899                       | 107.9%                       | 4.2%                         |

Based on the differences between the tank reference volumes and the meter totalizer volumes, it appears that the City Meter is accurately measuring flow and the District Meter is over-registering volume by approximately 8% with a test margin of error of +/-4.2%.

## 5 Summary of findings and recommendations

The City and District meters from the Fish Creek WTP meter were tested on September 8<sup>th</sup> and 9<sup>th</sup>, 2022 using a representative flow rate for each meter and comparing to the volume of water in the 2 MG tank.

- The volumetric change for the tank was determined to be 98,180 gallons/foot using tank drawings provided
- The City Meter is operating at 99.6% accuracy with a margin of error of 1.6% at the test flow rate
- The District Meter is operating at 107.9% accuracy with a margin of error of +/- 4.2% at the test flow rate.
- The District Meter appears to be over-registering flow and recalibration is recommended.
- E Source recommends that Mount Werner follow the test procedure described to confirm the accuracy of both meters on at least an annual basis.

# Meter Test Results

Pueblo Water

*December 2023*



**COLORADO**

**Colorado Water  
Conservation Board**

Department of Natural Resources

## Contents

|     |  |    |
|-----|--|----|
| 1   | Executive Summary.....                       | 1  |
| 2   | Background .....                             | 2  |
| 2.1 | Site Description .....                       | 2  |
| 2.2 | Site Infrastructure .....                    | 2  |
| 3   | Methods.....                                 | 5  |
| 3.1 | Flow Rate Selection.....                     | 5  |
| 3.2 | General Test Procedures.....                 | 6  |
| 3.3 | Quantification of Uncertainty .....          | 6  |
| 3.4 | Speed of Sound .....                         | 6  |
| 4   | Results.....                                 | 7  |
| 4.1 | Old Gardner.....                             | 7  |
| 4.2 | McCabe 42" Meter.....                        | 9  |
| 4.3 | McCabe 48" Meter.....                        | 11 |
| 4.4 | Summary .....                                | 13 |
| 5   | Summary of findings and recommendations..... | 14 |

## List of Figures

|  |    |
|--|----|
| Figure 1: Old Gardner Meter.....         | 3  |
| Figure 2: McCabe 42" Meter.....          | 3  |
| Figure 3: McCabe 48" Meter.....          | 4  |
| Figure 4: E Source Reference Meter ..... | 5  |
| Figure 5: Old Gardner Test.....          | 8  |
| Figure 5: McCabe 42" Meter Test .....    | 10 |
| Figure 5: Old Gardner Test.....          | 12 |

## List of Tables

|   |    |
|---|----|
| Table 1: Test Results .....                 | 1  |
| Table 2: Speed of Sound Values.....         | 7  |
| Table 3: Measured Speed of Sound .....      | 7  |
| Table 4: Test Results for Old Gardner ..... | 7  |
| Table 5: Test Results for McCabe 42" .....  | 10 |
| Table 6: McCabe 48" Test Results.....       | 11 |
| Table 7: Test Results .....                 | 13 |

## 1 Executive Summary

Pueblo Water produces water at the Whitlock Water Treatment Plant, and measures production through a total of five finished flow meters. As part of the Colorado Water Loss Initiative, E Source and Pueblo performed tests to determine the accuracy of three finished water meters.

E Source and Pueblo completed tests of the Old Gardner, McCabe 42” and McCabe 48” flow meters using a Flexim F601 ultrasonic flow meter. This report describes the test method and results. Table 1 below summarizes the results of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name   | Test Duration | Reference Meter Flow (MGD) | SCADA Flow (MGD) | Meter Accuracy (%) | Test Confidence |
|-------------|---------------|----------------------------|------------------|--------------------|-----------------|
| Old Gardner | 40 min        | 7.19                       | 7.07             | <b>98.4%</b>       | <b>High</b>     |
| McCabe 42”  | 46 min        | 5.40                       | 5.83             | <b>107.9%</b>      | <b>Low</b>      |
| McCabe 48”  | 41 min        | 7.00                       | 7.53             | <b>107.6%</b>      | <b>Moderate</b> |

The test results show that the Old Gardner meter is accurately registering flow, while the McCabe 42” and 48” meters appear to be over-registering. It is important to note that there is an uncertain level of confidence in the test results, as the length of straight pipe available could not be verified on site. Based on conversations with Pueblo staff, it is believed both McCabe meters have a sufficient length of straight pipe. The McCabe 42” meter test could also be impacted by the build-up present on the exterior of the pipe.

E Source recommends that all 3 meters undergo calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program continues offering water audit validations, but also goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to CWLI participants.

Pueblo Water completed a Level 1 validation through CWLI in 2022. Based on the results of the water audit validation and conversations with CWLI, Pueblo selected source meter testing as the direct technical assistance. This report summarizes the methodology and results of the accuracy test performed for Pueblo Water.

### 2.1 Site Description

Pueblo Water produces water at the Whitlock Water Treatment Plant, and measures production through a total of five finished flow meters. Three meters are located at the Whitlock WTP and two meters are located at the McCabe Pump Station. During planning discussions between E Source and Pueblo, it was determined that the Old Gardner meter and both McCabe meters would be included in testing, while further evaluations would be completed to determine the feasibility of testing the Gardner North and South meters.

### 2.2 Site Infrastructure

**Old Gardner Meter:** Pueblo has installed a Controlotron 1011 ultrasonic flowmeter to measure water on the 30" discharge line. The meter is installed 16.25' downstream of a tee and is connected to SCADA. The meter is shown below in Figure 1.



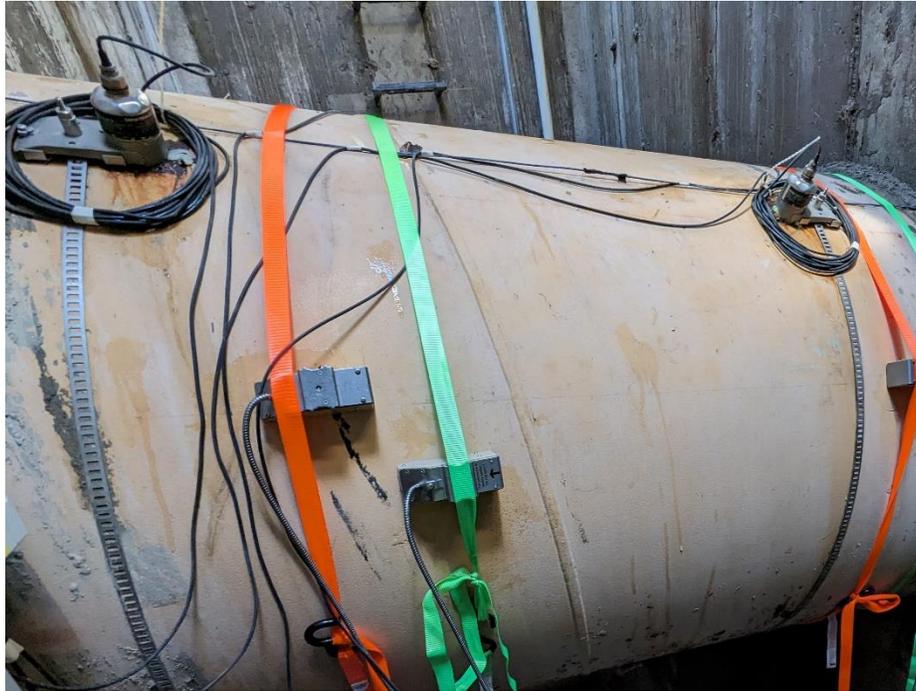
Figure 1: Old Gardner Meter

**McCabe 42" Meter:** Pueblo has installed an Endress Hauser Prosonic ultrasonic flowmeter to measure water on the 42" discharge line. The meter is installed in a vault, so the installation conditions could not be evaluated while on stie. The meter is shown below in Figure 2.



Figure 2: McCabe 42" Meter

**McCabe 48" Meter:** Pueblo has installed an Endress Hauser Prosonic ultrasonic flowmeter to measure water on the 48" discharge line. The meter is installed in a vault, so the installation conditions could not be evaluated while on stie. The meter is shown below in Figure 3.



**Figure 3: McCabe 48" Meter**

**E Source Reference Meter:** To complete the comparative meter testing, E Source used a Flexim F601 ultrasonic flowmeter. The meter has a visible display and is shown in Figure 4.



**Figure 4: E Source Reference Meter**

### 3 Methods

E Source and Pueblo completed the comparative meter tests using a Flexim F601 ultrasonic flow meter. The tests were performed by installing the E Source reference meter in line with the Pueblo flow meters and recording flow measurements from the reference meter and the Pueblo flow meters. The volume recorded by the Pueblo meter was then compared to the volume recorded by the E Source reference meter to determine the meter accuracy.

#### 3.1 Flow Rate Selection

To determine the accuracy of a source meter, it is best practice to conduct the test at the full range of flowrates that the meter will typically experience. Due to limitations while on site, each meter was tested at only the most common operating flow as determined by the Pueblo staff.

### 3.2 General Test Procedures

The comparative meter tests were completed using the following procedure:

1. Confirm pipe dimensions and specifications with Pueblo staff.
2. Program reference meter with pipe specifications.
3. Attach transducers to the pipe at the distance specified.
4. Operate pumps and/or valves as necessary to achieve desired flow
5. Record flow from Pueblo meter and E Source reference meter for at least 30 minutes
6. Compare volume recorded by Pueblo to volume recorded by reference meter

### 3.3 Quantification of Uncertainty

There is uncertainty in the results of any meter test. With a temporary reference meter, test uncertainty comes from the inherent meter inaccuracy, uncertainty related to the flow profile at the test location, and uncertainty related to the pipe dimensions and condition. When using a clamp-on meter, there is no way to directly measure the internal pipe diameter to know if there is build up or to assess the flow profile at the test location. To gain a preliminary understanding of potential uncertainty, E Source recorded the speed of sound measured by the transducers and compared the measured value to the theoretical value. It should be noted that this may be helpful for detecting high levels of uncertainty but does not provide a precise quantification of the test uncertainty.

In place of providing a test measurement uncertainty, E Source generally categorizes tests as high, medium, or low confidence based on the conditions of the test location. High confidence corresponds to a metallic pipe in good condition with a suitable length of upstream and downstream straight pipe and no other factors that may impact the measurement. Moderate confidence is assigned for tests that do not meet one of those conditions and low confidence is assigned for tests that fail multiple of those conditions or have less than 60% of the required length of straight pipe.

### 3.4 Speed of Sound

As discussed, E Source recorded the speed of sound measured by the reference meter and compared the recorded speed to the theoretical speed of sound to gain insight into potential measurement uncertainty. A table including the theoretical speed of sound at different water temperatures is shown in the table below.

**Table 2: Speed of Sound Values**

| Water Temperature | Speed of Sound (f/s) |
|-------------------|----------------------|
| 45                | 4711                 |
| 50                | 4747                 |
| 55                | 4777                 |
| 60                | 4816                 |

The measured speed of sound for each transducer set is shown in the table below and compared to the theoretical speed of sound at 55 degrees.

**Table 3: Measured Speed of Sound**

| Sensor        | Measured Speed of Sound (ft/s) | Speed of Sound at 55° (ft/s) |
|---------------|--------------------------------|------------------------------|
| Old Gardner A | 4943                           | 4777                         |
| Old Gardner B | 4889                           | 4777                         |
| McCabe 42 A   | 4672                           | 4777                         |
| McCabe 42 B   | 4801                           | 4777                         |
| McCabe 48 A   | 4761                           | 4777                         |
| McCabe 48 B   | 4762                           | 4777                         |

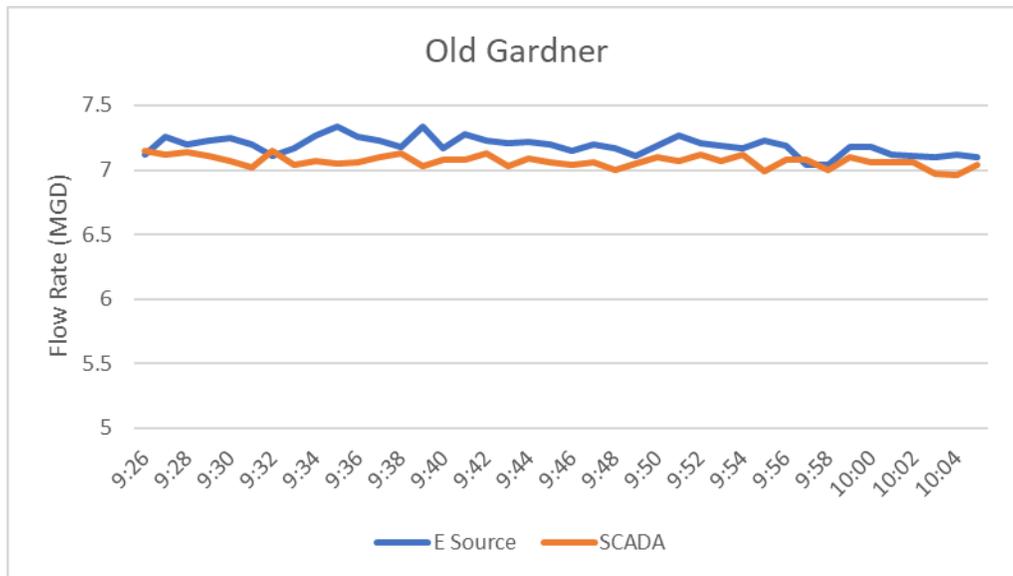
## 4 Results

### 4.1 Old Gardner

At the Old Gardner Meter, E Source completed a 40-minute test at a flow rate of 7 MGD. Due to operational constraints, a high flow test was not possible during the time of the site visit. The results of the test are shown in Table 4 and the figure below.

**Table 4: Test Results for Old Gardner**

| Test Name   | Test Duration | Reference Meter Flow (MGD) | SCADA Flow (MGD) | Meter Accuracy (%) | Test Confidence |
|-------------|---------------|----------------------------|------------------|--------------------|-----------------|
| Old Gardner | 40 min        | 7.19                       | 7.07             | 98.4%              | High            |



**Figure 5: Old Gardner Test**

The E Source meter was installed along the 20’ length of straight pipe between the wall and the first tee. Pueblo was able to operate the furthest pump from the test location, so the total length of straight pipe at the time of the test was over 50’. The length of straight pipe available is greater than the required 15 pipe diameters.



**Figure 6: Old Gardner Reference Meter Set Up**

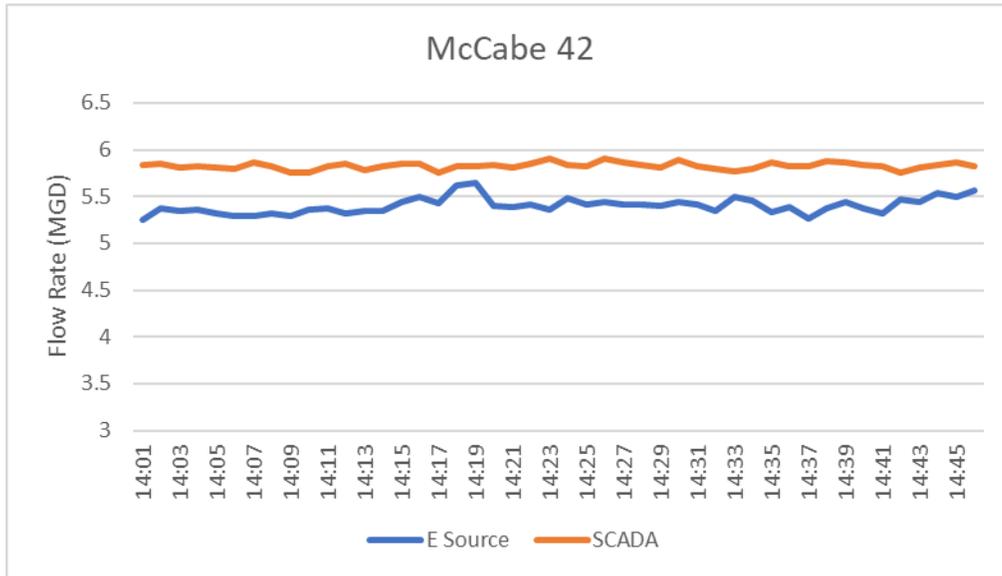
Based on the difference between the reference meter and SCADA, it appears that the Old Gardner meter is accurately recording flow. The test results were assigned high level of confidence based on the length of straight pipe being between greater than the recommended length.

#### 4.2 McCabe 42" Meter

At the McCabe 42" Meter, E Source completed a 46-minute test at a flow rate of 5.5 MGD. Due to operational constraints, a high flow test was not possible during the time of the site visit. The results of the test are shown in Table 5 and the figure below.

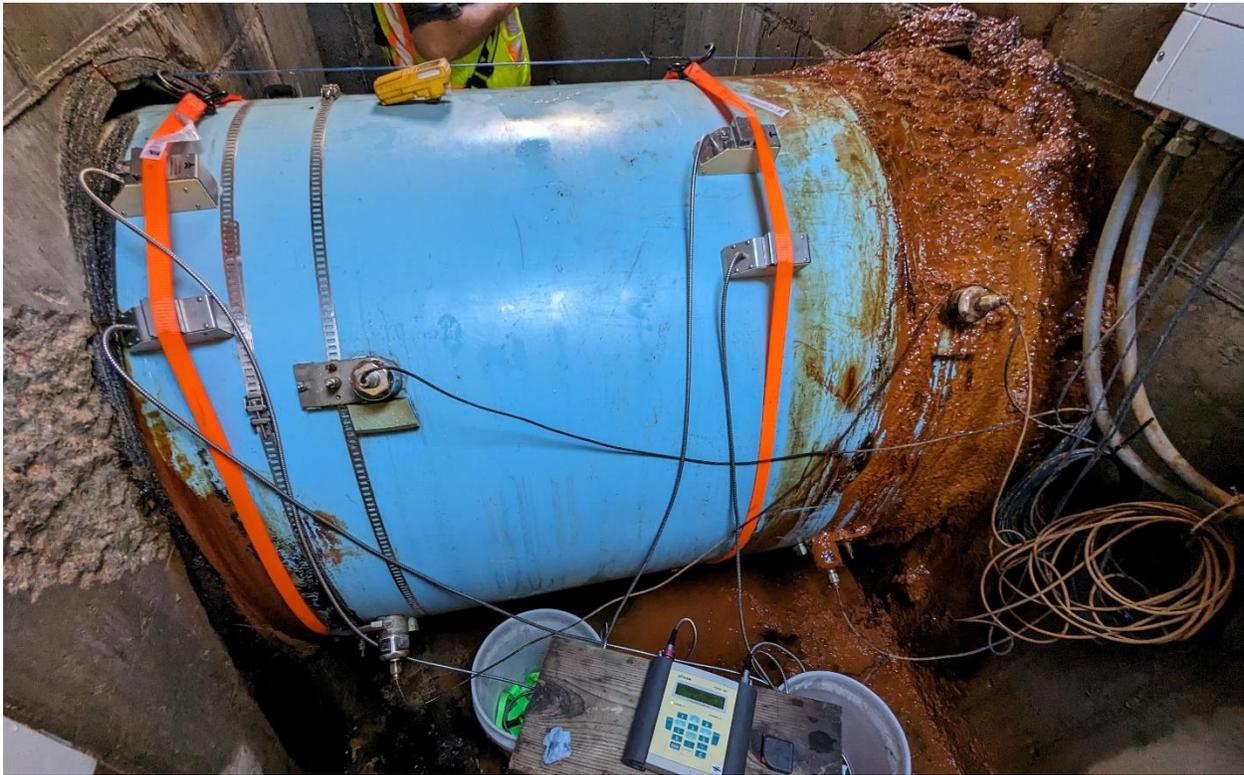
**Table 5: Test Results for McCabe 42"**

| Test Name  | Test Duration | Reference Meter Flow (MGD) | SCADA Flow (MGD) | Meter Accuracy (%) | Test Confidence |
|------------|---------------|----------------------------|------------------|--------------------|-----------------|
| McCabe 42" | 46 min        | 5.40                       | 5.83             | 107.9%             | Low             |



**Figure 6: McCabe 42" Meter Test**

The E Source meter was installed along the exposed length of straight pipe inside of the meter vault. The length of straight pipe available is uncertain but believed to be at least 15 pipe diameters based on conversations with the Pueblo staff. There was moderate build up on the outside of the pipe which may have impacted readings.



**Figure 6: McCabe 42" Reference Meter Set Up**

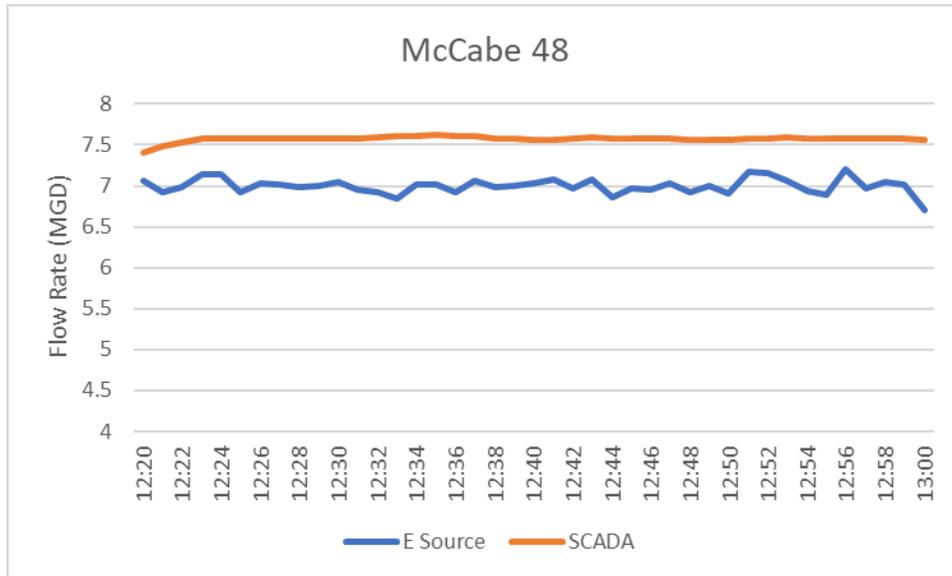
Based on the difference between the reference meter and SCADA, it appears that the McCabe 42" meter is over-registering flow. The test results were assigned a low level of confidence based on pipe condition and material.

