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California's Water Loss Technical Assistance Program

HEIGHTENED AWARENESS OF THE NEED TO CONSERVE WATER IN CALIFORNIA PROMPTED ORGANIZATIONS AND AGENCIES TO JOIN FORCES TO TRAIN URBAN WATER SUPPLIERS ON THE ESSENTIALS OF WATER LOSS CONTROL.

In 2015, AWWA's California-Nevada (CA-NV) Section established the California Water Loss Control Collaborative (2016) to connect stakeholders with a wide range of perspectives on water loss control efforts. The State Water Resources Control Board (SWRCB), the Department of Water Resources, conservation advocacy organizations like the Natural Resources Defense Council, the US Environmental Protection Agency (USEPA), consultant experts, and water suppliers themselves were involved in the Collaborative. Informed by the state of Georgia's Water Loss Technical Assistance Program (Georgia Environmental Finance Authority, n.d.) and a comprehensive understanding of water audit engagement in California, the Collaborative recognized the first years of California Senate Bill No. 555—Urban Retail Water Suppliers: Water Loss Management (SB-555 2015) as a critical opportunity for training, refining data, and establishing a standard of review.

In early 2016, the SWRCB secured funding through USEPA to support the first year of training and water audit submissions with level 1 validation, a process of review that confirms the audit's completeness, identifies evident errors, and confirms data validity grades. AWWA CA-NV was awarded a two-year grant and subcontracted with Water Systems Optimization and Cavanaugh to serve as the project management team (PM team). The CA-NV Section and the PM team developed and implemented the Water Loss Technical Assistance Program (WL TAP) beginning in summer 2016.

The WL TAP set out to train and support urban water suppliers through the first year of SB-555 submission. To do this, the WL TAP

- established a progressive training program that offered customized attention to each participating agency;
- taught the fundamentals of nonrevenue water assessment and use of AWWA's water audit software;
- taught urban water suppliers how to prepare for level 1 validation (Andrews et al. 2016);
- completed a level 1 validation for each urban water supplier; and
- provided the necessary documentation for final submission to the Department of Water Resources.

The WL TAP served to satisfy regulatory reporting requirements, and the process delivered benefits well beyond compliance. The WL TAP accelerated California water suppliers' appreciation of the water audit as a valuable diagnostic. Through dozens of workshops and hundreds of validation conference calls, water agency employees grappled with their data sources, identified areas for improvement, and reflected on the significance of their audit results. Feedback from participants showed that the WL TAP not only helped with the new requirements; it equipped and motivated agencies to focus on future water loss management.

PROGRAM STRUCTURE

To achieve these goals, the WL TAP started with a phase of recruitment and registration, followed by four touch points with participating suppliers. As shown in Table 1, each phase of the program—or "wave"—built on previous waves to establish and reinforce fluency in water audit fundamentals and ultimately validate each supplier's water audit. Within the wave progression, two tracks facilitated the spread of suppliers' experiences in water auditing: the New Learner track for beginners and the Early Adopter track for the more experienced, which provided more customized curricula.

TAP RESULTS

The WL TAP's reach qualifies it as the biggest audit validation effort in the United States to date. Participation in the WL TAP was strong and sustained over the course of the year-and-a-half-long program. In the course of conducting 72 workshops and producing more than 400 validated water audits, more than 1,500 water utility employees participated. Table 2 summarizes total participation in the WL TAP across all agency types. (Only one statewide validation effort—in Georgia—was completed before the WL TAP, in which just over 200 water audits were validated. The only other programs coordinated to date were pilots that had 10–20 utilities participating.)

To isolate those legislatively mandated to submit validated audits,

TABLE 1 Phases of California's Water Loss Technical Assistance Program

Registration Outreach Campaign	Wave 1: In-Person Workshop	Wave 2: Remote Conference Call	Wave 3: In-Person Workshop	Wave 4: Remote Conference Call
E-mail and phone recruitment campaigns Introductory webcast Stakeholder outreach	Reviewed basics of water auditing Introduced goals and process of validation	Conducted two-hour interview to review a recent water audit Practiced validation process, discussing data sources and data validity grade justification	Reviewed wave 2 lessons learned and common water audit improvements Guided supporting documentation preparation	Conducted two-hour interview to review either the calendar year 2016 or fiscal year 2016–2017 water audit Completed a level 1 validation and provided all necessary documentation
New Learner focus	Emphasized AWWA methodology introduction and audit software		Reinforced water audit methodology and performance indicator interpretation	
Early Adopter focus	Emphasized data improvement opportunities		Introduced water-loss-control best practices	