### 4.3 McCabe 48" Meter

At the McCabe 48" Meter, E Source completed a 41-minute test at a flow rate of 7.5 MGD. Due to operational constraints, only one flow rate possible during the time of the site visit. The results of the test are shown in Table 6 and the figure below.

**Table 6: McCabe 48" Test Results**

| Test Name  | Test Duration | Reference Meter Flow (MGD) | SCADA Flow (MGD) | Meter Accuracy (%) | Test Confidence |
|------------|---------------|----------------------------|------------------|--------------------|-----------------|
| McCabe 48" | 41 min        | 7.00                       | 7.53             | 107.6%             | Moderate        |



**Figure 7: McCabe 48" Test**

The E Source meter was installed along the exposed length of straight pipe inside of the meter vault. The length of straight pipe available is uncertain but believed to be at least 15 pipe diameters based on conversations with Pueblo staff.



**Figure 6: McCabe 48" Reference Meter Set Up**

Based on the difference between the reference meter and SCADA, it appears that the McCabe 48" meter is over-registering flow. The test results were assigned a moderate level of confidence, as it is believed

the test location has a sufficient length of straight pipe, but PVC pipe is less suitable for a comparative test.

#### 4.4 Summary

E Source completed a comparative meter test at a single flow rate for the Old Gardner, McCabe 42” and McCabe 48” flowmeters. The results presented in the table below show a comparison between the calculated reference volume and the volume recorded by the meter being tested.

**Table 7: Test Results**

| Test Name   | Test Duration | Reference Meter Flow (MGD) | SCADA Flow (MGD) | Meter Accuracy (%) | Test Confidence |
|-------------|---------------|----------------------------|------------------|--------------------|-----------------|
| Old Gardner | 40 min        | 7.19                       | 7.07             | <b>98.4%</b>       | <b>High</b>     |
| McCabe 42”  | 46 min        | 5.40                       | 5.83             | <b>107.9%</b>      | <b>Low</b>      |
| McCabe 48”  | 41 min        | 7.00                       | 7.53             | <b>107.6%</b>      | <b>Moderate</b> |

The test results show that the Old Gardner meter is accurately registering flow, while the McCabe 42” and 48” meters appear to be over-registering. It is important to note that there is an uncertain level of confidence in the test results, as the length of straight pipe available could not be verified on site. Based on conversations with Pueblo staff, it is believed both McCabe meters have a sufficient length of straight pipe. The McCabe 42” meter test could also be impacted by the build-up present on the exterior of the pipe.

E Source recommends that all 3 meters undergo calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters.

## 5 Summary of findings and recommendations

E Source completed tests for the Old Gardner, McCabe 42" and McCabe 48" flow meters on November 13, 2023. Below are the main findings of the test and recommendations:

- When using ultrasonic flowmeters, E Source is not able to calculate a measurement uncertainty since much of the information about the pipe cannot be directly measured or verified. Therefore, E Source generally categorizes tests as high, medium, or low confidence based on the conditions of the test location.
- The accuracy of the Old Gardner meter was 98.4% with a high test confidence at the test flow rate. It is recommended that this meter be calibrated and then tested on an annual basis.
- The accuracy of the McCabe 42" meter was 107.9% with an uncertain test confidence at the test flow rate. This measurement could have been impacted to build up on the exterior of the pipe. It is recommended that this meter be calibrated and then tested on an annual basis.
- The accuracy of the McCabe 48" meter was 107.6% with a moderate test confidence at the test flow rate. It is recommended that this meter be calibrated and then tested on an annual basis.

# Meter Test Results

Pueblo Water

*December 2024*



**COLORADO**

**Colorado Water  
Conservation Board**

Department of Natural Resources

## Contents

|     |   |    |
|-----|---|----|
| 1   | Executive Summary .....                       | 1  |
| 2   | Background.....                               | 2  |
| 2.1 | Site Description .....                        | 2  |
| 2.2 | Site Infrastructure.....                      | 2  |
| 3   | Methods.....                                  | 6  |
| 3.1 | Flow Rate Selection .....                     | 6  |
| 3.2 | General Test Procedures .....                 | 6  |
| 3.3 | Quantification of Uncertainty .....           | 6  |
| 3.4 | Speed of Sound .....                          | 7  |
| 4   | Results.....                                  | 8  |
| 4.1 | McCabe 42" Meter .....                        | 8  |
| 4.2 | McCabe 48" Meter .....                        | 9  |
| 4.3 | Summary .....                                 | 11 |
| 5   | Summary of findings and recommendations ..... | 12 |

## List of Figures

|   |    |
|---|----|
| Figure 1: McCabe 42" Meter .....                        | 3  |
| Figure 2: McCabe 48" Meter .....                        | 3  |
| Figure 3: E Source Reference Meter .....                | 4  |
| Figure 4: Reference Meter Calibration Certificate ..... | 5  |
| Figure 5: McCabe 42" Meter Test .....                   | 8  |
| Figure 6: McCabe 42" Reference Meter Set Up.....        | 9  |
| Figure 7: McCabe 48" Test.....                          | 10 |
| Figure 8: McCabe 48" Reference Meter Set Up.....        | 10 |

## List of Tables

|  |    |
|--|----|
| Table 1: Test Results .....                | 1  |
| Table 2: Speed of Sound Values .....       | 7  |
| Table 3: Measured Speed of Sound .....     | 7  |
| Table 4: Test Results for McCabe 42" ..... | 8  |
| Table 5: McCabe 48" Test Results .....     | 9  |
| Table 6: Test Results .....                | 11 |

# 1 Executive Summary

Pueblo Water produces water at the Whitlock Water Treatment Plant, and measures production through a total of five finished flow meters. As part of the Colorado Water Loss Initiative, E Source and Pueblo performed tests to determine the accuracy of three finished water meters during testing completed in 2023. After determining that 2 of the meters were over-registering flow, the 2 meters were tested again in 2024, following the same procedure.

In October 2024, E Source and Pueblo completed tests of the McCabe 42” and McCabe 48” flow meters using a Flexim F601 ultrasonic flow meter. This report describes the test method and results. Table 1 below summarizes the results of the tests. More detail on how the test results were derived can be found in the body of this report.

**Table 1: Test Results**

| Test Name      | Test Duration | Reference Meter Flow (MGD) | Pueblo Meter Flow (MGD) | Meter Accuracy (%) | Test Confidence | 2023 Accuracy |
|----------------|---------------|----------------------------|-------------------------|--------------------|-----------------|---------------|
| McCabe 42 Low  | 50 min        | 7.345                      | 7.941                   | 108.1%             | Moderate        | 107.9%        |
| McCabe 42 High | 60 min        | 11.742                     | 12.598                  | 107.3%             | Moderate        | n/a           |
| McCabe 48 Low  | 45 min        | 7.802                      | 7.953                   | 101.9%             | Moderate        | 107.6%        |
| McCabe 48 High | 45 min        | 14.116                     | 14.463                  | 102.5%             | Moderate        | n/a           |

The test results show that the McCabe 48” meter is accurately registering flow, while the McCabe 42” meter appears to be over-registering. In 2023, both McCabe meters appeared to be over-registering flow. After investigation, E Source determined that the likely change in test results for the 48” meter is that inaccurate pipe information was used in 2023, which would alter the results of the test.

It is important to note that there is an uncertain level of confidence in the test results, as the length of straight pipe available could not be verified on site. Based on conversations with Pueblo staff, it is believed both McCabe meters have a sufficient length of straight pipe. The McCabe 42” meter test could also be impacted by the build-up present on the exterior of the pipe.

E Source recommends that both meters undergo annual calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters. Based on the test results, E Source also recommends that the McCabe 42” meter production data be adjusted to account for probable over-registration. No adjustments are required for the McCabe 48” meter data, and the 2023 test results should not be used due to the inaccurate pipe information that was used during the test.

## 2 Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs. Water loss reduction is one of the tactics identified by the Statewide Water Supply Initiative (SWSI) to close the gap between the available water supply and demand for Colorado's projected growth.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program continues offering water audit validations, but also goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to CWLI participants.

Pueblo Water completed a Level 1 validation through CWLI in 2022. Based on the results of the water audit validation and conversations with CWLI, Pueblo selected source meter testing as the direct technical assistance. Source meter testing was completed in 2023, and the results indicated 2 flow meters were over-registering flow. Therefore, Pueblo requested that another round of testing be completed to confirm the results of the 2023 testing. This report summarizes the methodology and results of the accuracy tests performed for Pueblo Water in 2024.

### 2.1 Site Description

Pueblo Water produces water at the Whitlock Water Treatment Plant, and measures production through a total of five finished flow meters. Three meters are located at the Whitlock WTP and two meters are located at the McCabe Pump Station. During 2023 discussions between E Source and Pueblo, it was determined that the Old Gardner meter and both McCabe meters would be included in testing, while further evaluations would be completed to determine the feasibility of testing the Gardner North and South meters. In 2024, a low flow and high flow test were conducted at each of the McCabe meters.

### 2.2 Site Infrastructure

**McCabe 42" Meter:** Pueblo has installed an Endress Hauser Prosonic ultrasonic flowmeter to measure water on the 42" discharge line. The meter is installed in a vault, so the installation conditions could not be evaluated while on site. The meter is shown below in Figure 1.



Figure 1: McCabe 42" Meter

**McCabe 48" Meter:** Pueblo has installed an Endress Hauser Prosonic ultrasonic flowmeter to measure water on the 48" discharge line. The meter is installed in a vault, so the installation conditions could not be evaluated while on site. The meter is shown below in Figure 2.



Figure 2: McCabe 48" Meter

**E Source Reference Meter:** To complete the comparative meter testing, E Source used a Flexim F601 ultrasonic flowmeter. The meter has a visible display and is shown in Figure 3.



**Figure 3: E Source Reference Meter**

The E Source reference meter was factory calibrated on February 15, 2024, with an acceptable error limit of  $\pm 0.5\%$ . The calibration certificate is shown below in Figure 4.

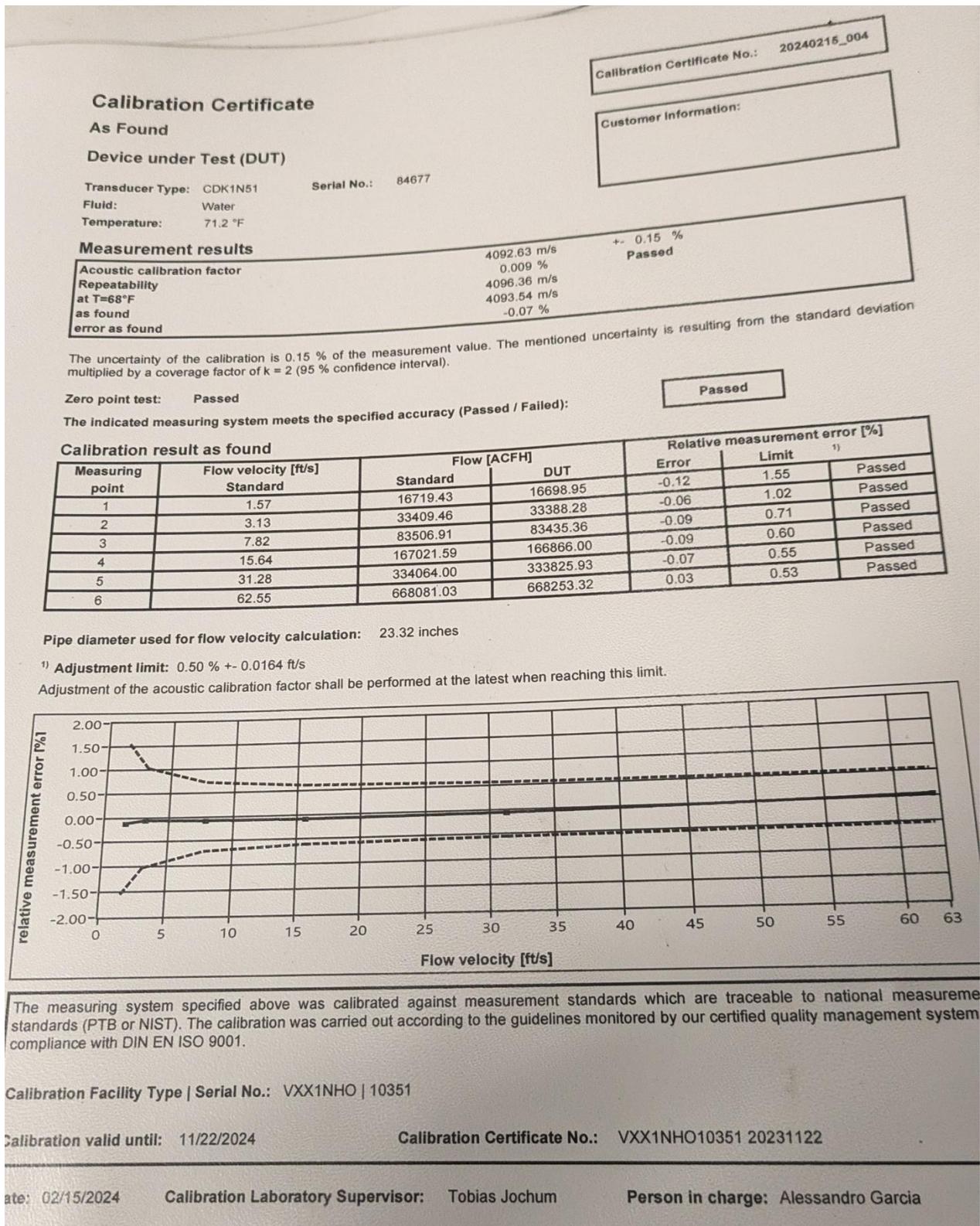


Figure 4: Reference Meter Calibration Certificate

## 3 Methods

E Source and Pueblo completed the comparative meter tests using a Flexim F601 ultrasonic flow meter. The tests were performed by installing the E Source reference meter in line with the Pueblo flow meters and recording flow measurements from the reference meter and the Pueblo flow meters. The volume recorded by the Pueblo meter was then compared to the volume recorded by the E Source reference meter to determine the meter accuracy.

### 3.1 Flow Rate Selection

To determine the accuracy of a source meter, it is best practice to conduct the test at the full range of flowrates that the meter will typically experience. The McCabe 42" and 48" meters were both tested at a high and low flow rate which is believed to be representative.

### 3.2 General Test Procedures

The comparative meter tests were completed using the following procedure:

1. Confirm pipe dimensions and specifications with Pueblo staff.
2. Program reference meter with pipe specifications.
3. Attach transducers to the pipe at the distance specified.
4. Operate pumps and/or valves as necessary to achieve desired flow
5. Record flow from Pueblo meter and E Source reference meter for at least 30 minutes
6. Compare volume recorded by Pueblo to volume recorded by reference meter

### 3.3 Quantification of Uncertainty

There is uncertainty in the results of any meter test. With a temporary reference meter, test uncertainty comes from the inherent meter inaccuracy, uncertainty related to the flow profile at the test location, and uncertainty related to the pipe dimensions and condition. When using a clamp-on meter, there is no way to directly measure the internal pipe diameter to know if there is build up or to assess the flow profile at the test location. To gain a preliminary understanding of potential uncertainty, E Source recorded the speed of sound measured by the transducers and compared the measured value to the theoretical value. It should be noted that this may be helpful for detecting high levels of uncertainty but does not provide a precise quantification of the test uncertainty.

In place of providing a test measurement uncertainty, E Source generally categorizes tests as high, medium, or low confidence based on the conditions of the test location. High confidence corresponds to a metallic pipe in good condition with a suitable length of upstream and downstream straight pipe and no other factors that may impact the measurement. Moderate confidence is assigned for tests that do not meet one of those conditions and low confidence is assigned for tests that fail multiple of those conditions or have less than 60% of the required length of straight pipe.

### 3.4 Speed of Sound

As discussed, E Source recorded the speed of sound measured by the reference meter and compared the recorded speed to the theoretical speed of sound to gain insight into potential measurement uncertainty. A table including the theoretical speed of sound at different water temperatures is shown in the table below.

**Table 2: Speed of Sound Values**

| Water Temperature | Speed of Sound (f/s) |
|-------------------|----------------------|
| 50                | 4747                 |
| 55                | 4777                 |
| 60                | 4816                 |
| 65                | 4845                 |

The measured speed of sound for each transducer set is shown in the table below and compared to the theoretical speed of sound at 65 degrees.

**Table 3: Measured Speed of Sound**

| Sensor      | Measured Speed of Sound (ft/s) | Speed of Sound at 65° (ft/s) |
|-------------|--------------------------------|------------------------------|
| McCabe 42 A | 4827                           | 4845                         |
| McCabe 42 B | 4836                           | 4845                         |
| McCabe 48 A | 4824                           | 4845                         |
| McCabe 48 B | 4793                           | 4845                         |

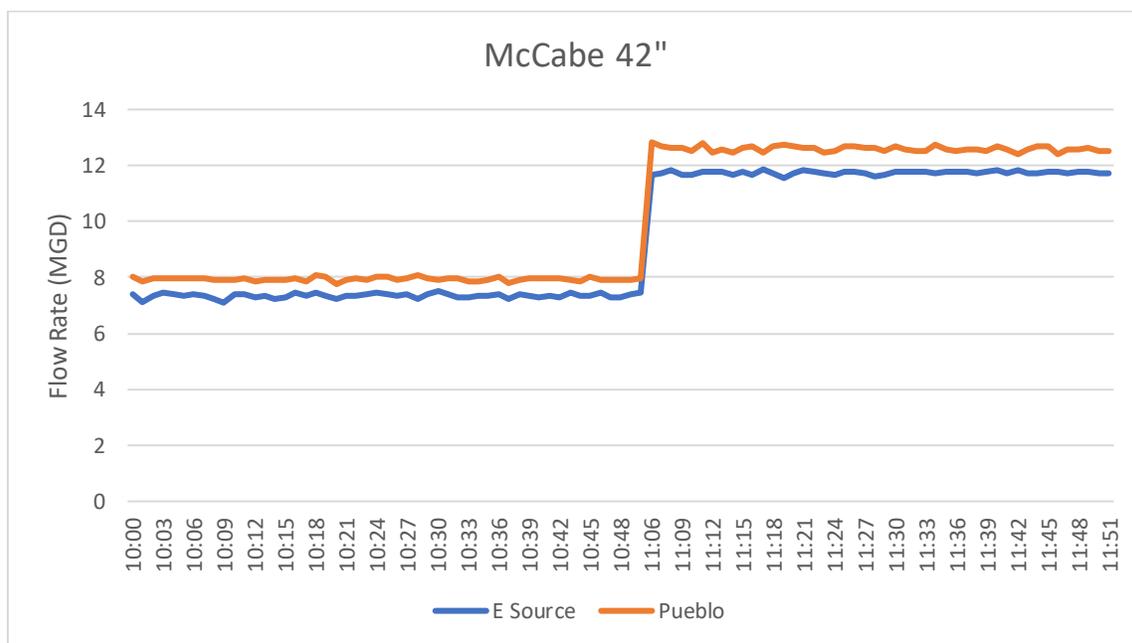
## 4 Results

### 4.1 McCabe 42" Meter

At the McCabe 42" Meter, E Source completed a 50-minute test at a flow rate of 7.3 MGD and a 60-minute test at a flow rate of 11.7 MGD. The test results are shown in Table 5 and the figure below.

**Table 4: Test Results for McCabe 42"**

| Test Name      | Test Duration | Reference Meter Flow (MGD) | SCADA Flow (MGD) | Meter Accuracy (%) | Test Confidence |
|----------------|---------------|----------------------------|------------------|--------------------|-----------------|
| McCabe 42 Low  | 50 min        | 7.345                      | 7.941            | <b>108.1%</b>      | <b>Moderate</b> |
| McCabe 42 High | 60 min        | 11.742                     | 12.598           | <b>107.3%</b>      | <b>Moderate</b> |



**Figure 5: McCabe 42" Meter Test**

The E Source meter was installed along the exposed length of straight pipe inside of the meter vault. The length of straight pipe available is uncertain but believed to be at least 15 pipe diameters based on conversations with the Pueblo staff. There was slight build up on the outside of the pipe which may have impacted readings.



**Figure 6: McCabe 42” Reference Meter Set Up**

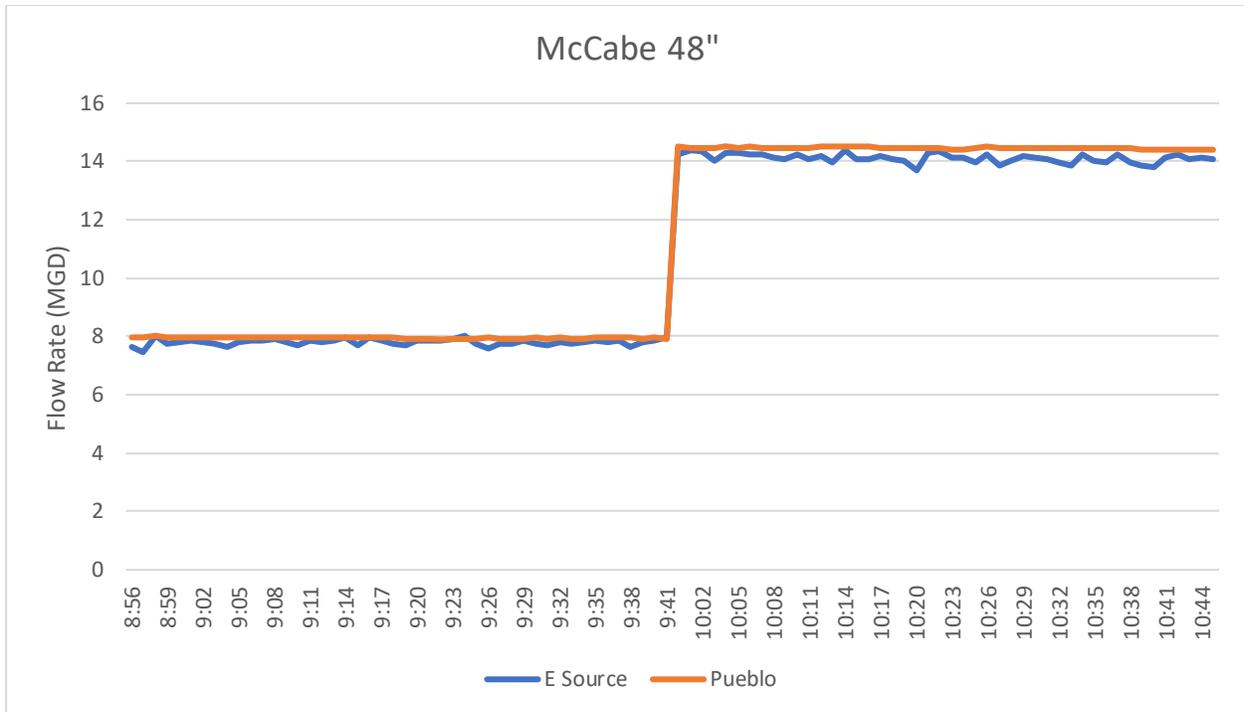
Based on the difference between the reference meter and SCADA, it appears that the McCabe 42” meter is over-registering flow. The test results were assigned a moderate level of confidence based on pipe condition and material.

#### 4.2 McCabe 48” Meter

At the McCabe 48” Meter, E Source completed 2 45-minute tests at flow rates of 7.8 and 14.1 MGD. The results of the test are shown in Table 6 and the figure below.

**Table 5: McCabe 48” Test Results**

| Test Name      | Test Duration | Reference Meter Flow (MGD) | SCADA Flow (MGD) | Meter Accuracy (%) | Test Confidence |
|----------------|---------------|----------------------------|------------------|--------------------|-----------------|
| McCabe 48 Low  | 45 min        | 7.802                      | 7.953            | 101.9%             | Moderate        |
| McCabe 48 High | 45 min        | 14.116                     | 14.463           | 102.5%             | Moderate        |



**Figure 7: McCabe 48" Test**

The E Source meter was installed along the exposed length of straight pipe inside of the meter vault. The length of straight pipe available is uncertain but believed to be at least 15 pipe diameters based on conversations with Pueblo staff.



**Figure 8: McCabe 48" Reference Meter Set Up**

Based on the difference between the reference meter and SCADA, it appears that the McCabe 48” meter is accurately registering flow. The test results were assigned a moderate level of confidence, based on pipe condition and material.

### 4.3 Summary

E Source completed a comparative meter test at a two flow rates for the McCabe 42” and McCabe 48” flowmeters. The results presented in the table below show a comparison between the calculated reference volume and the volume recorded by the meter being tested, as well as the calculated test results from 2023.

**Table 6: Test Results**

| Test Name      | Test Duration | Reference Meter Flow (MGD) | Pueblo Meter Flow (MGD) | Meter Accuracy (%) | Test Confidence | 2023 Accuracy |
|----------------|---------------|----------------------------|-------------------------|--------------------|-----------------|---------------|
| McCabe 42 Low  | 50 min        | 7.345                      | 7.941                   | <b>108.1%</b>      | <b>Moderate</b> | 107.9%        |
| McCabe 42 High | 60 min        | 11.742                     | 12.598                  | <b>107.3%</b>      | <b>Moderate</b> | n/a           |
| McCabe 48 Low  | 45 min        | 7.802                      | 7.953                   | <b>101.9%</b>      | <b>Moderate</b> | 107.6%        |
| McCabe 48 High | 45 min        | 14.116                     | 14.463                  | <b>102.5%</b>      | <b>Moderate</b> | n/a           |

The test results show that the McCabe 48” meter is accurately registering flow, while the McCabe 42” meter appears to be over-registering. In 2023, both McCabe meters appeared to be over-registering flow. After investigation, E Source determined that the likely change in test results for the 48” meter is that inaccurate pipe information was used in 2023, which would alter the results of the test.

It is important to note that there is an uncertain level of confidence in the test results, as the length of straight pipe available could not be verified on site. Based on conversations with Pueblo staff, it is believed both McCabe meters have a sufficient length of straight pipe.

E Source recommends that both meters undergo annual calibration and that further testing be completed on an annual basis, if possible, to ensure the continued accuracy of the flow meters. Based on the test results, E Source also recommends that the McCabe 42” meter production data be adjusted to account for probable over-registration. No adjustments are required for the McCabe 48” meter data, and the 2023 test results should not be used due to the inaccurate pipe information that was used during the test.

## 5 Summary of findings and recommendations

E Source completed tests for the McCabe 42" and McCabe 48" flow meters on October 23-24, 2024. Below are the main findings of the test and recommendations:

- When using ultrasonic flowmeters, E Source is not able to calculate a measurement uncertainty since much of the information about the pipe cannot be directly measured or verified. Therefore, E Source generally categorizes tests as high, medium, or low confidence based on the conditions of the test location.
- The accuracy of the McCabe 42" meter was 108.1% during the low test and 107.3% during the high test with a moderate test confidence.
- These results are generally in line with the 2023 testing which found the meter to be registering 107.9% accuracy.
- It is recommended that this meter be calibrated and tested on an annual basis.
- Additionally, it is recommended that production volumes from this meter be adjusted for annual reporting.
- The accuracy of the McCabe 48" meter was 101.9% during the low test and 102.5% during the high test with a moderate test confidence.
- These results differ from the 2023 testing which found the meter to be registering 107.6% accuracy. The difference is likely caused by inaccurate pipe information that was used during the 2023 tests, and therefore the 2024 test results are believed to be more accurate.
- It is recommended that this meter be calibrated and tested on an annual basis.
- Based on the test results, no adjustment to the reported volume is required.



**Appendix E: Billing Data Analysis Reports**



## TECHNICAL MEMORANDUM

---

### **Pueblo West Billing Data Analysis**

**PREPARED FOR:** Pueblo West  
**DATE:** December 2023  
**PREPARED BY:** Colorado Water Loss Initiative  
**PROJECT TEAM:** Tory Wagoner, P.E. (Cavanaugh), Drew Blackwell (Cavanaugh)

### **Objective Statement**

The Colorado Water Loss Initiative team conducted a billing data analysis for Pueblo West as part of Phase 2 of the program. Raw billing data to the account level was requested and received.

### **Billing Data Integrity Review Process**

A Level 2 Validation was performed on the account level billing data provided via a detailed export from the Utility's billing system. The following is a general description of the process completed to review the data. It should be noted that any potential anomalies identified can have legitimate explanations or be a direct result of the data export process.

1. Count of Accounts per Bill Cycle – A review of the total number of records for each month/bill cycle was conducted. This review provides insight into the completeness of the export as well as identifies any potential issues related to missed billing of existing customers.
2. Verification of Exclusion of Non-Potable Volumes – A utility's billing software is often used to store and bill volumes other than the potable volumes used in the water audit. These volumes are often designated through a rate schedule, customer classification or other identifier. In this review, any unique identifiers presented in the raw data were used to confirm that only potable volumes were used in the water audit.
3. Duplicate Records – Prior to review of the exported account level data, a check for duplicate records is performed. Often, the export will contain duplicate records where volumes are duplicated in multiple rows of data.
4. Negative Consumption – Negative consumption within the database can be indicative of a data archival issue. Many billing software applications maintain a separate database that stores the original, uncorrected readings and usage from the adjusted database where adjustments and corrections are archived. Other negative consumptions are legitimate as a utility may use to correct an incorrect reading or overestimate in a previous period.
5. Monthly Consumption Outliers (High/Low) – A review of each account's monthly consumption pattern was conducted, and outliers were flagged. Many outliers are legitimate but should be examined by the utility. Higher consumption is to be expected in the summer months and thus the filters used to determine high volume outliers are less restrictive during those time periods.
6. Active Accounts with Zero Consumption for the Audit Period – An account in the database that is active, but has zero consumption for the entire audit period could be indicative of a meter issue or an account that is not active.



7. Consecutive Months of Zero Consumption – Like active accounts with zero consumption, this review identifies accounts with multiple, consecutive months with zero consumption which could be indicative of a meter or data handling issue on the account.
8. Accounts with “Blank” Consumption – This is an examination of accounts that a read did not occur (in the data) for that account. This can be caused by an account getting skipped or can show when account was read twice during the same billing period, i.e., on January 1 and January 31, but not read in February.
9. Days in Read Cycle – This is an examination of the days in a read cycle. Any accounts with read cycles over the normal will be flagged for review.
10. Read Consumption vs. Billed Consumption – Many billing systems separate the read consumption (current reading minus previous reading) with the billed consumption (consumption billed to customer. This examination reviews discrepancies between these volumes to determine if there is a systematic issue with customers not being billed for the consumption their meter is reading.
11. Multiplier vs. Meter Size – One common issue in the billing system is the use of multipliers. A multiplier is used to convert from units read to units billed, as many meters in the field are read in different units as the published billing rate units. This can either be a full conversion of units (cubic feet to gallons) but is most commonly a conversion to a different form of the same unit (cf to ccf or gallons to thousands of gallons). An incorrect multiplier assigned to a given account results in either an under or over billing of the customer, usually by a factor of 10, 100, etc. A comparison of the assigned multiplier to the meter size can be an indication of an issue with accounts, as it would be common to have the same multiplier on like sized meters, assuming the meters are the same make and model.
12. Verification of the Summary Volume – Most utilities utilize a summary report to record and track volumes monthly. For this review, the account level raw data is summed to compare to the summary report volumes to assure the summary report is sufficient for monthly tracking. Additionally, a lag time adjustment was conducted.



**Data Integrity Review Outcomes**

*Note: Data as initially received included a single row of data for each consumption month including two months prior and two months after. There was a separate export for each customer classification. These files were combined through a simple copy/paste process. The total number of “reads” examined was 208,752.*

| Data Integrity Checkpoint                                  | Pass/Flag | Finding & impact on BMAC / Recommended action (if any)  |
|--|-----------|---|
| Count of bills per billing cycle                           | Pass      | A total of 13,047 unique Account #s were contained in the database. The most recent audit received from Pueblo West (2022) included 13,131 number of service connections listed. Follow-up should be completed on if the difference represents inactive connections.  |
| Verification of non-potable exclusion                      | Pass      | There was one account included in the exports listed as a Non-potable user type. This account was removed prior to analysis of the data.  |
| Record duplicates  | Pass      | There were 1,308 duplicate rows of data found in the initial query. NOTE: This could be the result of the combination of multiple data exports.   |
| Negative consumption                                       | Pass      | There were no negative consumption volumes included in the data.  |
| High/Low volume outliers                                   | Pass      | In review of the billing cycle consumption patterns for 2022 only, a total of 163 high volume and 1822 low volume outliers were found. These represent 0.08% and 0.87% of the total records and are deemed to be representative.<br><br>Many of the low outliers flagged were the result of a high outlier driving up the total consumption for the premise, making the other consumption periods appear low. It should be noted that accounts flagged for high consumption can be directly related to irrigation seasons and legitimate customer side leak events. |
| Active Accounts with Zero Consumption for the Audit Period | Pass      | There was a total of 8,148 reads with zero consumption (3.9%). Many of the zero reads were from the same premise.   |
| Consecutive Months of Zero Consumption                     | Pass      | There were 131 accounts (active for the entire year) included that were logged as zero consumption for the entire consumption period reviewed.  |
| Accounts with “Blank” Consumption                          | Pass      | There were no blank consumption months in the data export. This is likely a representative of how the export was created, i.e. each month was generated direct from the billing database. In review of read dates, there are months were accounts were not read in a given billing month, but these were mostly limited.  |
| Days in Read Cycle   | Pass      | There were a few accounts where the days of service (time between reads) was greater than 35 days, with the maximum being 84 days.  |



|                                       |  |  |         |  |        |   |        |                     |
|---------------------------------------|--|--|---------|--|--------|---|--------|---------------------|
| Read Consumption v Billed Consumption | n/a  | Only billed consumption was included in the data export, so no comparison was conducted.   |         |  |        |   |        |                     |
| Multiplier vs. Meter Size             | Pass   | All meters included in the exports were listed with a multiplier of 1.   |         |  |        |   |        |                     |
| Raw data total v summary data total   | Pass   | <p>The BMAC volume used in the 2022 Water Audit was 1,412 MG. The total volume included in the account level export was 1,392.326 MG, a difference of 1.39%</p> <p>A lag time calculation was conducted resulting in the following adjustment:</p> <table border="1"> <tr> <td>-40.587</td> <td>Volume to subtract (consumption prior to audit period)</td> </tr> <tr> <td>51.010</td> <td>Volume to add (consumption billed after audit period)</td> </tr> <tr> <td>10.423</td> <td>Net adjustment (MG)</td> </tr> </table> | -40.587 | Volume to subtract (consumption prior to audit period) | 51.010 | Volume to add (consumption billed after audit period) | 10.423 | Net adjustment (MG) |
| -40.587                               | Volume to subtract (consumption prior to audit period) |  |         |  |        |   |        |                     |
| 51.010                                | Volume to add (consumption billed after audit period)  |  |         |  |        |   |        |                     |
| 10.423                                | Net adjustment (MG)                                    |  |         |  |        |   |        |                     |

| Account | User Type Code | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Grand Total |
|---------|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------------|
| 135860  | Commercial     | 0   | 3   | 1   | 0   | 0   | 0   | 1   | 6   | 4   | 359 | 4   | 6   | 0   | 0   | 1   | 0   | 385         |
| 196340  | Residential    | 4   | 4   | 2   | 2   | 2   | 3   | 2   | 8   | 8   | 11  | 15  | 12  | 76  | 1   | 2   | 2   | 154         |
| 128040  | Residential    | 1   | 1   | 0   | 1   | 1   | 2   | 2   | 2   | 2   | 2   | 4   | 9   | 60  | 1   | 0   | 1   | 89          |
| 117970  | Residential    | 1   | 0   | 5   | 103 | 128 | 3   | 5   | 6   | 6   | 6   | 8   | 4   | 7   | 7   | 8   | 10  | 307         |
| 212571  | Commercial     | 0   | 0   | 0   | 0   | 18  | 0   | 1   | 1   | 0   | 1   | 2   | 1   | 0   | 0   | 0   | 2   | 26          |
| 160690  | Commercial     | 231 | 154 | 189 | 161 | 134 | 116 | 138 | 125 | 144 | 96  | 19  | 84  | 74  | 47  | 105 | 13  | 1,830       |
| 112480  | Commercial     | 26  | 1   | 0   | 0   | 0   | 6   | 131 | 173 | 170 | 146 | 178 | 93  | 48  | 12  | 13  | 12  | 1,009       |
| 212974  | Commercial     | 119 | 104 | 99  | 106 | 95  | 121 | 120 | 33  | 9   | 2   | 1   | 7   | 10  | 8   | 6   | 0   | 840         |
| 203250  | Commercial     | 57  | 51  | 50  | 64  | 55  | 60  | 54  | 64  | 45  | 42  | 43  | 40  | 49  | 51  | 59  | 54  | 838         |
| 164770  | Commercial     | 35  | 64  | 65  | 46  | 64  | 36  | 26  | 0   | 97  | 69  | 51  | 59  | 76  | 44  | 49  | 46  | 827         |

Examples of Identified Anomalies



## TECHNICAL MEMORANDUM

---

### City of Fort Collins - Utilities Billing Data Analysis

**PREPARED FOR:** City of Fort Collins - Utilities  
**DATE:** January 2023  
**PREPARED BY:** Colorado Water Loss Initiative  
**PROJECT TEAM:** Tory Wagoner, P.E. (Cavanaugh), Drew Blackwell (Cavanaugh)

### Objective Statement

The Colorado Water Loss Initiative team conducted a billing data analysis for the City of Fort Collins as part of Phase 2 of the program. Raw billing data to the account level was requested and received.

### Billing Data Integrity Review Process

A Level 2 Validation was performed on the account level billing data provided via a detailed export from the City's billing system. The following is a general description of the process completed to review the data. It should be noted that any potential anomalies identified can have legitimate explanations or be a direct result of the data export process.

1. Count of Accounts per Bill Cycle – A review of the total number of records for each month/bill cycle was conducted. This review provides insight into the completeness of the export as well as identifies any potential issues related to missed billing of existing customers.
2. Verification of Exclusion of Non-Potable Volumes – A utility's billing software is often used to store and bill volumes other than the potable volumes used in the water audit. These volumes are often designated through a rate schedule, customer classification or other identifier. In this review, any unique identifiers presented in the raw data were used to confirm that only potable volumes were used in the water audit.
3. Duplicate Records – Prior to review of the exported account level data, a check for duplicate records is performed. Often, the export will contain duplicate records where volumes are duplicated in multiple rows of data.
4. Negative Consumption – Negative consumption within the database can be indicative of a data archival issue. Many billing software applications maintain a separate database that stores the original, uncorrected readings and usage from the adjusted database where adjustments and corrections are archived. Other negative consumptions are legitimate as a utility may use to correct an incorrect reading or overestimate in a previous period.
5. Monthly Consumption Outliers (High/Low) – A review of each account's monthly consumption pattern was conducted, and outliers were flagged. Many outliers are legitimate but should be examined by the utility. Higher consumption is to be expected in the summer months and thus the filters used to determine high volume outliers are less restrictive during those time periods.
6. Active Accounts with Zero Consumption for the Audit Period – An account in the database that is active, but has zero consumption for the entire audit period could be indicative of a meter issue or an account that is not active.

7. Consecutive Months of Zero Consumption – Like active accounts with zero consumption, this review identifies accounts with multiple, consecutive months with zero consumption which could be indicative of a meter or data handling issue on the account.
8. Accounts with “Blank” Consumption – This is an examination of accounts that a read did not occur (in the data) for that account. This can be caused by an account getting skipped or can show when account was read twice during the same billing period, i.e., on January 1 and January 31, but not read in February.
9. Days in Read Cycle – This is an examination of the days in a read cycle. Any accounts with read cycles over the normal will be flagged for review.
10. Read Consumption vs. Billed Consumption – Many billing systems separate the read consumption (current reading minus previous reading) with the billed consumption (consumption billed to customer. This examination reviews discrepancies between these volumes to determine if there is a systematic issue with customers not being billed for the consumption their meter is reading.
11. Multiplier vs. Meter Size – One common issue in the billing system is the use of multipliers. A multiplier is used to convert from units read to units billed, as many meters in the field are read in different units as the published billing rate units. This can either be a full conversion of units (cubic feet to gallons) but is most commonly a conversion to a different form of the same unit (cf to ccf or gallons to thousands of gallons). An incorrect multiplier assigned to a given account results in either an under or over billing of the customer, usually by a factor of 10, 100, etc. A comparison of the assigned multiplier to the meter size can be an indication of an issue with accounts, as it would be common to have the same multiplier on like sized meters, assuming the meters are the same make and model.
12. Verification of the Summary Volume – Most utilities utilize a summary report to record and track volumes monthly. For this review, the account level raw data is summed to compare to the summary report volumes to assure the summary report is sufficient for monthly tracking. Additionally, a lag time adjustment was conducted.