TABLE 2 WL TAP participation by wave

Agency Type	Wave 1	Wave 2	Wave 3	Wave 4
Retailer—*no.*	306	349	338	392
Wholesaler—*no.*	14	14	18	12
Total participation—*no.*	320	363	356	404
Total—%[a]	70	79	78	88

WL TAP—Water Loss Technical Assistance Program

[a]Considers 458 agencies as the total, inclusive of wholesalers and small agencies that participated

wholesaler agencies and smaller systems were excluded from the totals in Table 2. A total of 412 agencies qualified as urban retail water suppliers as of 2017 and were required to submit a level 1 validation water audit per SB-555. For the official validation round in wave 4, 404 water suppliers participated (including some wholesaler agencies and small systems). Of those 412 systems required to submit a level 1 validated water audit per SB-555, 384 successfully participated in the WL TAP. For the first year of a new requirement, the WL TAP provided the necessary water audit review for 93% of the legislatively mandated suppliers.

Overarching program take-aways from the WL TAP include the following:

- Suppliers began the WL TAP with varying experience in water auditing.
- The program was structured as a progressive learning module with training, application of concepts, and reinforcement.
- The WL TAP provided participants with customized attention: suppliers received training aligned with their audit experience in waves 1 and 3, and each supplier received system specific attention in waves 2 and 4.
- A wealth of water audit reference material was developed for participants to enhance learning and emphasize key points.
- Given the repository of references and program material on the WL TAP website, a utility could catch up and join the WL TAP at any point over the course of the program.
- Participation rates were high throughout the program, culminating with 93% of the regulated retail urban water suppliers completing the level 1 validation process.

LEVEL 1 VALIDATED WATER AUDIT RESULTS

The first year of SB-555 validated water audit submissions provides the best snapshot currently available of water loss and utility operations for California retail urban water suppliers.

TABLE 3 Key performance indicator summary for all audits (*N* = 384)

Key Performance Indicator	Median	Mean	Minimum	Maximum
Volumetric				
Water losses per service connection per day—*gal*	34.1	42.7	–43.0	507.0
Apparent losses per service connection per day—*gal*	8.1	10.9	0.5	193.0
Real losses per service connection per day—*gal*	24.9	33.1	–49.5	505.3
Real losses per service connection per day per PSI	0.3	0.5	–0.8	10.1
Infrastructure Leakage Index	1.4	2.1	–3.6	42.2
Financial				
Annual cost of apparent losses—*$*	148,968	450,012	1,824	21,609,190
Annual cost of real losses—*$*	152,432	520,918	–165,244	38,936,077
Nonrevenue water as a percent of total operating cost	3.4	4.2	–0.8	68.2
Data validity score	60	61	36	89

TABLE 4 Key performance indicator summary for audits that passed filters (*N* = 278)

Key Performance Indicator	Median	Mean	Minimum	Maximum
Volumetric				
Water losses per service connection per day—*gal*	40.5	48.6	15.5	188.5
Apparent losses per service connection per day—*gal*	8.6	11.9	1.2	193.0
Real losses per service connection per day—*gal*	31.0	38.2	11.15	172.4
Real losses per service connection per day per PSI	0.4	0.5	0.2	2.5
Infrastructure Leakage Index	1.9	2.4	1.0	10.7
Financial				
Annual cost of apparent losses—*$*	153,789	508,908	3,423	21,609,190
Annual cost of real losses—*$*	219,769	655,181	5,562	38,936,077
Nonrevenue water as a percent of total operating cost	3.9	4.8	0.4	68.2
Data validity score	60	60	37	89