**Data Integrity Review Outcomes**

*Note: Data as initially received included a separate row of data for each consumption month including two months prior and two months after (i.e., generally, 16 row of data for monthly accounts). A pivot table was utilized to create a column-based reporting of consumption (i.e. 1 line of data per account). The total number of “reads” examined was 573,668.*

| Data Integrity Checkpoint                                  | Pass/Flag | Finding & impact on BMAC / Recommended action (if any)   |
|--|-----------|--|
| Count of bills per billing cycle                           | Pass      | A total of 35,689 unique Premise Code #s were contained in the database and a total number of 37,829 unique Customer Codes. This difference seems reasonable when considering the number of new customers that may replace old customers at the same premise location. The most recent audit received from Fort Collins (2021) included 37,604 number of service connections listed.   |
| Verification of non-potable exclusion                      | n/a       | The City of Fort Collins does not bill for any non-potable volumes; thus, this review was not conducted.   |
| Record duplicates  | Pass      | There were no duplicate rows of data found in the initial query.   |
| Negative consumption                                       | Pass      | There were no negative consumption volumes included in the data.   |
| High/Low volume outliers                                   | Pass      | <p>In review of the billing cycle consumption patterns, a total of 975 high volume and 14,226 low volume outliers were found. These represent 0.17% and 2.48% of the total records and are deemed to be representative. Some of the high consumptions were the result of timing of the billing cycle, i.e., reads were conducted on March 1, thus no February read, and then again on March 31. This resulted in “double” the consumption in March.</p> <p>Many of the low outliers flagged were the result of a high outlier driving up the total consumption for the premise, making the other consumption periods appear low. It should be noted that accounts flagged for high consumption can be directly related to irrigation seasons and legitimate customer side leak events.</p> |
| Active Accounts with Zero Consumption for the Audit Period | Pass      | There was a total of 9,510 reads with zero consumption (1.66%). Many of the zero reads were from the same premise.   |
| Consecutive Months of Zero Consumption                     | Pass      | There were 13 accounts included that were logged as zero consumption for the entire consumption period reviewed, with another 64 accounts with 12 or greater (out of 16) billing months with zero consumption.   |
| Accounts with “Blank” Consumption                          | Pass      | There was a total of 20,740 (3.62%) of entries with a blank consumption month during the period reviewed. Generally, those accounts showing an individual blank (read immediately before and after) showed a consumption approximately double in the preceding or receding period. A spot check of these accounts verified that multiple reads were taken in the same billing month. Additionally, new premises created during the year would show blanks for the preceding months.  |

| Days in Read Cycle                    | Pass   | There were 10 premises where the days of service (time between reads) was 45 days or greater, with the longest being 999 days.   |          |  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
|---------------------------------------|--|--|----------|--|---------|---|--------|---------------------|---------|---|--|--|--|--|--------------|--|--|---|-------|--|----------|--|---|-------|---|--|----------|--|---|---|-----|--|----------|--|----|----|----|--|------------|--|---|--------|--|--|----------|--|----|---|----|--|-------------|--|--|---|---|--|----------|--|---|--|--|---|----------|--|---|--|---|---|
| Read Consumption v Billed Consumption | n/a  | Only billed consumption was included in the data export, so no comparison was conducted.   |          |  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| Multiplier vs. Meter Size             | Pass   | <p>The following chart shows the count of premise code for each meter size and multiplier:</p> <table border="1"> <thead> <tr> <th></th> <th>(blank)</th> <th>1</th> <th>10</th> <th>100</th> <th>1000</th> </tr> </thead> <tbody> <tr> <th>(blank)</th> <td>1</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <th>1 1/2" meter</th> <td></td> <td></td> <td>1</td> <td>1,295</td> <td></td> </tr> <tr> <th>1" meter</th> <td></td> <td>2</td> <td>1,919</td> <td>1</td> <td></td> </tr> <tr> <th>2" meter</th> <td></td> <td>3</td> <td>2</td> <td>541</td> <td></td> </tr> <tr> <th>3" meter</th> <td></td> <td>89</td> <td>15</td> <td>15</td> <td></td> </tr> <tr> <th>3/4" meter</th> <td></td> <td>2</td> <td>31,738</td> <td></td> <td></td> </tr> <tr> <th>4" meter</th> <td></td> <td>28</td> <td>7</td> <td>20</td> <td></td> </tr> <tr> <th>5/8" x 3/4"</th> <td></td> <td></td> <td>7</td> <td>1</td> <td></td> </tr> <tr> <th>6" meter</th> <td></td> <td>5</td> <td></td> <td></td> <td>7</td> </tr> <tr> <th>8" meter</th> <td></td> <td>4</td> <td></td> <td>1</td> <td>2</td> </tr> </tbody> </table> |          | (blank)  | 1       | 10  | 100    | 1000                | (blank) | 1 |  |  |  |  | 1 1/2" meter |  |  | 1 | 1,295 |  | 1" meter |  | 2 | 1,919 | 1 |  | 2" meter |  | 3 | 2 | 541 |  | 3" meter |  | 89 | 15 | 15 |  | 3/4" meter |  | 2 | 31,738 |  |  | 4" meter |  | 28 | 7 | 20 |  | 5/8" x 3/4" |  |  | 7 | 1 |  | 6" meter |  | 5 |  |  | 7 | 8" meter |  | 4 |  | 1 | 2 |
|                                       | (blank)  | 1  | 10       | 100  | 1000    |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| (blank)                               | 1  |  |          |  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 1 1/2" meter                          |  |  | 1        | 1,295  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 1" meter                              |  | 2  | 1,919    | 1  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 2" meter                              |  | 3  | 2        | 541  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 3" meter                              |  | 89   | 15       | 15   |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 3/4" meter                            |  | 2  | 31,738   |  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 4" meter                              |  | 28   | 7        | 20   |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 5/8" x 3/4"                           |  |  | 7        | 1  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 6" meter                              |  | 5  |          |  | 7       |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 8" meter                              |  | 4  |          | 1  | 2       |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| Raw data total v summary data total   | n/a  | <p>The same export used for this evaluation is also used for the Billed Metered volume summary included in the audit.</p> <p>A lag time calculation was conducted resulting in the following adjustment:</p> <table border="1"> <tr> <td>-127.887</td> <td>Volume to subtract (consumption prior to audit period)</td> </tr> <tr> <td>163.096</td> <td>Volume to add (consumption billed after audit period)</td> </tr> <tr> <td>35.209</td> <td>Net adjustment (MG)</td> </tr> </table>   | -127.887 | Volume to subtract (consumption prior to audit period) | 163.096 | Volume to add (consumption billed after audit period) | 35.209 | Net adjustment (MG) |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| -127.887                              | Volume to subtract (consumption prior to audit period) |  |          |  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 163.096                               | Volume to add (consumption billed after audit period)  |  |          |  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |
| 35.209                                | Net adjustment (MG)                                    |  |          |  |         |   |        |                     |         |   |  |  |  |  |              |  |  |   |       |  |          |  |   |       |   |  |          |  |   |   |     |  |          |  |    |    |    |  |            |  |   |        |  |  |          |  |    |   |    |  |             |  |  |   |   |  |          |  |   |  |  |   |          |  |   |  |   |   |

| Premise ID | 2020   |            | 2021       |            |            |            |         | 2022       |         |            |         |            | Grand Total |            |            |        |             |
|------------|--------|------------|------------|------------|------------|------------|---------|------------|---------|------------|---------|------------|-------------|------------|------------|--------|-------------|
|            | 11     | 12         | 1          | 2          | 3          | 4          | 5       | 6          | 7       | 8          | 9       | 10         |             | 11         | 12         | 1      | 2           |
| 78995      |        |            |            |            |            |            | 47,500  |            |         |            |         |            |             |            |            |        | 47,500      |
| 52178      | 260    | 230        | 11,580     | 120,600    | 210        | 220        | 240     | 230        | 220     | 240        | 250     | 190        | 200         | 210        | 220        | 290    | 135,390     |
| 24121      | 90     | 90         | 60         | 60         | 60         | 100        | 90      | 80         | 80      | 80         | 180     |            | 90          | 110        | 80         | 15,660 | 16,910      |
| 50336      | 100    | 0          | 50         | 23,500     | 100        | 50         | 100     | 100        | 150     | 50         | 50      | 50         | 50          | 0          | 100        |        | 24,450      |
| 54603      | 2,080  | 2,600      | 2,110      | 2,360      | 2,280      | 530        | 3,560   | 2,070      | 4,410   | 5,930      | 2,210   | 3,370      | 318,700     | 0          | 2,590      | 2,530  | 357,330     |
| 14217      |        | 0          |            | 0          |            | 60,000     | 0       |            | 0       | 0          |         | 935,500    | 0           |            | 0          |        | 995,500     |
| 24172      |        | 0          |            | 0          | 0          | 0          | 0       | 0          | 0       | 0          | 0       | 0          | 5,005,000   | 60,000     | 70,000     | 65,000 | 5,200,000   |
| 91215      | 63,300 | 27,000     |            | 161,400    | 75,600     | 68,500     | 143,600 | 154,500    | 117,900 | 97,100     | 95,500  | 82,500     | 74,900      | 87,600     | 79,400     |        | 1,328,800   |
| 79474      |        | 33,735,000 | 17,890,000 | 17,090,000 | 17,715,000 | 18,420,000 |         | 38,655,000 |         | 40,600,000 |         | 20,195,000 | 17,915,000  | 18,965,000 | 35,305,000 |        | 276,485,000 |
| 21783      | 0      | 0          | 0          | 0          | 0          | 0          | 0       | 1,616,000  |         | 6,162,500  | 0       | 0          | 0           | 0          | 0          |        | 7,778,500   |
| 43898      | 61,600 | 65,300     |            | 119,700    |            | 125,600    | 67,200  | 61,600     | 58,400  | 56,900     | 50,100  | 5,400      | 98,700      | 53,700     | 54,500     |        | 878,700     |
| 22047      | 52,900 |            | 45,700     | 90,300     | 41,000     | 49,000     | 49,400  | 141,100    | 184,700 | 134,600    | 113,700 | 7,000      | 80,200      | 36,200     | 37,500     |        | 1,063,300   |

Examples of Identified Anomalies



## TECHNICAL MEMORANDUM

---

### City of Fountain - Utilities Billing Data Analysis

**PREPARED FOR:** City of Fountain - Utilities  
**DATE:** October 2023  
**PREPARED BY:** Colorado Water Loss Initiative  
**PROJECT TEAM:** Tory Wagoner, P.E. (Cavanaugh), Drew Blackwell (Cavanaugh)

### **Objective Statement**

The Colorado Water Loss Initiative team conducted a billing data analysis for the City of Fountain as part of Phase 2 of the program. Raw billing data to the account level was requested and received.

### **Billing Data Integrity Review Process**

A Level 2 Validation was performed on the account level billing data provided via a detailed export from the City's billing system. The following is a general description of the process completed to review the data. It should be noted that any potential anomalies identified can have legitimate explanations or be a direct result of the data export process.

1. Count of Accounts per Bill Cycle – A review of the total number of records for each month/bill cycle was conducted. This review provides insight into the completeness of the export as well as identifies any potential issues related to missed billing of existing customers.
2. Verification of Exclusion of Non-Potable Volumes – A utility's billing software is often used to store and bill volumes other than the potable volumes used in the water audit. These volumes are often designated through a rate schedule, customer classification or other identifier. In this review, any unique identifiers presented in the raw data were used to confirm that only potable volumes were used in the water audit.
3. Duplicate Records – Prior to review of the exported account level data, a check for duplicate records is performed. Often, the export will contain duplicate records where volumes are duplicated in multiple rows of data.
4. Negative Consumption – Negative consumption within the database can be indicative of a data archival issue. Many billing software applications maintain a separate database that stores the original, uncorrected readings and usage from the adjusted database where adjustments and corrections are archived. Other negative consumptions are legitimate as a utility may use to correct an incorrect reading or overestimate in a previous period.
5. Monthly Consumption Outliers (High/Low) – A review of each account's monthly consumption pattern was conducted, and outliers were flagged. Many outliers are legitimate but should be examined by the utility. Higher consumption is to be expected in the summer months and thus the filters used to determine high volume outliers are less restrictive during those time periods.
6. Active Accounts with Zero Consumption for the Audit Period – An account in the database that is active, but has zero consumption for the entire audit period could be indicative of a meter issue or an account that is not active.



7. Consecutive Months of Zero Consumption – Like active accounts with zero consumption, this review identifies accounts with multiple, consecutive months with zero consumption which could be indicative of a meter or data handling issue on the account.
8. Accounts with “Blank” Consumption – This is an examination of accounts that a read did not occur (in the data) for that account. This can be caused by an account getting skipped or can show when account was read twice during the same billing period, i.e., on January 1 and January 31, but not read in February.
9. Days in Read Cycle – This is an examination of the days in a read cycle. Any accounts with read cycles over the normal will be flagged for review.
10. Read Consumption vs. Billed Consumption – Many billing systems separate the read consumption (current reading minus previous reading) with the billed consumption (consumption billed to customer. This examination reviews discrepancies between these volumes to determine if there is a systematic issue with customers not being billed for the consumption their meter is reading.
11. Multiplier vs. Meter Size – One common issue in the billing system is the use of multipliers. A multiplier is used to convert from units read to units billed, as many meters in the field are read in different units as the published billing rate units. This can either be a full conversion of units (cubic feet to gallons) but is most commonly a conversion to a different form of the same unit (cf to ccf or gallons to thousands of gallons). An incorrect multiplier assigned to a given account results in either an under or over billing of the customer, usually by a factor of 10, 100, etc. A comparison of the assigned multiplier to the meter size can be an indication of an issue with accounts, as it would be common to have the same multiplier on like sized meters, assuming the meters are the same make and model.
12. Verification of the Summary Volume – Most utilities utilize a summary report to record and track volumes monthly. For this review, the account level raw data is summed to compare to the summary report volumes to assure the summary report is sufficient for monthly tracking. Additionally, a lag time adjustment was conducted.



**Data Integrity Review Outcomes**

*Note: Data as initially received included a separate row of data for each consumption month including two months prior and two months after (i.e., generally, 16 row of data for monthly accounts). A pivot table was utilized to create a column-based reporting of consumption (i.e. 1 line of data per account). The total number of “reads” examined was 146,737.*

| <b>Data Integrity Checkpoint</b>                           | <b>Pass/Flag</b> | <b>Finding &amp; impact on BMAC / Recommended action (if any)</b>   |
|--|------------------|---|
| Count of bills per billing cycle                           | Pass             | A total of 8,701 unique Premise Code #s were contained in the database. This difference seems reasonable when considering the number of new customers that may replace old customers at the same premise location. The most recent audit received from Fountain (2022) included 8,672 number of service connections listed.   |
| Verification of non-potable exclusion                      | n/a              | The City of Fountain does not bill for any non-potable volumes; thus, this review was not conducted.  |
| Record duplicates  | Pass             | There were no duplicate rows of data found in the initial query.  |
| Negative consumption                                       | Pass             | There were no negative consumption volumes included in the data.  |
| High/Low volume outliers                                   | Pass             | In review of the billing cycle consumption patterns, a total of 178 high volume and 1,485 low volume outliers were found. These represent 2.04% and 17.07% of the total records and are deemed to be representative.<br><br>Many of the low outliers flagged were the result of a high outlier driving up the total consumption for the premise, making the other consumption periods appear low. It should be noted that accounts flagged for high consumption can be directly related to irrigation seasons and legitimate customer side leak events. |
| Active Accounts with Zero Consumption for the Audit Period | Pass             | There was a total of 436 reads with zero consumption (5.01%). Many of the zero reads were from the same premise.  |
| Consecutive Months of Zero Consumption                     | Pass             | There were 11 accounts included that were logged as zero consumption for the entire consumption period reviewed, with another 9 accounts with 12 or greater (out of 16) billing months with zero consumption.   |
| Accounts with “Blank” Consumption                          | Pass             | There was a total of 210 (0.14%) of entries with a blank consumption month during the period reviewed. Generally, those accounts showing an individual blank (read immediately before or after) showed a high consumption in the preceding or receding period. Additionally, new premises created during the year would show blanks for the preceding months.   |
| Days in Read Cycle   | Pass             | There were 26 premises where the days of service (time between reads) was 45 days or greater, with the longest being 55 days.   |
| Read Consumption v Billed Consumption                      | n/a              | Only billed consumption was included in the data export, so no comparison was conducted.  |
| Multiplier vs. Rate Code/Meter Size                        | Pass             | The following chart shows the count of premise code for each rate code and multiplier:  |



| Rate Code/Meter Size (blank) | 1           | 10          | 100       | Total Count |
|------------------------------|-------------|-------------|-----------|-------------|
| <b>W15IN</b>                 |             |             |           |             |
| 1.5-6-100                    |             |             | 30        | 30          |
| 1/6/2010                     |             | 1           |           | 1           |
| Unknown                      |             |             | 13        | 13          |
| <b>W1IN</b>                  |             |             |           |             |
| 1/6/2010                     |             | 81          |           | 81          |
| 3/4-6-10                     |             | 1           |           | 1           |
| <b>W2IN</b>                  |             |             |           |             |
| 1.5-6-100                    |             |             | 2         | 2           |
| 1/6/2010                     |             | 2           |           | 2           |
| 2/6/2010                     |             | 1           |           | 1           |
| 2-6-100                      |             | 2           | 32        | 32          |
| 3/4-6-10                     |             | 3           |           | 3           |
| Unknown                      |             |             | 1         | 1           |
| <b>W3IN</b>                  |             |             |           |             |
| 1/6/2010                     |             | 2           |           | 2           |
| 3/6/2010                     |             | 1           | 1         | 1           |
| 3-6-100                      |             | 5           | 12        | 12          |
| <b>W3INNM</b>                |             |             |           |             |
| 3-6-100                      |             |             | 2         | 2           |
| <b>W4IN</b>                  |             |             |           |             |
| 1/6/2010                     |             | 1           |           | 1           |
| 4-6-100                      |             | 5           | 5         | 5           |
| <b>WC75IN</b>                |             |             |           |             |
| 1/6/2010                     |             | 2           |           | 2           |
| 3/4-6-10                     |             | 101         |           | 101         |
| 3/6/2010                     |             | 3           |           | 3           |
| <b>WC75OU</b>                |             |             |           |             |
| 3/4-6-10                     |             | 1           |           | 1           |
| <b>WHYCIT</b>                |             |             |           |             |
| 2/6/2001                     | 1           |             |           | 1           |
| 3/4-10-1                     | 3           |             |           | 3           |
| 3/4-6-1                      | 1           |             |           | 1           |
| 92-6-1                       | 1           |             |           | 1           |
| <b>WHYDRN</b>                |             |             |           |             |
| 2/6/2001                     | 1           |             |           | 1           |
| 3/4-6-1                      | 5           |             |           | 5           |
| 92-6-1                       | 4           |             |           | 4           |
| <b>WR75IN</b>                |             |             |           |             |
| 1/6/2010                     |             | 1           |           | 1           |
| 3/4-6-10                     |             | 8390        |           | 8390        |
| 4/6/2010                     |             | 1           |           | 1           |
| <b>WR75OU</b>                |             |             |           |             |
| 3/4-6-10                     |             | 5           |           | 5           |
| <b>Grand Total</b>           | <b>1 16</b> | <b>8606</b> | <b>96</b> | <b>8701</b> |



A review of multipliers is recommended.

\*Summary compiled by rate code instead of meter size due to the way the raw data was provided and some ambiguity of meter size (e.g., meter size = '2/6/2001' = WHYDRN and WHYCIT; or meter size = 1/6/2010 = various rate codes that indicate various meter sizes)

|                                     |  |  |         |  |        |   |       |                     |
|-------------------------------------|--|--|---------|--|--------|---|-------|---------------------|
| Raw data total v summary data total | n/a  | <p>The BMAC volumes used in the 2022 Water Audit was 799.766 MG. The total volume included in the account level export was 785.418 MG.</p> <p>A lag time calculation was conducted resulting in the following adjustment:</p> <table border="1" style="margin-left: 20px;"> <tr> <td style="text-align: right;">-21.389</td> <td>Volume to subtract (consumption prior to audit period)</td> </tr> <tr> <td style="text-align: right;">26.021</td> <td>Volume to add (consumption billed after audit period)</td> </tr> <tr> <td style="text-align: right;">4.632</td> <td>Net adjustment (MG)</td> </tr> </table> | -21.389 | Volume to subtract (consumption prior to audit period) | 26.021 | Volume to add (consumption billed after audit period) | 4.632 | Net adjustment (MG) |
| -21.389                             | Volume to subtract (consumption prior to audit period) |  |         |  |        |   |       |                     |
| 26.021                              | Volume to add (consumption billed after audit period)  |  |         |  |        |   |       |                     |
| 4.632                               | Net adjustment (MG)                                    |  |         |  |        |   |       |                     |

| Location | 2021  |       |      | 2022  |        |       |      |        |       |        |       |       |       |       |       | 2023  |       | Total  | # c    |        |  |
|----------|-------|-------|------|-------|--------|-------|------|--------|-------|--------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--|
|          | Oct   | Nov   | Dec  | Jan   | Feb    | Mar   | Apr  | May    | Jun   | Jul    | Aug   | Sep   | Oct   | Nov   | Dec   | Jan   | Feb   |        |        |        |  |
| 1107290  | 45500 | 26800 | 6700 | 6900  | 8000   | 7000  | 9000 | 245700 | 19900 | 11900  | 12900 | 16300 | 15400 | 12600 | 11600 | 9700  | 13700 | 479600 |        |        |  |
| 902580   | 6190  | 4840  | 3450 | 2550  | 319630 | 93990 |      | 0      | 80    | 1450   | 2520  | 4730  | 4400  | 3560  | 3520  | 4010  | 4730  | 3910   | 463560 |        |  |
| 10006909 |       |       |      |       |        |       |      |        | 2300  | 216800 |       | 49300 | 6700  | 0     | 33900 | 2400  |       |        | 3100   | 314500 |  |
| 602540   | 10    | 10    | 10   | 20    | 167650 | 21610 |      | 0      | 0     | 0      | 0     | 0     | 80    | 0     | 10    | 30    | 0     | 0      | 189430 |        |  |
| 613800   | 3510  | 3100  | 3900 | 4140  | 2830   | 2630  | 3550 | 7420   | 8160  | 8100   | 7940  | 18120 | 9280  |       | 98450 | 2770  | 3760  | 187660 |        |        |  |
| 10003957 | 16780 | 7080  | 6430 | 6630  | 5660   | 5090  | 5420 | 13750  | 11830 | 8930   | 13510 | 11450 |       | 21600 | 6480  | 10200 | 470   | 151310 |        |        |  |
| 10001689 | 1930  | 3150  | 2560 | 23440 | 1400   | 1820  | 1840 |        | 9970  | 7960   | 9020  | 7520  | 6460  | 7200  | 7300  | 8750  | 10110 | 110430 |        |        |  |
| 10004743 | 9620  | 7450  | 7680 | 6870  | 6340   | 4510  | 5420 | 11420  |       | 3860   | 6020  | 6750  | 6100  | 5490  | 6920  | 4500  | 6800  | 105750 |        |        |  |
| 10005717 | 3900  | 4730  | 3750 | 4780  | 3330   | 3810  | 4440 | 9840   |       |        | 50090 | 1270  | 2770  | 3220  | 1970  | 1580  | 1430  | 100910 |        |        |  |
| 1104030  | 70    | 30    | 120  | 30    | 84190  |       | 40   | 180    |       | 90     | 70    | 290   | 410   | 320   | 160   | 50    | 40    | 0      | 86120  |        |  |
| 10003123 | 3920  | 4200  | 3640 | 4010  | 3880   | 4500  | 3160 | 3640   | 5810  | 5080   | 4480  | 5210  | 4520  | 4620  | 7140  | 5650  | 4690  | 78150  |        |        |  |
| 720111   | 1820  | 1390  | 800  | 2060  | 1650   | 5760  | 5270 |        | 12920 | 5530   | 5180  | 7470  | 4960  | 4740  | 4750  | 6440  | 6060  | 76800  |        |        |  |
| 10001247 | 7550  | 5600  | 4400 | 3100  | 3250   | 3650  | 5400 | 6650   | 3400  | 4150   | 20050 |       |       | 0     | 2870  | 520   | 70    | 70660  |        |        |  |

Examples of Identified Anomalies



## TECHNICAL MEMORANDUM

---

### Town of Fredrick Billing Data Analysis

**PREPARED FOR:** Town of Fredrick  
**DATE:** October 2023  
**PREPARED BY:** Colorado Water Loss Initiative  
**PROJECT TEAM:** Tory Wagoner, P.E. (Cavanaugh), Drew Blackwell (Cavanaugh)

### **Objective Statement**

The Colorado Water Loss Initiative team conducted a billing data analysis for the Town of Fredrick as part of Phase 2 of the program. Raw billing data to the account level was requested and received.

### **Billing Data Integrity Review Process**

A Level 2 Validation was performed on the account level billing data provided via a detailed export from the Town's billing system. The following is a general description of the process completed to review the data. It should be noted that any potential anomalies identified can have legitimate explanations or be a direct result of the data export process.

1. Count of Accounts per Bill Cycle – A review of the total number of records for each month/bill cycle was conducted. This review provides insight into the completeness of the export as well as identifies any potential issues related to missed billing of existing customers.
2. Verification of Exclusion of Non-Potable Volumes – A utility's billing software is often used to store and bill volumes other than the potable volumes used in the water audit. These volumes are often designated through a rate schedule, customer classification or other identifier. In this review, any unique identifiers presented in the raw data were used to confirm that only potable volumes were used in the water audit.
3. Duplicate Records – Prior to review of the exported account level data, a check for duplicate records is performed. Often, the export will contain duplicate records where volumes are duplicated in multiple rows of data.
4. Negative Consumption – Negative consumption within the database can be indicative of a data archival issue. Many billing software applications maintain a separate database that stores the original, uncorrected readings and usage from the adjusted database where adjustments and corrections are archived. Other negative consumptions are legitimate as a utility may use to correct an incorrect reading or overestimate in a previous period.
5. Monthly Consumption Outliers (High/Low) – A review of each account's monthly consumption pattern was conducted, and outliers were flagged. Many outliers are legitimate but should be examined by the utility. Higher consumption is to be expected in the summer months and thus the filters used to determine high volume outliers are less restrictive during those time periods.
6. Active Accounts with Zero Consumption for the Audit Period – An account in the database that is active, but has zero consumption for the entire audit period could be indicative of a meter issue or an account that is not active.



7. Consecutive Months of Zero Consumption – Like active accounts with zero consumption, this review identifies accounts with multiple, consecutive months with zero consumption which could be indicative of a meter or data handling issue on the account.
8. Accounts with “Blank” Consumption – This is an examination of accounts that a read did not occur (in the data) for that account. This can be caused by an account getting skipped or can show when account was read twice during the same billing period, i.e., on January 1 and January 31, but not read in February.
9. Days in Read Cycle – This is an examination of the days in a read cycle. Any accounts with read cycles over the normal will be flagged for review.
10. Read Consumption vs. Billed Consumption – Many billing systems separate the read consumption (current reading minus previous reading) with the billed consumption (consumption billed to customer. This examination reviews discrepancies between these volumes to determine if there is a systematic issue with customers not being billed for the consumption their meter is reading.
11. Multiplier vs. Meter Size – One common issue in the billing system is the use of multipliers. A multiplier is used to convert from units read to units billed, as many meters in the field are read in different units as the published billing rate units. This can either be a full conversion of units (cubic feet to gallons) but is most commonly a conversion to a different form of the same unit (cf to ccf or gallons to thousands of gallons). An incorrect multiplier assigned to a given account results in either an under or over billing of the customer, usually by a factor of 10, 100, etc. A comparison of the assigned multiplier to the meter size can be an indication of an issue with accounts, as it would be common to have the same multiplier on like sized meters, assuming the meters are the same make and model.
12. Verification of the Summary Volume – Most utilities utilize a summary report to record and track volumes monthly. For this review, the account level raw data is summed to compare to the summary report volumes to assure the summary report is sufficient for monthly tracking. Additionally, a lag time adjustment was conducted.



**Data Integrity Review Outcomes**

*Note: Data as initially received included a separate row of data for each consumption month including two months prior and two months after (i.e., generally, 16 row of data for monthly accounts). A pivot table was utilized to create a column-based reporting of consumption (i.e. 1 line of data per account). The total number of “reads” examined was 74,067.*

| <b>Data Integrity Checkpoint</b>                           | <b>Pass/Flag</b> | <b>Finding &amp; impact on BMAC / Recommended action (if any)</b>   |
|--|------------------|---|
| Count of bills per billing cycle                           | Pass             | A total of 5,227 unique Account #s were contained in the database. The most recent audit received from Fredrick (2022) included 4,685 number of service connections listed. In review the consumption data and the Account # make-up, it is apparent that Account #'s are the combination of a premise based identifier with - # added to the end. The number at the end appears to be increased by 1 for each new customer at that location. The number of unique premise based identifiers in the data was 4,699 which is much closer to the service connections listed in the audit. |
| Verification of non-potable exclusion                      | n/a              | None of the rate code descriptions included in the data export referenced non-potable volumes and given that this is an import only system, it was concluded that non-potable volumes were not applicable.  |
| Record duplicates  | Pass             | There were no duplicate rows of data found in the initial query.  |
| Negative consumption                                       | Pass             | There were no negative consumption volumes included in the data.  |
| High/Low volume outliers                                   | Pass             | In review of the billing cycle consumption patterns, a total of 240 high volume and 924 low volume outliers were found. These represent 0.32% and 1.25% of the total records and are deemed to be representative.<br><br>Many of the low outliers flagged were the result of a high outlier driving up the total consumption for the premise, making the other consumption periods appear low. It should be noted that accounts flagged for high consumption can be directly related to irrigation seasons and legitimate customer side leak events.                                    |
| Active Accounts with Zero Consumption for the Audit Period | Pass             | There was a total of 2,137 reads with zero consumption (2.89%). Many of the zero reads were from the same premise.  |
| Consecutive Months of Zero Consumption                     | Pass             | There were 19 accounts (active for the entire year) included that were logged as zero consumption for the entire consumption period reviewed, with another 280 accounts with zero consumption for the year, but only active for part of the year.   |
| Accounts with “Blank” Consumption                          | n/a              | Based on the unique identifier being the Account #, which as noted changes with a customer change, blank consumptions were not thoroughly scrutinized because when a customer change occurred, it resulted in blank values for the remainder of the billing months.   |



| Days in Read Cycle                    | Pass | There were no accounts where the days of service (time between reads) was greater than 35 days.   |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
|---------------------------------------|------|---|--|---|------|---------|----|-----|------|---|-------|------|--|----|----|--|----|--------|--|----|----|--|----|----|--|---|----|--|---|
| Read Consumption v Billed Consumption | n/a  | Only billed consumption was included in the data export, so no comparison was conducted.  |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| Multiplier vs. Meter Size             | Pass | <p>The following chart shows the count of premise code for each meter size and multiplier:</p> <table border="1"> <thead> <tr> <th></th> <th>1</th> <th>1000</th> </tr> </thead> <tbody> <tr> <td>(blank)</td> <td>47</td> <td>205</td> </tr> <tr> <td>5/8"</td> <td>1</td> <td>4,886</td> </tr> <tr> <td>3/4"</td> <td></td> <td>26</td> </tr> <tr> <td>1"</td> <td></td> <td>41</td> </tr> <tr> <td>1 1/2"</td> <td></td> <td>25</td> </tr> <tr> <td>2"</td> <td></td> <td>11</td> </tr> <tr> <td>3"</td> <td></td> <td>4</td> </tr> <tr> <td>4"</td> <td></td> <td>1</td> </tr> </tbody> </table> <p>Upon further investigation it was determined that many of the blank meter sizes were tagged as "Hydrant Water Usage". All account should be reviewed and an appropriate meter size assigned.</p>  |  | 1 | 1000 | (blank) | 47 | 205 | 5/8" | 1 | 4,886 | 3/4" |  | 26 | 1" |  | 41 | 1 1/2" |  | 25 | 2" |  | 11 | 3" |  | 4 | 4" |  | 1 |
|                                       | 1    | 1000  |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| (blank)                               | 47   | 205   |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| 5/8"                                  | 1    | 4,886   |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| 3/4"                                  |      | 26  |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| 1"                                    |      | 41  |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| 1 1/2"                                |      | 25  |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| 2"                                    |      | 11  |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| 3"                                    |      | 4   |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| 4"                                    |      | 1   |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |
| Raw data total v summary data total   | Fail | <p>The BMAC volumes used in the 2022 Water Audit was 650.200 MG. The total volume included in the account level export was 765.875 MG, nearly 18% in excess of the audit volume. Additionally, the audit resulted in a negative leakage volume, with overstated BMAC being one of the possible sources of this error.</p> <p>The first two lines in the example anomalies below account for nearly 85 MG of volumes. Even assuming these volumes are in error, this does not account for the full discrepancy.</p> <p>It was noted in the Validation Notes that Fredrick believes there are master meters and other pass-through meters that were erroneously included in the original audit. It is assumed that those were also included in the account level information evaluated. The initial investigation of these master meters included identifying them by address, but unfortunately addresses were not included in the account level export.</p> <p>The scope of this billing analysis provided through the free technical assistance stage of the Colorado Water Loss Initiative is not sufficient to thoroughly investigate these billing volume issues. It is recommended that the utility work internally to fully evaluate each account and its inclusion in the BMAC volume or engage a third-party expert to assist in that process. This is most often resolved by the creation of alternate rate codes that allow for easy disaggregation of volumes.</p> |  |   |      |         |    |     |      |   |       |      |  |    |    |  |    |        |  |    |    |  |    |    |  |   |    |  |   |



A lag time calculation was conducted resulting in the following adjustment:

|        |  |
|--------|--|
| -7.998 | Volume to subtract (consumption prior to audit period) |
| 9.396  | Volume to add (consumption billed after audit period)  |
| 1.398  | Net adjustment (MG)                                    |

| Account #    | Nov    | Dec    | Jan    | Feb     | Mar    | Apr    | May    | Jun     | Jul        | Aug     | Sep     | Oct     | Nov    | Dec    | Jan     | Feb     | Grand Total |
|--------------|--------|--------|--------|---------|--------|--------|--------|---------|------------|---------|---------|---------|--------|--------|---------|---------|-------------|
| 10-800013-13 |        |        |        |         |        |        |        |         | 84,712,100 | 0       | 0       | 0       | 0      | 0      | 0       | 1,900   | 84,714,000  |
| 10-800023-07 |        |        |        |         |        |        |        |         | 9,999,900  | 0       | 0       | 0       | 0      | 0      | 0       | 0       | 9,999,900   |
| 01-102270-01 | 74,000 | 82,000 | 76,000 | 102,000 | 56,000 | 1,000  | 11,000 | 463,000 | 681,000    | 907,000 | 747,000 | 396,000 | 1,000  | 7,000  | 189,000 | 275,000 | 4,068,000   |
| 01-100574-01 | 18,000 | 17,000 | 15,000 | 11,000  | 11,000 | 16,000 | 15,000 | 50,000  | 498,000    | 63,000  | 80,000  | 38,000  | 20,000 | 18,000 | 14,000  | 13,000  | 897,000     |
| 01-100572-01 | 14,000 | 17,000 | 11,000 | 13,000  | 31,000 | 20,000 | 24,000 | 712,000 |            |         |         |         |        |        |         |         | 842,000     |
| 10-300382-01 | 20,000 | 17,000 | 9,000  | 11,000  | 15,000 | 19,000 | 25,000 | 126,000 | 429,000    | 10,000  | 0       | 0       | 0      | 4,000  | 5,000   | 2,000   | 692,000     |
| 10-800024-05 | 64,200 | 42,000 | 22,300 | 0       | 0      | 55,000 | 0      | 116,000 | 0          | 160,200 | 0       | 0       | 0      | 0      | 0       | 0       | 459,700     |
| 01-101089-01 | 3,000  | 3,000  | 7,000  | 4,000   | 2,000  | 2,000  | 5,000  | 3,000   | 3,000      | 2,000   | 3,000   | 0       | 0      | 0      | 228,000 | 0       | 265,000     |

Examples of Identified Anomalies



## TECHNICAL MEMORANDUM

---

### City of Golden - Utilities Billing Data Analysis

**PREPARED FOR:** City of Golden - Utilities  
**DATE:** March 2025  
**PREPARED BY:** Colorado Water Loss Initiative  
**PROJECT TEAM:** Drew Blackwell (Cavanaugh), Chris Penwell (Cavanaugh)

#### **Objective Statement**

The Colorado Water Loss Initiative team conducted a billing data analysis for the City of Golden as part of Phase 2 of the program. Raw billing data to the account level was requested and received.

#### **Billing Data Integrity Review Process**

A Level 2 Validation was performed on the account level billing data provided via a detailed export from the City's billing system. The following is a general description of the process completed to review the data. It should be noted that any potential anomalies identified can have legitimate explanations or be a direct result of the data export process.

1. Count of Accounts per Bill Cycle – A review of the total number of records for each month/bill cycle was conducted. This review provides insight into the completeness of the export as well as identifies any potential issues related to missed billing of existing customers.
2. Verification of Exclusion of Non-Potable Volumes – A utility's billing software is often used to store and bill volumes other than the potable volumes used in the water audit. These volumes are often designated through a rate schedule, customer classification or other identifier. In this review, any unique identifiers presented in the raw data were used to confirm that only potable volumes were used in the water audit.
3. Duplicate Records – Prior to review of the exported account level data, a check for duplicate records is performed. Often, the export will contain duplicate records where volumes are duplicated in multiple rows of data.
4. Negative Consumption – Negative consumption within the database can be indicative of a data archival issue. Many billing software applications maintain a separate database that stores the original, uncorrected readings and usage from the adjusted database where adjustments and corrections are archived. Other negative consumptions are legitimate as a utility may use to correct an incorrect reading or overestimate in a previous period.
5. Monthly Consumption Outliers (High/Low) – A review of each account's monthly consumption pattern was conducted, and outliers were flagged. Many outliers are legitimate but should be examined by the utility. Higher consumption is to be expected in the summer months and thus the filters used to determine high volume outliers are less restrictive during those time periods.
6. Active Accounts with Zero Consumption for the Audit Period – An account in the database that is active, but has zero consumption for the entire audit period could be indicative of a meter issue or an account that is not active.



7. Consecutive Months of Zero Consumption – Like active accounts with zero consumption, this review identifies accounts with multiple, consecutive months with zero consumption which could be indicative of a meter or data handling issue on the account.
8. Accounts with “Blank” Consumption – This is an examination of accounts that a read did not occur (in the data) for that account. This can be caused by an account getting skipped or can show when account was read twice during the same billing period, i.e., on January 1 and January 31, but not read in February.
9. Days in Read Cycle – This is an examination of the days in a read cycle. Any accounts with read cycles over the normal will be flagged for review.
10. Read Consumption vs. Billed Consumption – Many billing systems separate the read consumption (current reading minus previous reading) with the billed consumption (consumption billed to customer. This examination reviews discrepancies between these volumes to determine if there is a systematic issue with customers not being billed for the consumption their meter is reading.
11. Multiplier vs. Meter Size – One common issue in the billing system is the use of multipliers. A multiplier is used to convert from units read to units billed, as many meters in the field are read in different units as the published billing rate units. This can either be a full conversion of units (cubic feet to gallons) but is most commonly a conversion to a different form of the same unit (cf to ccf or gallons to thousands of gallons). An incorrect multiplier assigned to a given account results in either an under or over billing of the customer, usually by a factor of 10, 100, etc. A comparison of the assigned multiplier to the meter size can be an indication of an issue with accounts, as it would be common to have the same multiplier on like sized meters, assuming the meters are the same make and model.
12. Verification of the Summary Volume – Most utilities utilize a summary report to record and track volumes monthly. For this review, the account level raw data is summed to compare to the summary report volumes to assure the summary report is sufficient for monthly tracking. Additionally, a lag time adjustment was conducted.



**Data Integrity Review Outcomes**

*Note: Data as initially received included a separate row of data for each consumption. A pivot table was utilized to create a column-based reporting of consumption (i.e. 1 line of data per account). The total number of “reads” examined was 65,745.*

| Data Integrity Checkpoint                                  | Pass/Flag | Finding & impact on BMAC / Recommended action (if any)   |
|--|-----------|--|
| Count of bills per billing cycle                           | Pass      | A total of 5,924 unique Account #s was contained in the database. The most recent audit received from Golden (2024) included 5,515 number of service connections listed.   |
| Verification of non-potable exclusion                      | Pass      | The City of Golden does bill for non-potable volumes, but those values are filtered from the billing data used in the audit BMAC.  |
| Record duplicates  | Pass      | There were no duplicate rows of data found in the initial query.   |
| Negative consumption                                       | Pass      | There was one negative consumption volume included in the billing data, with a volume of -2 gallons. This could possibly be due to air in the lines after turning on irrigation systems.   |
| High/Low volume outliers                                   | Pass      | In review of the billing cycle consumption patterns, a total of 352 high volume and 633 low volume outliers were found. These represent 0.5% and 0.96% of the total records. Many of the low outliers flagged were the result of a high outlier driving up the total consumption for the premise, making the other consumption periods appear low. It should be noted that accounts flagged for high consumption can be directly related to irrigation seasons and legitimate customer side leak events. |
| Active Accounts with Zero Consumption for the Audit Period | Pass      | There was a total of 4,445 reads with zero consumption (6.76%). Many of the zero reads were from the same premise. Accounts with zeroes are evaluated monthly, but in many cases, zeroes can be expected.  |
| Consecutive Months of Zero Consumption                     | Pass      | There were 47 accounts included that were logged as zero consumption for the entire consumption period reviewed.   |
| Accounts with “Blank” Consumption                          | Pass      | There was a total of 3,975 (6.05%) entries with a blank consumption month during the period reviewed. These blank values are estimated at a later date. New premises created during the year would show blanks for the preceding months.   |
| Days in Read Cycle   | Pass      | There were 20 accounts where the days of service (time between reads) were 45 days or greater, with the longest being 92 days.   |
| Read Consumption v Billed Consumption                      | Pass      | Both Billed Consumption and Service Consumption were listed in the raw data. The difference in potable water consumption for the year was 77.08 AF (2.85% of BMAC), with Service Consumption registering higher than Billed Consumption. Service consumption accounts for both meter and submeter reads, while Billed consumption subtracts the submeter reads.  |



|                                     |     |   |
|-------------------------------------|-----|---|
| Multiplier vs. Meter Size           | n/a | The billing data appears to be consistently measured, with no multipliers listed in the raw dataset.  |
| Raw data total v summary data total | n/a | A lag-time adjustment was not conducted due to the billing data ranging from 12/31/2023-1/2/2025. To conduct a lag-time adjustment, billing data must range from 2 months before and 2 months after the audit period. |

| UTILITY LIST                     |     |     |     |     |     |      |      |      |      |     |     |     |             |
|----------------------------------|-----|-----|-----|-----|-----|------|------|------|------|-----|-----|-----|-------------|
| BASED ON TOTALS, HIGH/LOW VALUES |     |     |     |     |     |      |      |      |      |     |     |     |             |
| Account #                        | Jan | Feb | Mar | Apr | May | Jun  | Jul  | Aug  | Sep  | Oct | Nov | Dec | Grand Total |
| 44-003823-000                    | 0   | 1   | 0   | 153 | 263 | 593  | 1665 | 639  | 1707 | 732 | 250 | 488 | 6491        |
| 51-000421-000                    | 0   | 0   | 0   | 14  | 600 | 1170 | 1248 | 1166 | 1114 | 830 | 318 | 5   | 6465        |
| 11-000292-000                    | 29  | 213 | 185 | 180 | 218 | 559  | 775  | 621  | 637  | 526 | 295 | 239 | 4477        |
| 51-000194-000                    | 0   | 0   | 0   | 0   | 24  | 629  | 842  | 890  | 865  | 281 | 0   | 0   | 3531        |
| 72-000460-000                    | 0   | 0   | 0   | 0   | 20  | 539  | 827  | 910  | 604  | 593 | 0   | 0   | 3493        |
| 51-000210-000                    | 0   | 0   | 0   | 0   | 25  | 788  | 734  | 824  | 728  | 301 | 0   | 0   | 3400        |
| 11-001028-000                    | 0   | 0   | 0   | 3   | 189 | 710  | 731  | 790  | 524  | 388 | 0   | 0   | 3335        |
| 15-005575-000                    | 0   | 0   | 0   | 0   | 18  | 558  | 678  | 720  | 562  | 352 | 0   | 0   | 2888        |
| 55-000012-000                    | 0   | 0   | 0   | 0   | 2   | 0    | 539  | 873  | 823  | 344 | 153 | 0   | 2734        |
| 63-000331-000                    | 0   | 0   | 0   | 2   | 1   | 518  | 746  | 566  | 287  | 430 | 92  | 0   | 2642        |
| 64-000903-000                    | 0   | 0   | 0   | 0   | 6   | 491  | 601  | 495  | 669  | 168 | 0   | 0   | 2430        |
| 51-000735-000                    | 0   | 0   | 0   | 0   | 15  | 507  | 584  | 487  | 403  | 429 | 0   | 0   | 2425        |
| 16-006190-000                    | 0   | 0   | 0   | 0   | 0   | 0    | 0    | 1329 | 836  | 0   | 0   | 0   | 2165        |
| 55-000010-000                    | 30  | 31  | 40  | 36  | 278 | 887  | 248  | 10   | 2    | 22  | 37  | 39  | 1660        |
| 73-000470-001                    | 6   | 11  | 9   | 9   | 47  | 220  | 245  | 262  | 257  | 190 | 39  | 24  | 1319        |
| 16-006240-000                    | 0   | 1   | 1   | 1   | 6   | 39   | 164  | 82   | 60   | 47  | 6   | 1   | 408         |
| 73-001251-000                    | 0   | 0   | 0   | 1   | 1   | 0    | 113  | 237  | 153  | 74  | 4   | 0   | 583         |
| 63-000220-000                    | 1   | 1   | 2   | 2   | 1   | 50   | 19   | 9    | 7    | 3   | 3   | 2   | 100         |
| 55-000010-000                    | 30  | 31  | 40  | 36  | 278 | 887  | 248  | 10   | 2    | 22  | 37  | 39  | 1660        |
| 15-004690-000                    | 1   | 3   | 2   | 13  | 2   | 123  | 5    | 6    | 10   | 2   | 1   | 2   | 170         |
| 64-000904-000                    | 0   | 0   | 0   | 0   | 1   | 48   | 353  | 58   | 150  | 118 | 0   | 0   | 728         |

Examples of Identified Anomalies



**Appendix F: Customer Meter Test Design Report**

## TECHNICAL MEMORANDUM

---

### Arapahoe County Water & Wastewater Authority Customer Meter Testing Technical Guidance

**PREPARED FOR:** Arapahoe County Water & Wastewater Authority  
**DATE:** October 2022  
**PREPARED BY:** Colorado Water Loss Initiative  
**PROJECT TEAM:** Tory Wagoner, P.E. (Cavanaugh), Drew Blackwell (Cavanaugh)

#### **Objective Statement**

The Colorado Water Loss Initiative team conducted an analysis for the Arapahoe County Water & Wastewater Authority (ACWWA) as part of Phase 2 of the program. Basic customer meter inventory – including size, type, age, and throughput) was requested and received for 2017 through 2021 to perform the analysis.