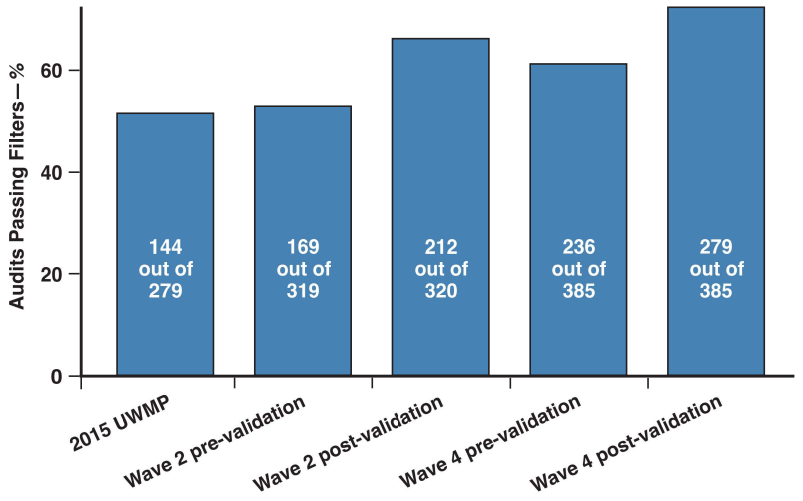
Table 3 summarizes the key performance indicators for the complete data set of level 1 validated audits.

It is important to note that it is not safe to assume each audit's leakage estimation is accurate. Level 1 validation does not guarantee a perfect calculation of water losses for each utility, but it does check that each utility is compiling the best audit possible given their current data sources.

To evaluate the overall quality and consistency of the audit data sets collected over the course of the WL TAP, the PM team used high-level filters to remove audits with suspected errors. The filtering criteria flag audits that report physically impossible results (i.e., negative losses) or audits that posit exceptionally low or high leakage. The data filters applied here are consistent with industry standards developed in Water Research Foundation publication 4372b, *Water Audits in the United States: A Review of Water Losses and Data Validity* (Sturm et al. 2015).

Excluding the filtered audits from database statistics is a conservative measure to avoid potentially erroneous audits. Consider the filter on the Infrastructure Leakage Index (ILI) that flags audits with an ILI below 1.0 or above 20.0 which, while physically possible, signal exceptionally low or high leakage.

FIGURE 1 Filter performance by submission round



UWMP—urban water management plan

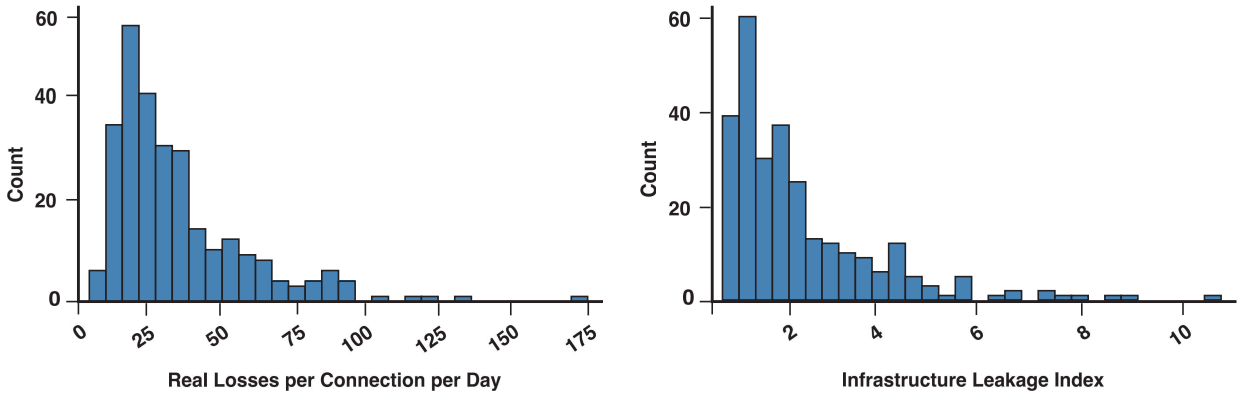
Audit filter results improve as submission rounds progress.

Level 1 validation cannot always discern between audits that rightly reflect exceptional performance and those that have errors requiring advanced validation or correction. Taking a conservative approach, any audits that present outside of the ILI filter range were excluded from the data set analysis presented here. Table 4 summarizes the key performance indicators (KPIs) for the 278 audits that passed the outlier filters.

After filtering the outlier audits, Figure 1 shows that the California water audit data set steadily improved throughout the WL TAP. Specifically, only 46% of California water audits submitted with 2015 urban water management plans passed the filter for outliers before the WL TAP. In contrast, after the WL TAP was implemented, 71% of water audits submitted for SB-555 compliance passed.