First, it is important to distinguish between 1) billed and unbilled metered consumption and 2) small and large customer meters since testing practices can be different and the overall consumption helps prioritize testing practices. ACWWA has both billed and unbilled metered authorized consumption. The **unbilled metered authorized consumption** (see Table 1). is approximately 0.1% of the Billed metered consumption, indicated by the accounts below:

*Table 1: Unbilled Metered accounts*

| UMAC by account | kgal         |
|-----------------|--------------|
| F33-128652      | <b>8,643</b> |
| <b>2"</b>       | 52           |
| <b>3/4"</b>     | 8,590        |
| <b>4"</b>       | 1            |
| F33-129066      | <b>137</b>   |
| <b>3/4"</b>     | 137          |
| Grand Total     | <b>8,780</b> |

The focus of this technical memo is on the **billed metered authorized consumption** (see Table 2).

*Table 2: Billed metered consumption and count by meter size*

| Meter Sizes | Consumption per meter size (kgal) | % Consumption per meter size | Count per Meter Size | % of meter population |
|-------------|-----------------------------------|------------------------------|----------------------|-----------------------|
| <b>5/8"</b> | 319,720                           | 6%                           | 999                  | 19%                   |
| <b>3/4"</b> | 1,268,620                         | 23%                          | 3,142                | 61%                   |
| <b>1"</b>   | 682,195                           | 12%                          | 344                  | 7%                    |
| <b>1.5"</b> | 1,476,380                         | 27%                          | 455                  | 9%                    |
| <b>2"</b>   | 694,124                           | 13%                          | 166                  | 3%                    |
| <b>3"</b>   | 609,674                           | 11%                          | 47                   | 1%                    |
| <b>4"</b>   | 134,571                           | 2%                           | 3                    | 0.06%                 |
| <b>6"</b>   | 273,619                           | 5%                           | 2                    | 0.04%                 |
| Grand Total | <b>5,458,903</b>                  | <b>100%</b>                  | <b>5,158</b>         | <b>100%</b>           |

While the large meters in the ACWWA system make up a very small part of the overall meter population, they account for nearly one-third of the overall consumption by volume (see Figure 1) – small meters defined as 1.5” and smaller; large meters defined as 2” & larger -- . ACWWA may choose to define their small and large meter differently.

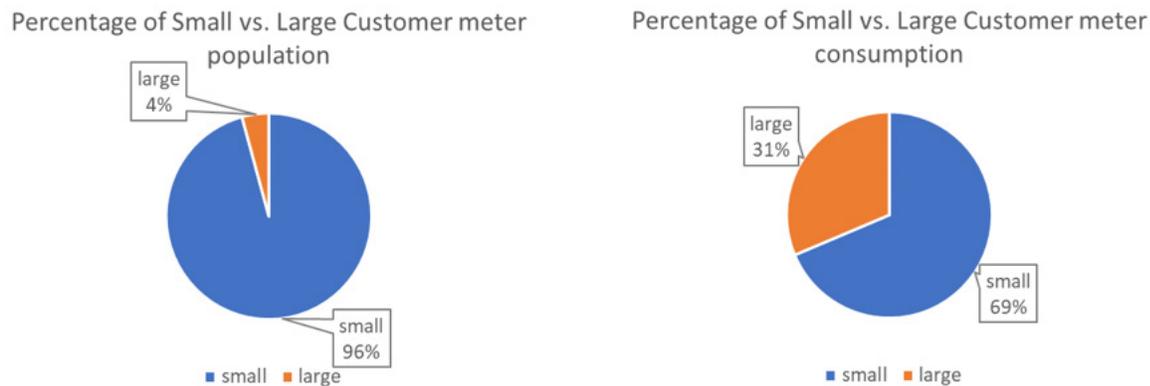


Figure 1: ACWWA Small vs. Large Customer Meters

### **Small Meters (1-1/2” & smaller)**

The industry has continued to evolve and review customer meter testing procedures and best practices. A Water Research Foundation study published in 2011 (Report 4028) performed accuracy testing on a group of 595 meters pulled from various utilities. An excerpt from the report (Figure 2) details the outcomes of this portion of the project:

The accuracy testing of 595 pulled meters (shipped to the UWRL from water utilities across the United States) indicated that potable water quality from the different utilities had less of an effect on meter accuracy than did sand and other particulates found in the utility’s water system. Generally, most of the degradation trends for the pulled meter tests correlated very closely to the new meter laboratory endurance degradation trends and there were very few notable correlations between interior meter wear and indicated meter accuracy with the exception of some extreme wear cases.

Particulate test results also indicated that the subject meters had a surprisingly high percentage of meters that passed the AWWA flow rate registry tests in spite of the fact that a relatively large slug of sand had been passed through them. Measurable accuracy degradation was noted, however, for the piston type meters at the AWWA minimum flow rate.

Figure 2: Results/Conclusions from WRF Project 4028

More recently, a respected industry expert Water Systems Optimization (WSO, now ESource), performed analysis on a combined database of approximately 4,400 random test results from small meters, primarily from California utilities. Their analysis was published in an article in the Source magazine in the fall of 2018 ([https://www.apogeepublications.com/emags/source\\_fall2018/page\\_31.html](https://www.apogeepublications.com/emags/source_fall2018/page_31.html).) The results from their evaluation indicated that “no statistically meaningful relationship between accuracy and age or total throughput among meters in our dataset.” Cavanaugh’s experience has shown that this finding is highly specific to individual utilities and meter make/model.

However, one important outcome from the WSO analysis was their conclusions relative to sample size. Their conclusions stated, “A closer examination reveals that for sample sizes below 100 meters, there is risk of underestimating the true population’s accuracy. There is also diminishing returns on testing additional meters within a group, especially beyond about 250 to 300 meters.” This outcome is in line with our experience and consistent with statistical sample population calculations.

It should also be noted that these samples are only valid to the population they represent. Specifically, these subgroups should be established based on meter manufacturer and meter type. Manufacturing year is not as valid, if there is consistency in the product year over year. As an example, a meter manufactured in 2008 can be included in the same population as one manufactured in 2012, assuming the general materials and components of the meter are consistent.

Additionally, the goal of the testing is to determine if there is a degradation of the meter performance over time or based on the throughput (use) of the meter. As such, test results represent an individual data point in the database and are relevant year over year, not just in the year the test was conducted. As an example, a meter tested in 2017 with a throughput of 1.2 million gallons is applicable to the subgroup population in 2019, as there will be meters with those characteristics present at that time.

Based on the above parameters, the following testing program is recommended for the ACWWA system:

1. Determine the applicable sub-groups based on:
  - a. Meter manufacturer
  - b. Meter type
  - c. Meter size
2. Test meters within each sub-group based on the following guidelines:

| Population Size   | Sample Size |
|-------------------|-------------|
| 0 to 5,000        | 100         |
| 5,001 to 10,000   | 250         |
| 10,001 to 25,000  | 300         |
| 25,001 and larger | 350         |

3. Establish a meter test results database, and continue to add new test data to accumulate an adequate sample size.

**Additional Notes:**

- All meters sampled should be randomly selected for testing based on the applicable sub-group population of properly functioning meters.
- Care should be taken to assure meters are as near to field operational conditions as possible, including the following recommended process:
  - Always keep the meter upright
  - Plug or place endcaps on the meter connection points immediately after removal
  - Place the meter in a sealed plastic bag for transport to the testing facility
- Meters should be tested per AWWA, M6 recommendations
- Composite meter accuracy should be calculated as a weighted average
  - Weighting shall be determined based on a sample of use from the sub-group population (flow profiling at 1-minute minimum intervals)

**Large Meters (2" & larger)**

Large meters should be evaluated and tested on a meter-by-meter basis. It is recommended to include the revenue generated by the specific meter in the determination of the testing frequency, regardless of size. All meters should be tested no less than every five years. Table 1 shows the top 10 largest consumers in the ACWWA system from 2017 – 2021 make up for approximately 15% of the consumption.

*Table 3: Largest users in ACWWA system*

| <b>Current Account</b> | <b>Location</b> | <b>Svc Size</b> | <b>User Type</b> | <b>2021 - 2017 Total Usage</b> |
|------------------------|-----------------|-----------------|------------------|--------------------------------|
| <b>3596</b>            | F33-001126      | 6"              | M                | 137,389                        |
| <b>123817</b>          | F33-123817      | 6"              | C                | 136,230                        |
| <b>124712</b>          | F52-124712      | 4"              | C                | 134,246                        |
| <b>124422</b>          | F51-124422      | 3"              | C                | 126,644                        |
| <b>2270</b>            | F33-123483      | 3"              | C                | 58,063                         |
| <b>1151</b>            | F33-001151      | 3"              | C                | 46,203                         |
| <b>128830</b>          | F33-128830      | 2"              | C                | 27,390                         |
| <b>124485</b>          | F33-124485      | 3"              | C                | 27,131                         |
| <b>3120</b>            | 030-128416      | 3"              | C                | 25,886                         |
| <b>125992</b>          | F33-125992      | 3"              | C                | 24,948                         |

As with small meters, flow profile information should be used to determine the appropriate weighting for the composite accuracy calculation. Additionally, repair/replacement decisions should be made based on a business case evaluation for simple payback rather than a generic pass/fail standard.

### Why Test Large Customer Meters?

Customer meters are the most important part of the revenue generation process for a water utility. Without accurate meters, the opportunity for potable water to be delivered to the customer without proper revenue generation is suspect. Naturally, the customers with the largest meters are often the largest users of waters and thus the largest revenue generators. Figure 3 and Figure 4 show large customer meters should be the primary focus of any optimized customer meter testing program.

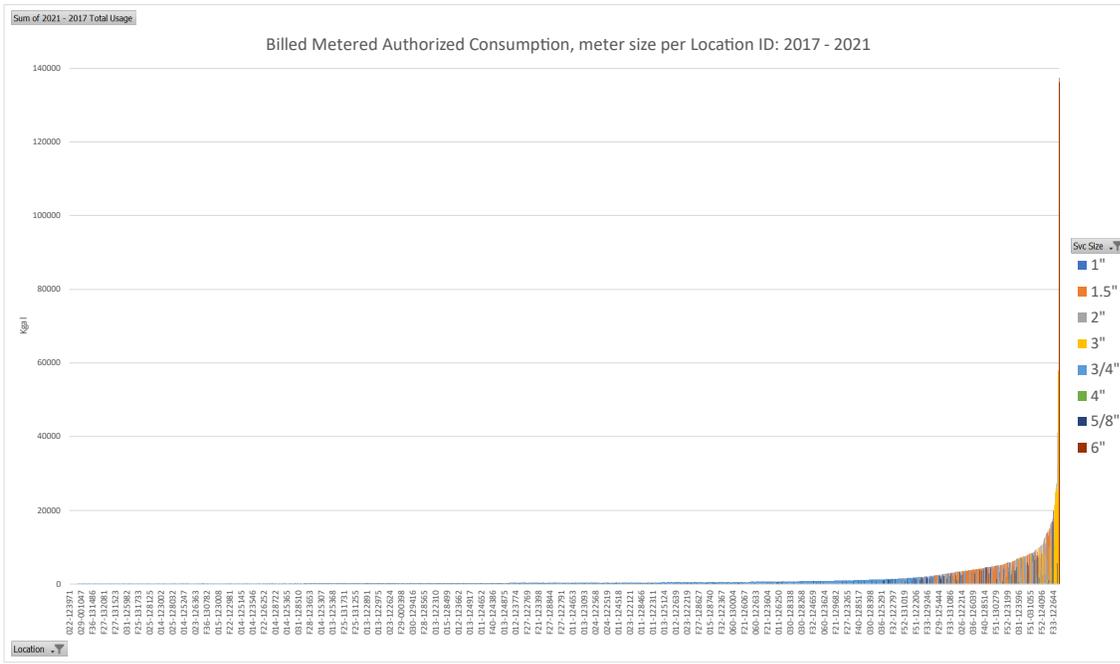


Figure 3: Consumption per meter size (all)

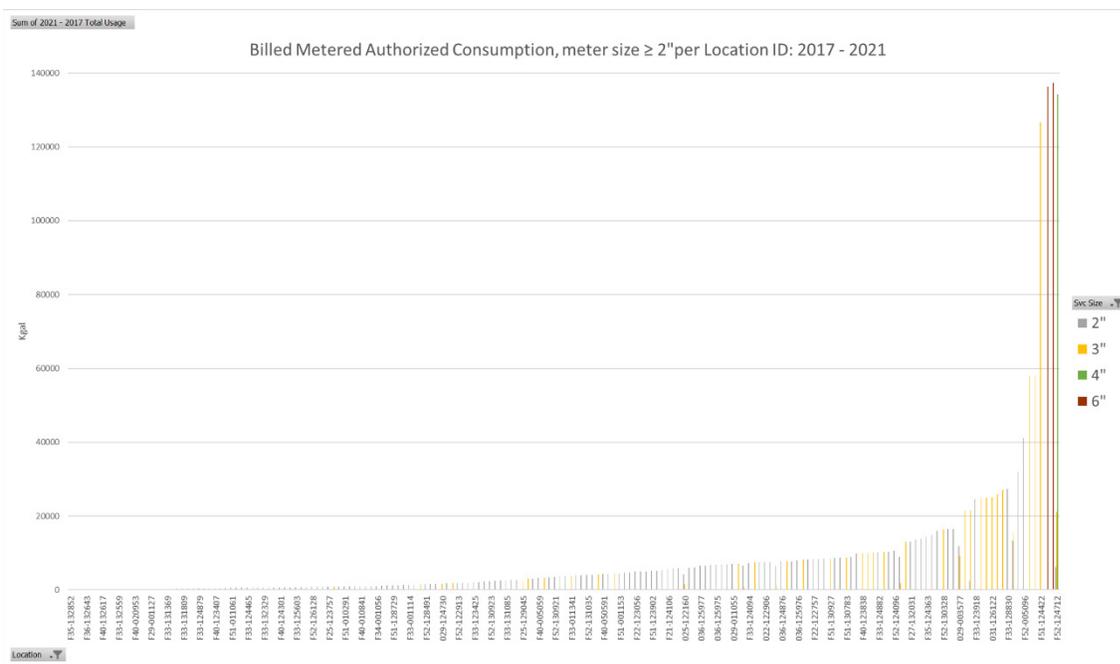


Figure 4: Consumption per meter size (2" and larger)

An optimized customer meter testing program should be separated between large and small meters. Typically, a utility will have more small meters and thus cannot focus on the performance of each individual meter. Instead, focus should be on a sample of these meters to represent the larger population. For large meters, there are typically less meters in the system and therefore these meters should be evaluated and managed individually.

Simply stated, testing of large meters serves two main purposes:

1. The testing results can be used to inform the Customer Metering Inaccuracies calculation and subsequent input in the water audit helping provide an accurate representation of the Apparent Loss volume, thus improving the accuracy outcome of the overall water audit;
2. Most important, the testing provides revenue assurance for the utility's largest revenue generators.

### **Description of Potential Testing Methods**

#### 1. Comparative Testing

When applicable, volumetric comparison (see Figure 5) is the preferred method of testing. This test can be undertaken using a calibrated “test” meter, whereby a test port immediately downstream of the subject meter is used to flow the same volume through both meters. The volumes can then be compared for accuracy. This method requires the proper valving and testing port to be performed. Additionally, unless water service to the customer can be interrupted, an unmetered bypass is also needed. This method of testing is preferable for several reasons. Primarily, it tests the meter in its normal operating location and flow conditions providing a direct replication of its actual performance. Additionally, it does not require a replacement meter or long period of time of unmetered water delivery that would be required if the meter was removed to be tested on a test bench.

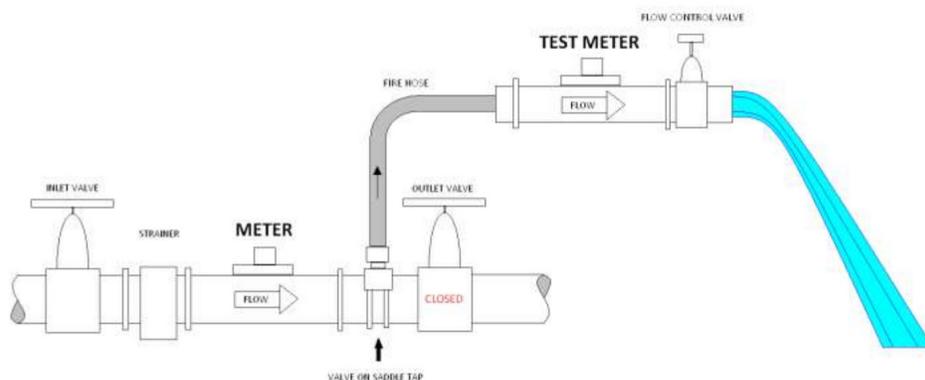


Figure 5: Comparative Testing Graphic (credit: ME Simpson)

## 2. Insertion Probe Comparison

This method of testing consists of the use of an insertion probe (magnetic meter, turbine or pitometer rod) either upstream or downstream of the subject meter. A velocity profile is generated and under ideal conditions, fully laminar flow is achieved, and the average velocity is measured, logged, and converted to flow utilizing inside pipe diameters. The velocity profile under these conditions will result in the shape of a bullet as show in the graphic below.

To achieve these ideal conditions, an upstream distance and downstream distance would need to be unobstructed. This would include being free from tees, bends, valves, pumps, and the subject meter. The results of this test include the suitability of the test site and the validity of the subject meter.

## 3. Time of Flight Ultrasonic Comparison

The use of strap-on type ultrasonic meters can be used to compare flows with the subject meter. As with all instruments and testing methods, their performance can be limited by site conditions. These meters are very easy to install and are completely non-intrusive. However, these ultrasonic meters are not as effective on cast iron pipes because the signal can be distorted by possible tuberculation on this type of pipe material. They have shown to be effective on plastic and steel pipes. Additionally, the accuracy of the output is dependent upon an assumption of inside diameter and potential liner of the pipe.

### **Overall Large Customer Meter Testing Program Description**

ACCWA currently has very limited meter test data for 10 customer meters ranging in size of  $\frac{3}{4}$ " to 2" meters. Staff verified that testing methods are based on the AWWA M6 recommendations. Meter testing frequency is currently reactive.

### **Testing Recommendation**

ACCWA should prioritize large meter testing with meter testing frequencies based on revenue. This will provide a consistent evaluation of the system's largest customers and provide maximum revenue protection. This would involve an evaluation of the potential lost revenue associated with a selected inaccuracy in comparison to the cost of testing the meter. This could lead to testing frequencies as often as every six months for the largest volume users and a minimum of at least every five years for lower volume users. Given that testing will likely occur using external forces, the number of tests annually will be governed by available resources.

Additionally, flow profiling should be an integral part of the evaluation of the meter test results. Calculating the composite meter accuracy should be directly dependent on the flow rates the meter typically measures. A meter test that potentially "fails" at a low flow rate may not warrant repair or replacement if the customer never uses water at the low flow rate. If existing infrastructure is not capable of obtaining the flow profile information, third-party products are available for use.

One final aspect of the optimized large meter testing program is the decision matrix associated with evaluation of the results. Again, with flow profile results included, the potential lost revenue should be the driver for repair/replacement. Simply said, many of the highest revenue meters could provide a reasonable rate of return for repair/replacement at a meter accuracy that AWWA standards would deem to "pass," while lower revenue meters could potentially "fail" and not be candidates for repair/replacement.



**Appendix G: Leak Detection Survey Reports**



# COLORADO WATER LOSS INITIATIVE

## ADVANCED TECHNICAL ASSISTANCE

### FINAL TECHNICAL MEMO

#### Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program, currently underway, goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase integrates basic training and practices to new participants as well as more advanced training and technical assistance to previous participants.

As an advanced participant, the City of Loveland was given the opportunity to receive Direct Technical Assistance (DTA) at no cost through the CWLI. Of the different offerings of DTA available through the program, the City of Loveland has selected to perform Leak Detection Survey. This report summarizes the leak detection work performed at Loveland.

#### Scope of Work

The work involved performing a leak detection survey on the water distribution system. For this purpose, E Source provided a field team of 2 experienced Leak Detection Technicians to perform the field work between September 11 to 22, 2023. During the field work, the Team surveyed approximately 22 miles of areas of the water distribution system that were selected by Loveland, as shown in Figure 1.

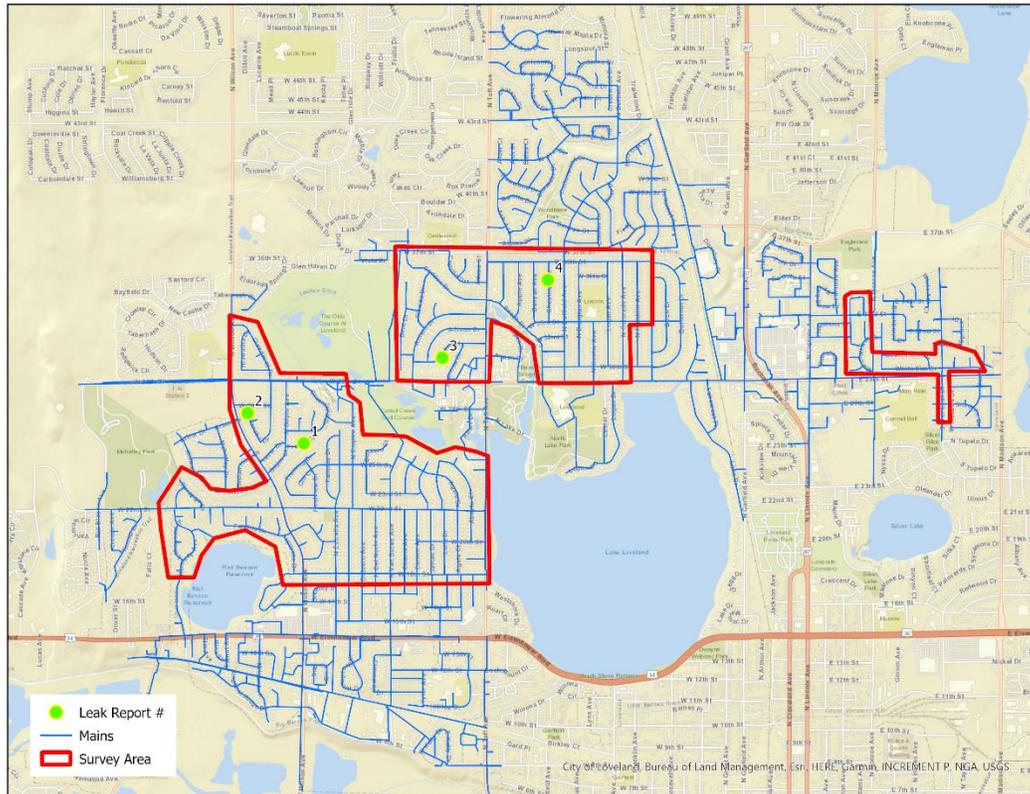


Figure 1. Leak Detection Survey Areas

The field work entailed an initial general surveying phase where all accessible assets are surveyed and then, a leak confirmation and pinpointing phase, where potential leak noises are verified and located.

During the initial survey work, E Source’s leak detection technicians used an acoustic leak sounding devices to come into contact with accessible water infrastructure, including customer meters, hydrants, and valves to listen for any potential leak noise. If there was a leak in the surrounding area, the electronic equipment amplifies the noise generated by the leak and the technician is alerted that there is a leak. When the technicians hear a potential leak noise and there are no visible signs of a leak, such as water on the surface, all potential leak noises are verified either with an alternate method or at a later time.

During the leak verification process, the technicians worked to confirm that the noise is caused by a leak and to identify a more exact location of the leak. Depending on the complexity in locating the leak, a leak noise correlator, noise loggers, or a ground-mic may be used.



## Results

The Field Team reported a total of 4 suspected leaks as summarized in Table 1. The individual leak reports are included as an Appendix.

**Table 1. Reported Leaks Summary**

| Leak Suspected On | Number of Leaks | Estimated Leak Flow (gpm) |
|-------------------|-----------------|---------------------------|
| Main              | 1               | 5                         |
| Service           | 1               | 1                         |
| Customer Side     | 2               | 0.6                       |
| <b>Total</b>      | <b>4</b>        | <b>6.6</b>                |

There was no visible water at the surface for the reported service leak, the main leak, and one of the customer-side leaks. There was water visible at the surface for the other customer-side leak. The suspected main leak was confirmed with the use of the digital correlator.

During the survey, the Field Technicians found many pit lids that were bolted shut or stuck with rust or pavement. In some cases, the lids were difficult to open because the nuts were worn and rounded. This delayed the surveying process and in some cases, they were not able to survey certain assets that were not accessible. To improve the efficiency of the field work in a future survey, E Source recommends for the lids of the buried infrastructure be made accessible and operable.

Considering the two reported utility-side leaks, the estimated volume of real losses is estimated at approximately 260,000 gallons per month. For the reported customer side leaks, the flow was being picked up by the customer meter, so that volume would not be considered a real loss by the AWWA M36 Methodology since the volume was being registered and billed. However, if the flow from the customer-side leaks were not registered by the meters (or not accurately), then the volume not registered would be considered an apparent loss by the AWWA M36 Methodology.

The City of Loveland should evaluate the results of their AWWA M36 Water Audit together with the results of this leak survey to determine if additional proactive leakage management activities may be cost effective for the City. A Real Loss Component Analysis is an additional analytical tool offered by the CWLI that the City may consider to assist with that analysis.



*Final Technical Memo  
Colorado Water Loss Initiative*

## Appendix: Individual Leak Reports



# LEAK REPORT

Date: September 12, 2023

Report #: 1

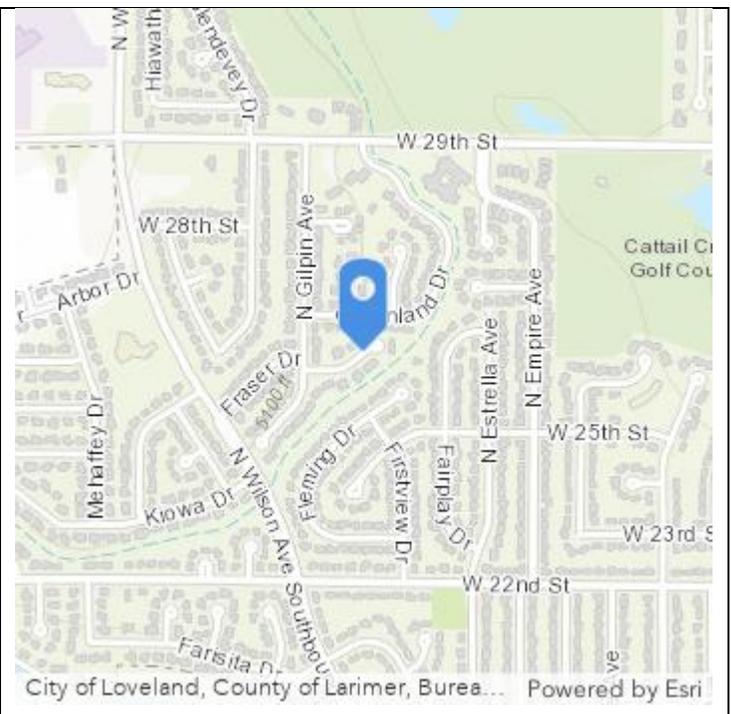
Survey

Recheck

Request

| LOCATION   | LEAK DATA                  | DETAILS                            |
|--|----------------------------|------------------------------------|
| Address: 2364 Fraser Ct, Loveland, Colorado, 80538 | Leak Suspected On: Service | Estimation (gpm): 1                |
| Cross Street:                                      | Leak Indication:<br>Sonic  | Leak Cover: Concrete               |
| ID:  | Priority: 1                | Action: Marked: Blue<br>(Excavate) |

| COORDINATES (DMS):           |                           |
|------------------------------|---------------------------|
| Longitude: <b>-105.11035</b> | Latitude: <b>40.41829</b> |



**Comments:**

|  |                              |
|--|------------------------------|
| <p><b>Note:</b><br/>This reported leak supersede an original leak report? No<br/>Reason:</p> | <p>Technician: U Navarro</p> |
|--|------------------------------|



# LEAK REPORT

Date: September 15, 2023

Report #: 2

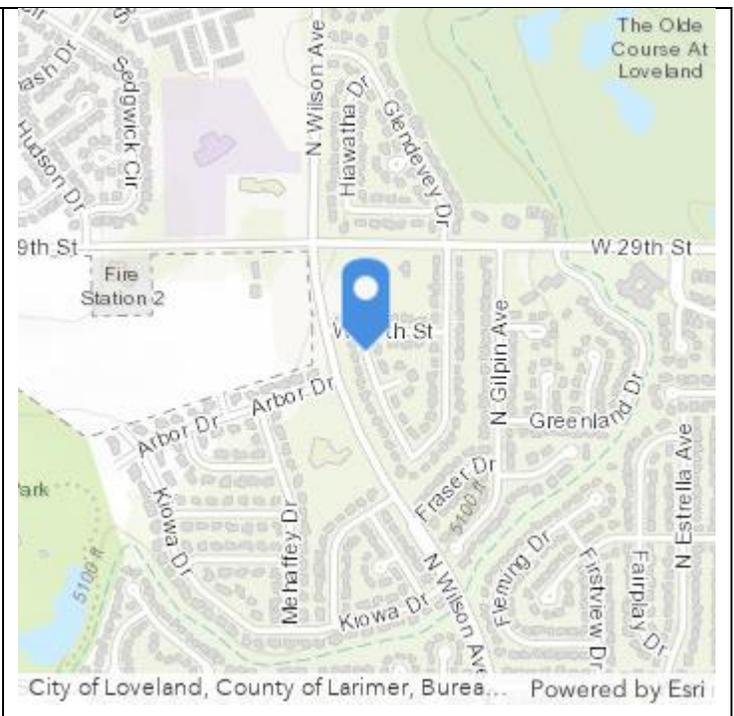
Survey

Recheck

Request

| LOCATION  | LEAK DATA                              | DETAILS                            |
|---|--|------------------------------------|
| Address: 2731 El Rancho Dr, Loveland, Colorado, 80538 | Leak Suspected On: Main                | Estimation (gpm): 5                |
| Cross Street:   | Leak Indication:<br>Sonic, Correlation | Leak Cover: Asphalt                |
| ID:   | Priority: 1                            | Action: Marked: Blue<br>(Excavate) |

| COORDINATES (DMS):           |                           |
|------------------------------|---------------------------|
| Longitude: <b>-105.11451</b> | Latitude: <b>40.42002</b> |



**Comments:**

|  |                                |
|--|--------------------------------|
| <p><b>Note:</b><br/>         This reported leak supersede an original leak report? No<br/>         Reason:</p> | <p>Technician: J Daugherty</p> |
|--|--------------------------------|



# LEAK REPORT

**Date: September 21, 2023**

**Report #: 3**

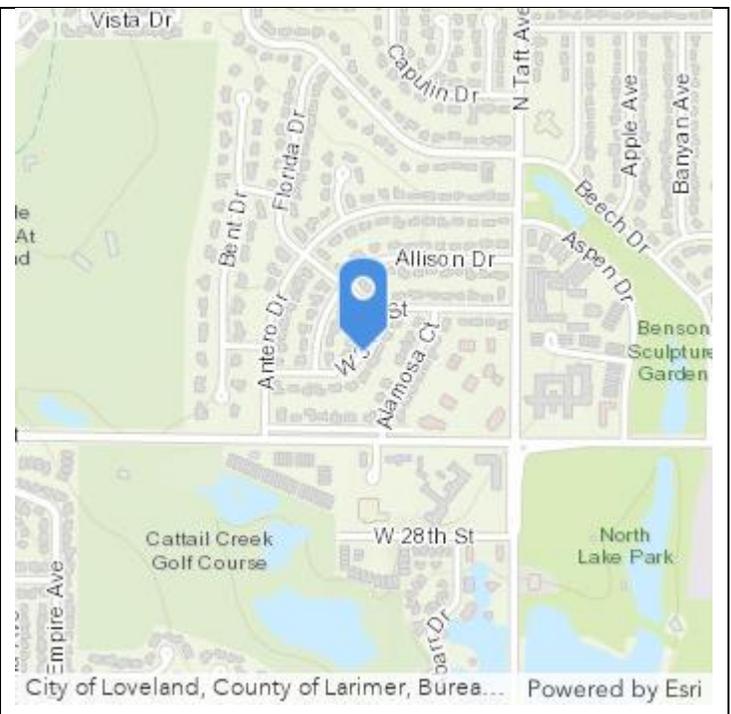
Survey

Recheck

Request

| LOCATION   | LEAK DATA                               | DETAILS                                  |
|--|---|--|
| Address: 1522 W 31st St, Loveland, Colorado, 80538 | Leak Suspected On: Customer Side        | Estimation (gpm): 0.1                    |
| Cross Street:                                      | Leak Indication:<br>Sonic, Visual Water | Leak Cover: Meter Pit                    |
| ID:  | Priority: 1                             | Action: Marked: Blue<br>(Further Action) |

| COORDINATES (DMS):           |                           |
|------------------------------|---------------------------|
| Longitude: <b>-105.10005</b> | Latitude: <b>40.42309</b> |



**Comments:** Small leak on customer side.

|  |                              |
|--|------------------------------|
| <p><b>Note:</b><br/>         This reported leak supersede an original leak report? No<br/>         Reason:</p> | <p>Technician: U Navarro</p> |
|--|------------------------------|



# LEAK REPORT

Date: September 21, 2023

Report #: 4

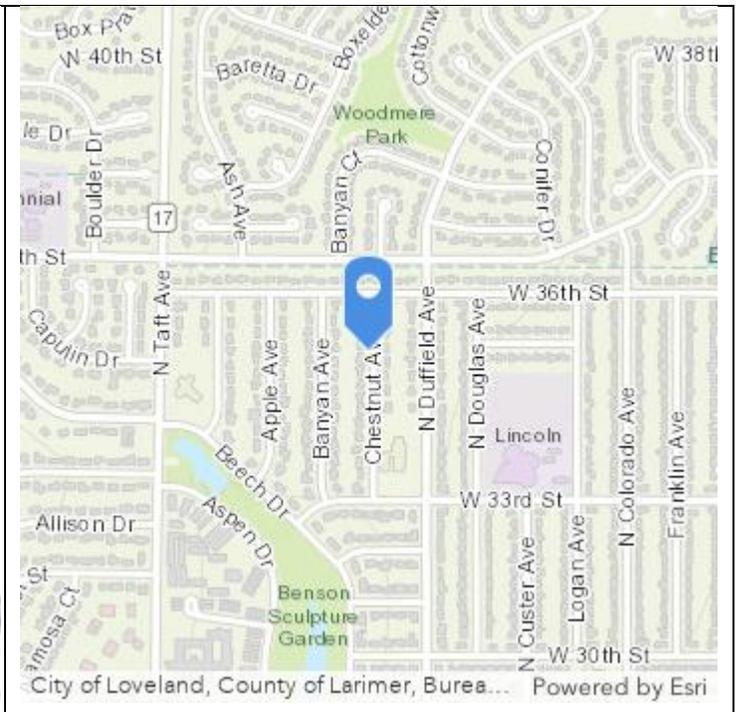
Survey

Recheck

Request

| LOCATION  | LEAK DATA                        | DETAILS                               |
|---|----------------------------------|---------------------------------------|
| Address: 3407 Chestnut Ave, Loveland, Colorado, 80538 | Leak Suspected On: Customer Side | Estimation (gpm): 0.5                 |
| Cross Street:   | Leak Indication: Sonic           | Leak Cover: Meter Pit                 |
| ID:   | Priority: 1                      | Action: Marked: Blue (Further Action) |

| COORDINATES (DMS):   |                    |
|----------------------|--------------------|
| Longitude: -105.0922 | Latitude: 40.42747 |



**Comments:** The hiss and the “bubbling” can be heard without equipment.

|  |                              |
|--|------------------------------|
| <p><b>Note:</b><br/>         This reported leak supersede an original leak report? No<br/>         Reason:</p> | <p>Technician: U Navarro</p> |
|--|------------------------------|



# COLORADO WATER LOSS INITIATIVE

## ADVANCED TECHNICAL ASSISTANCE

### FINAL TECHNICAL MEMO

#### Background

The Colorado Water Loss Initiative (CWLI) was created by the Colorado Water Conservation Board to continue supporting water providers in improving the management of their water systems, specifically through comprehensive water loss management programs.

Phase 1 of the CWLI was a 2-year program that concluded in 2020. During that phase, the CWLI provided individualized technical support and training workshops on water loss control best practices to over 150 water utility professionals across Colorado.

Phase 2 of the program, currently underway, goes beyond water audits and assists the water providers with targeted interventions for water loss management. This phase will integrate basic training and practices to new participants as well as more advanced training and technical assistance to Phase 1 participants. New participants will also get a chance to participate in the more advanced technical assistance in the latter part of the program.

As a participant of Phase 1, Colorado Springs Utilities is given the opportunity to receive Direct Technical Assistance (DTA) at no cost through the CWLI. Of the different offerings of DTA available through the program, Colorado Springs Utilities has selected to perform Leak Detection Survey. This report summarizes the leak detection work performed at Colorado Springs.

#### Scope of Work

The work involved performing a leak detection survey on the water distribution system at Colorado Springs Utilities. For this purpose, E Source provided a field team of 2 experienced Leak Detection Technicians to perform the field work between May 15 to 26, 2023.



The E Source Field Team was accompanied by Colorado Springs Leak Detection Crew. During the field work, the Team surveyed areas of the water distribution system that were selected by Colorado Springs. The following maps were partially or fully surveyed at the direction of Colorado Springs:

- M28: 1 – 5, 8, 11, 12
- N26: 1, 2, 4
- N27: 1-12
- N28: partial

Paper maps highlighted with the lines that were surveyed were provided to Colorado Springs.

The field work entailed an initial general surveying phase where all accessible assets are surveyed and then, a leak confirmation and pinpointing phase, where potential leak noises are verified and located.

During the initial survey work, E Source's leak detection technicians used an acoustic leak sounding devices to come into contact with accessible service connections, hydrants (if applicable), or valves throughout the water distribution system to listen for any possible leak noise. If there was a leak in the surrounding area, the electronic equipment amplifies the noise generated by the leak and the technician is alerted that there is a leak. When the technicians hear a potential leak noise and there are no visible signs of a leak, such as water on the surface, all potential leak noises are verified either with an alternate method or at a later time.

During the leak verification process, the technicians work to confirm that the noise is caused by a leak and to identify a more exact location of the leak. Depending on the complexity in locating the leak, a leak noise correlator, noise loggers, or a ground-mic may be used.

## Results

The Field Team located one potential leak suspected at a service line in map M28-5 with an estimated flow of 10 gpm. There was no water visible at the surface near the suspected leak location, but it was confirmed with a correlation. See attached Leak Sheet.

Colorado Springs confirmed that the reported leak was located and repaired. It was caused by a full circle break on an 8-inch CIP main that was running at 92 psi. The leak flow rate was estimated to be approximately 216 GPM.

# LEAK REPORT

Date: May 17, 2023

Report #: 1

Survey

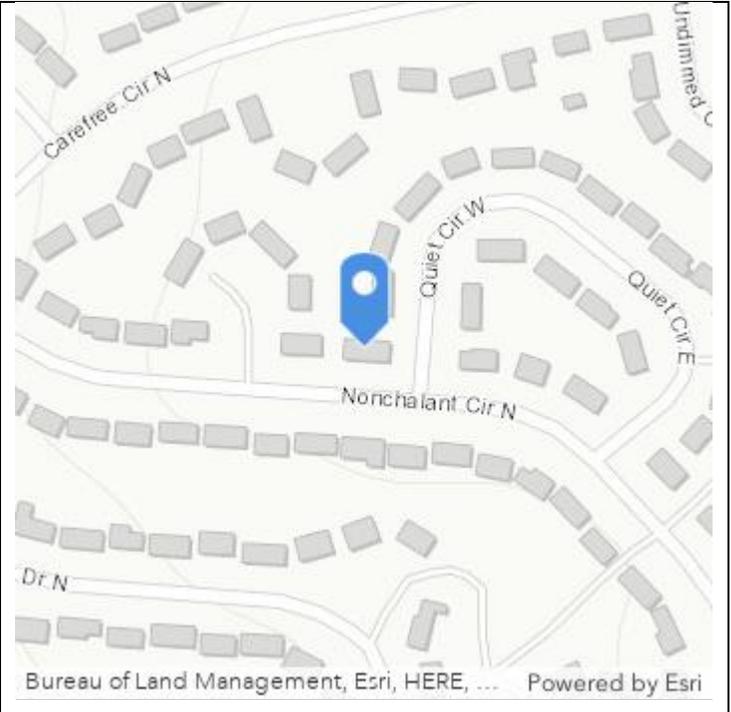
Recheck

Location Error

Request

| LOCATION  |               | LEAK DATA                              | DETAILS                         |
|---|---------------|--|---------------------------------|
| Address: 4330 N Nonchalant Cir, Colorado Springs, Colorado, 80917 |               | Leak Suspected On: Service             | ESTIMATION (GPM): 10            |
| Cross Street: Quiet Cir   |               | Leak Indication:<br>Correlation, Sonic | LEAK COVER: Asphalt             |
| Infrastructure ID:  | Map ID: M28-5 |  | ACTION: Marked: Blue (Excavate) |

| COORDINATES (DMS):        |                        |
|---------------------------|------------------------|
| Longitude: 104°44'50.76 W | Latitude: 38°53'5.51 N |



**Comments:** Appears to be at or near the corp valve

|   |                                       |
|---|---------------------------------------|
| <p>Note:<br/>Does this leak report supersede an original leak report? No</p> <p>Reason: N/A</p> | <p>Technician: U Navarro, C Bracy</p> |
|---|---------------------------------------|



**Appendix H: Real Loss Component Analysis Reports**



**TECHNICAL MEMORANDUM**

---

**Mount Werner Water District  
Real Loss Component Analysis**

**PREPARED FOR:** Mount Werner Water District  
**DATE:** December 2024  
**PREPARED BY:** Colorado Water Loss Initiative  
**PROJECT TEAM:** Chris Penwell (Cavanaugh), Drew Blackwell (Cavanaugh)

**Objective Statement**

The Colorado Water Loss Initiative team conducted a Real Loss Component analysis for the Mount Werner Water District as part of Phase 2 of the program. Leak and system data was requested and received.

**Background**

The water balance analysis is a top-down process, meaning the analysis starts with water supplied and then subsequently subtracts authorized consumption and apparent losses. The remainder in this top-down process yields an estimate of the real losses. It is important to further evaluate these real losses, by performing a bottom-up quantification of the volumes through a real loss “component analysis”. The central aspect in the component analysis is understanding there are three types of real losses. Most utilities associate all of their real losses with the leaks that come to the surface, are discovered and then repaired. This is “reported leakage”. From a volumetric standpoint, reported leakage generally equates to a very small percentage of the total real loss volume. This is because the time period from when a utility becomes aware of the leak, locates the leak to when the repair is made is generally a short period.

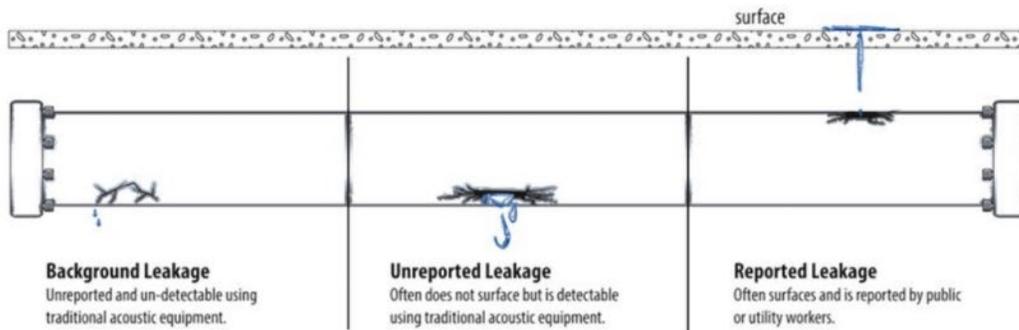


Figure 1 – Sub-Components of Real Loss (graphic credit WRF)

The other types of real loss are “background” and “unreported leakage”. Unreported leakage is described as detectable using proactive leak detection methods, but they generally do not surface. It takes a proactive action to discover these leaks. Therefore, the volume of unreported leaks can often be substantial if proactive leak detection is not occurring (i.e. the utility is not “aware” that the leakage is occurring, and the resulting cumulative leakage can be quite large as a result of the protracted run times).

The third type of real loss is classified as background leakage. This form of leakage is described as the small weeps and seeps present in all pressurized piping systems. The volume of background leakage in a system is dependent on the condition of the distribution system and service connection laterals. The age



and condition of the pipelines is used in the determination of the Infrastructure Condition Factor. The background leakage is a calculated volume that incorporates Infrastructure Condition Factor, miles of main/number of service connections and average operating pressure.

The goal of the component analysis is to understand the volume of each of the three types of real loss. This is important because the primary intervention strategy for most utilities is active leak detection. However, active leak detection is only an effective strategy for one of the sub-components, unreported leakage. If the top-down water balance analysis results in a large real loss volume, most utilities would immediately move to active leak detection, but if most of the leakage is a result of reported breaks and background leakage, the proactive leak detection efforts are likely to yield poor results.

One of the primary results of the real loss component analysis is understanding the potential recoverable leakage in the system. Using this information, an intervention frequency can be calculated providing directions on how often the system should be surveyed. This intervention frequency is an economic-based calculation, considering both the cost of the leak detection survey effort and the “value” of the recovered leakage. Finding the optimum point will result in the economic level of leakage and thus the utility will neither be spending too much on leak detection efforts nor too little, leaving potential recoverable leakage undetected.

The real loss component analysis quantifies the volumes of the reported breaks based on the actual results from breaks. For each system, data was provided by the utility based on their existing data collection and tracking methods. In the summary of each utility, specific recommendations for improvements in these tracking methods, if needed, are identified.

The methodology, as developed, has determined that the leakage to pressure relationship is governed by the following formula<sup>1</sup>:

**Relationships between Pressure (P) and Leakage Rate (L):**  
$$L_1/L_0 = (P_1/P_0)^{N1}$$

As shown, the ratio of leakage after and before pressure change is equal to the ratio of pressure after and before to the N1 power. The N1 exponent is used to represent the impact of pressure on various types of pipes (cast iron, PVC, DIP, etc.) and ranges from 0.5 to 1.5 (rigid to flexible pipe types).

For the background leakage on mains and services, a system-wide ICF of was assigned based on the average age of the distribution system. The background leakage is then calculated for the mainline, service laterals and the service connections. N1 exponent for background leakage is assigned as 1.5 as background leakage is highly sensitive to pressure changes. Background leakage was also attributed to all storage volumes in the system at a constant rate of 0.25 gallons per minute, a default estimate derived from WRF Project 4372A.



For each system, the following data was input into a model for analysis and evaluation:

- 2023 Top-Down Water Audit Inputs:
  - Water Supplied (Adjusted)
  - Authorized Consumption
  - Apparent Losses
  - System Data
    - Length of Mains
    - Service Connections
    - Average Operating Pressure
  - Cost Data
- Capacity of Storage Tanks/Reservoirs
- Infrastructure Condition Factor – selected based on average age of system
- Reported Leakage
  - Documented storage tank overflows
  - Reported breaks by mains size
  - Length of mains by line size
  - Reported breaks by service connection size (less than 1" and 1" and larger)
  - Service connections by size (less than 1" and 1" and larger)
  - Reported break by appurtenance (Hydrants, Valves, Meters & Other)
  - Awareness time
  - Location and Repair time
- Unreported Leakage\*
  - Unreported breaks by main size
  - Length of mains by line size
  - Unreported breaks by service connection size (less than 1" and 1" and larger)
  - Service connections by size (less than 1" and 1" and larger)
  - Unreported break by appurtenance (Hydrants, Valves, Meters & Other)
  - Awareness time (assumed to be 180 days)
  - Location and Repair time

*\*Unreported leakage information that is entered in the model comes from leaks documented from proactive leak detection. This information was requested but there was no data from the District.*

All volumes of real losses are valued at the Variable Production Cost (including the cost to purchase water if applicable). For many systems, only primary costs such as power and treatment chemicals are included meaning the value is simply the cost to replace the water that has escaped the distribution system. It should be noted that secondary costs such as wear and tear on pumping assets, liability claims, and supply expansion costs could also be applicable but require an in-depth analysis beyond the scope of this evaluation. These costs when appropriately added would only increase the value of the recoverable leakage in the economic analysis, thereby justifying a lower leakage target.



**Real Loss Component Review Process**

Real Loss Components:

For the Mount Werner system, reported break data was provided for the year 2023 and included the following relevant data fields:

- Date
- Location
- Pressure Zone
- Asset Type
- Pipe Type
- Pipe Size
- Installation Year
- Static Pressure
- Cost

| Repair Log |                 |               |            |           |                |                    |                       |              |
|------------|-----------------|---------------|------------|-----------|----------------|--------------------|-----------------------|--------------|
| Date       | Location        | Pressure Zone | Asset Type | Pipe Type | Pipe Size (in) | Asset Install Year | Static Pressure (PSI) | Cost         |
| 4/30/2024  | Meadow Lane     | Low           | Main       | Ductile   | 8              | 1995               | 86                    | \$ 11,000.00 |
| 11/3/2023  | Burgess Creek   | Pump          | Main       | Ductile   | 6              | 1974               | 105.6                 | n/a          |
| 10/3/2023  | Storm Meadows   | High          | Main       | Valve     | 10             | 1993               | 87.5                  | \$ 15,100.00 |
| 7/20/2023  | Central Park    | Low           | Main       | Ductile   | 8              | 1990               | 103.5                 | \$ 35,000.00 |
| 12/8/2022  | Temple Knoll    | Pump          | Main       | Ductile   | 6              | 1980               | 82.3                  | n/a          |
| 2/15/2022  | Majestic Valley | Low           | Main       | Valve     | 8              | 2014               | 100                   | \$ 5,000.00  |

*Figure 1 - Mount Werner Repair Log*

Mount Werner’s Repair Log reports a total of 6 breaks, 4 main line breaks and 2 valve breaks. The number of breaks were combined with an average flow rate per leak (adjusted for average operating pressure) and then applied to an average Awareness-Locate-Repair time. This period was assumed to be 3 days total, as some leaks are large and repaired immediately while others are less critical and may flow longer periods of time before repair. Data was not provided by Mount Werner to the specific awareness-location-repair times.

For the unreported leakage, no breaks were assumed since active leak detection has not been performed.

Thus, the difference between the volumetric total of real loss from the water balance and the volumetric total of the background and reported leakage results in the hidden leakage or leaks yet to be discovered. For the purposes of future analysis, this volume of leakage will be assumed to be recoverable.

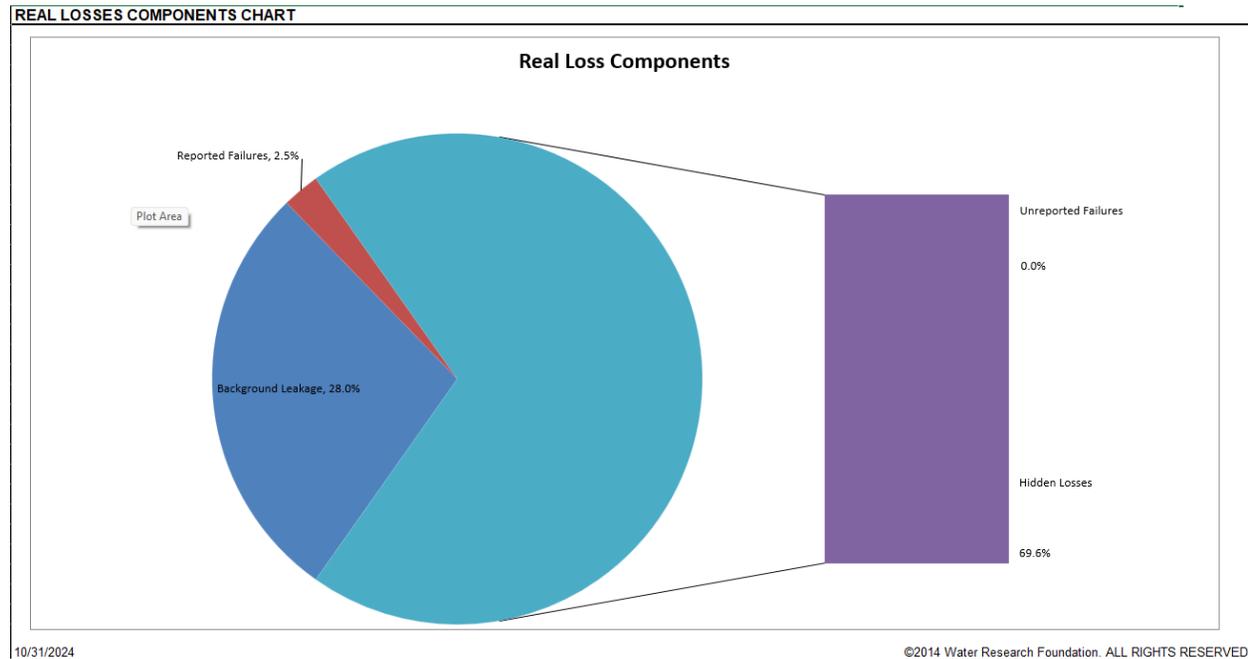


**Outcomes**

The tables below and charts summarize the result of the Real Loss Component Analysis for the overall Mount Werner system.

| System Component   | Background Leakage (MG) | Reported Failures (MG) | Unreported Failures (MG) | Total (MG)   |
|--|-------------------------|------------------------|--------------------------|--------------|
| Reservoirs   | 0.35                    | -                      | -                        | <b>0.35</b>  |
| Mains and Appurtenances  | 7.22                    | 2.22                   | -                        | <b>9.45</b>  |
| Service Connections  | 17.63                   | -                      | -                        | <b>17.63</b> |
| <b>Total Annual Real Loss</b>  | <b>25.20</b>            | <b>2.22</b>            | <b>-</b>                 | <b>27.42</b> |
| <b>Real Losses as Calculated by Water Audit</b>                      |                         |                        |                          | <b>90.14</b> |
| <b>Hidden Losses/Unreported Leakage Currently Running Undetected</b> |                         |                        |                          | <b>62.72</b> |

*Figure 2 - Real Loss Component Analysis Results - Total System*



*Figure 3 - Real Loss Component Analysis Breakdown - Total System*

For improvements to the data tracking of breaks for real loss component analysis, we would recommend tracking the awareness and repair durations in addition to the date of the event. Other enhancements that should be considered include break location specific information such as average pressure, infrastructure integrity, and estimate of water loss.



**Non-Revenue Water Components Breakdown**

Results from the L1V water audit show a clear majority of both volume and values correlating to real losses. Real losses are comprised of the following categories: reported, unreported, and background leakage. Because the real losses are based on the variable production cost, and the apparent losses are based on the customer retail unit charge, both components will stack differently when it comes to the volume of the NRW component and the value that they are worth.

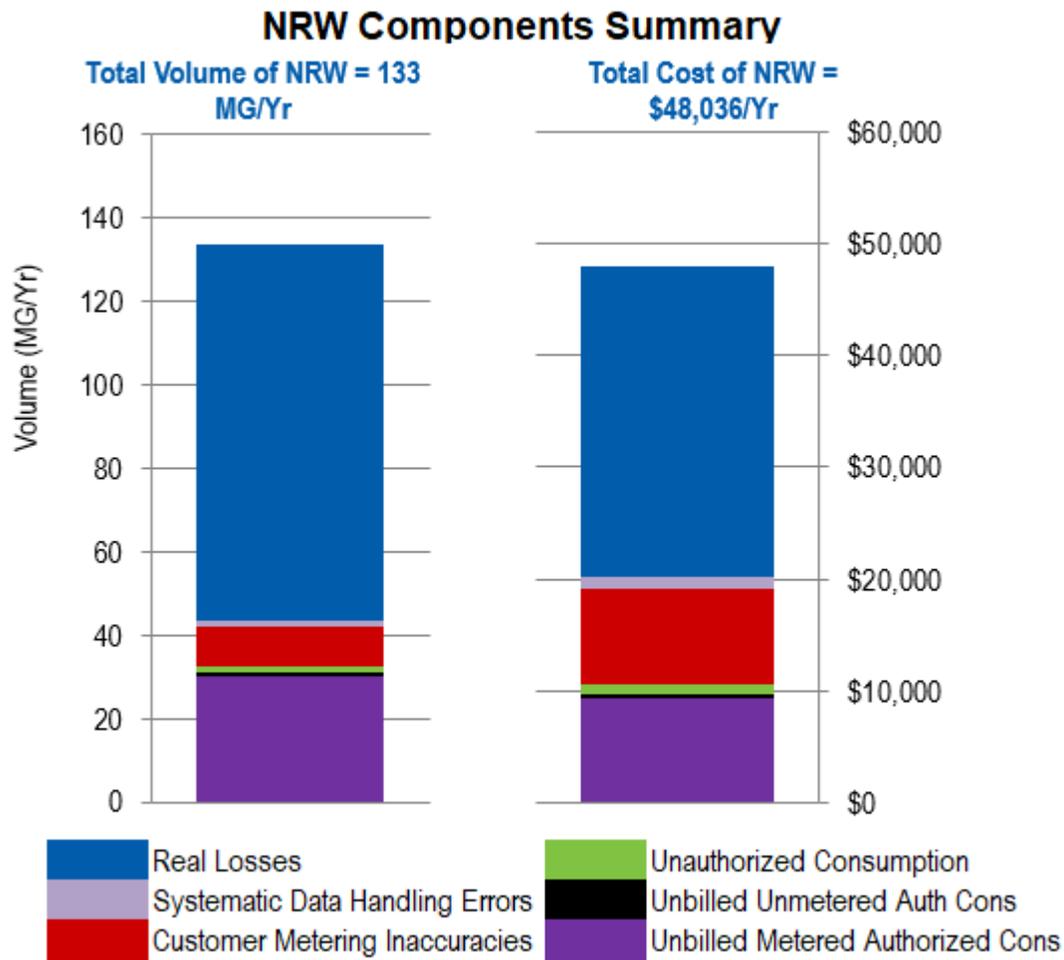


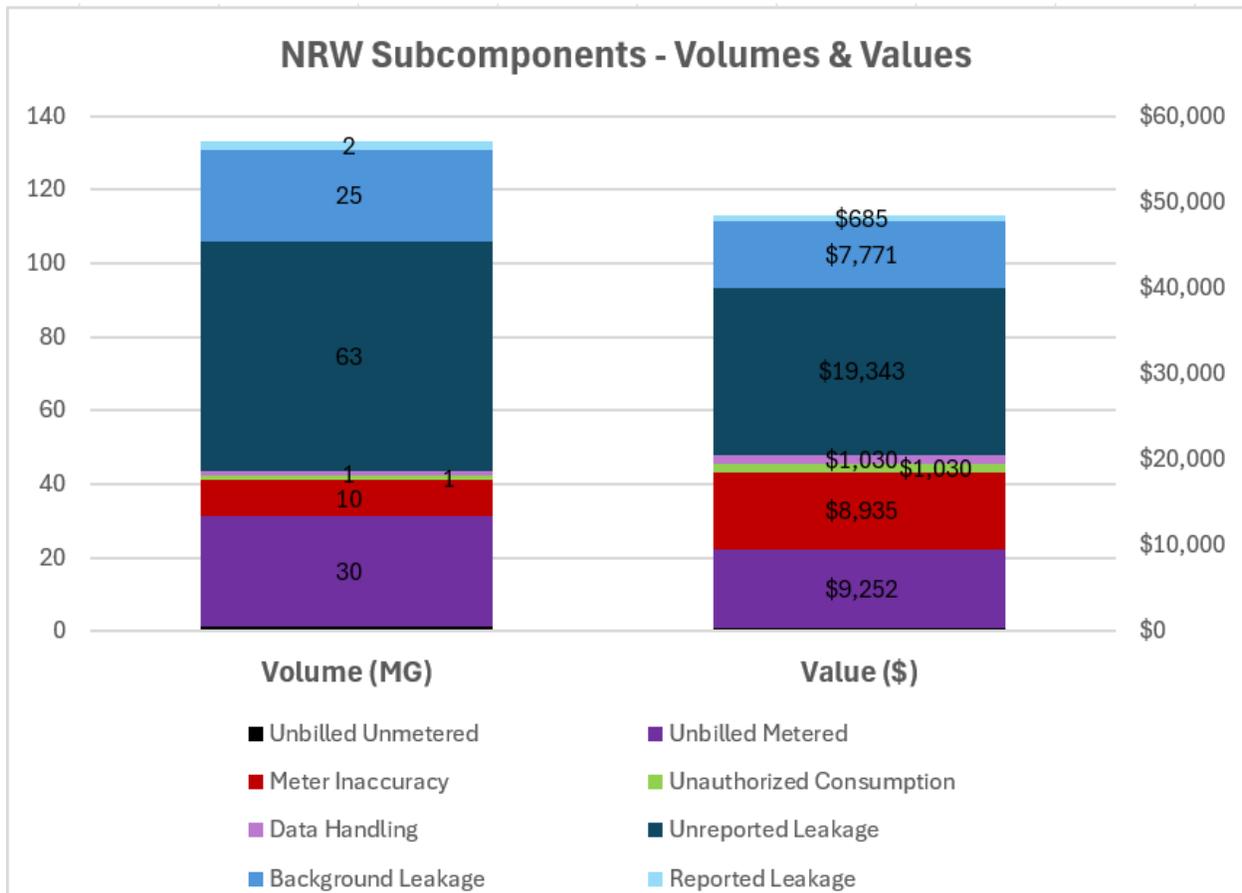
Figure 4 - NRW Components Summary - By Volume & Value



**Non-Revenue Water Subcomponent Analysis**

Upon completion of the breakdown of the NRW Components, a summary of the volumes and values of the NRW subcomponents are shown in Figure 5 and as follows:

The volumes on the left side of the figure show real loss being the largest cumulative component. The largest component of real losses, in both value and volume, is unreported leakage. This impact is comparatively high due to a lack of proactive leak detection, which results in many potential leaks going unnoticed until they are actively reported.



*Figure 5 - NRW Subcomponents Summary*



## Conclusion

From the Real Loss Component Analysis based on the reported break data provided, we conclude that the most water loss is present in real losses and unreported leakage from a financial and volumetric standpoint, with a significant monetary loss in customer metering inaccuracies as well. Based on the results of this detailed assessment, we would recommend the following for continued optimization of losses within the Mount Werner system.

In order to assist with the large percentage of unreported leakage present within the real losses, implementation of proactive leak detection surveys would be recommended. This process would greatly assist in identifying leakage in a timely manner and further validating existing leakage figures. Incorporation of the results of these surveys into the Real Loss Component Analysis will allow for a greater degree of transparency in understanding the system's total leakage.

Regarding reported leakage, in addition to the date of the break event, it would be beneficial to include information regarding the awareness duration and repair duration, so a more focused summary of the total loss can be drawn. Additionally, location specific data including estimated water loss per break, average pressure, and infrastructure integrity can contribute to a better estimate of losses per break.

Meter testing programs would also have a positive impact on revenue generation, as a large portion of the water loss' financial value was placed in meter inaccuracy, which can be accounted for by repair/replacement decisions generated by these programs.