The improvements result from the WL TAP's training on audit

FIGURE 2 Distributions of two key performance indicators



The distribution of wave 4 post-validation key performance indicators shows that results vary widely.

methodology and standardized third-party level 1 validation. In fact, the largest improvements were found between pre-validation audits and post-validation audits in waves 2 and 4. By the end of the WL TAP, the water audit data set had the fewest instances of submissions with outlier performance of any in the literature of water loss control to date.

Looking more closely at the individual audits within the data set, each KPI varies widely, serving as an important reminder of the spread of experiences across systems throughout the state. The distributions of two select KPIs, namely (1) real losses per connection per day and (2) ILI, are presented in Figure 2.

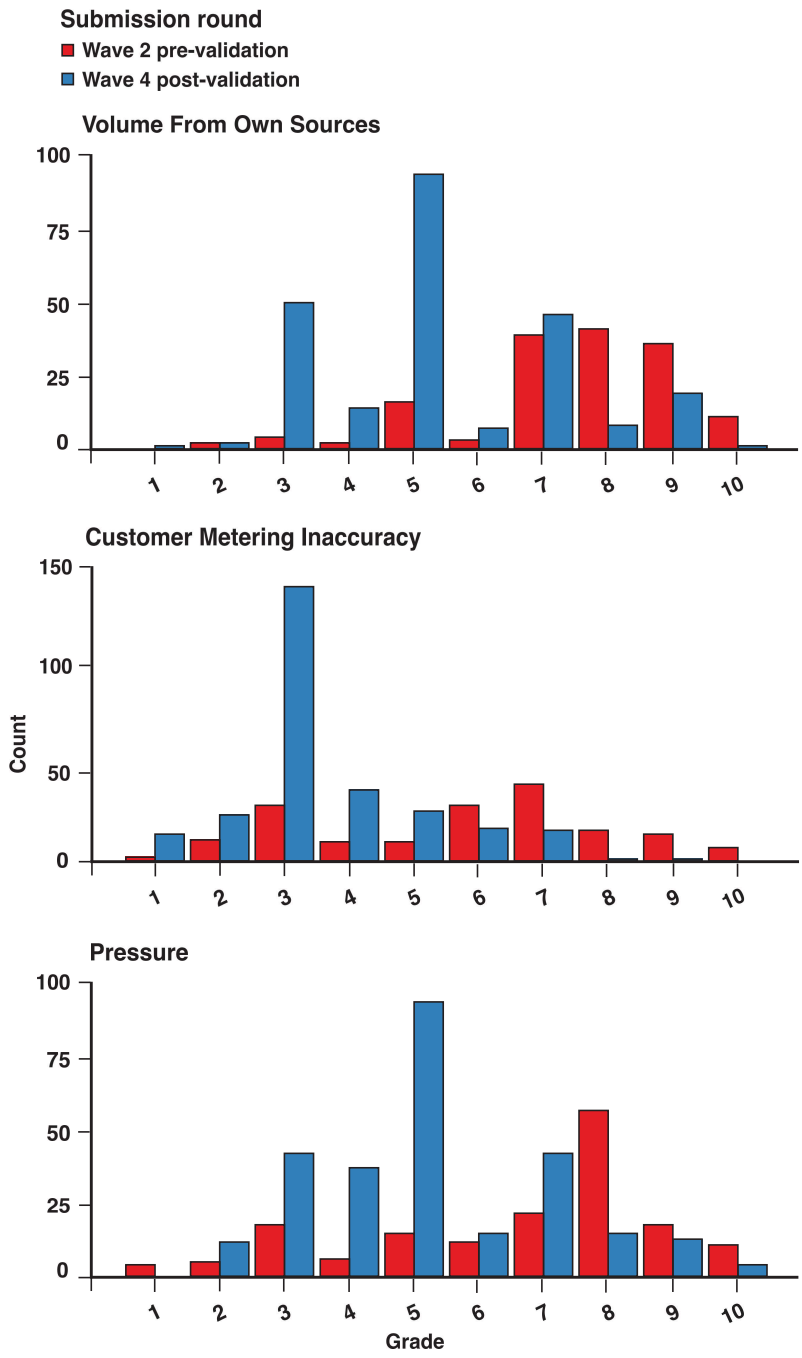
Given the diversity of infrastructure and financial parameters, it is critical to assess each supplier's water loss performance in the context of its unique operations and constraints.

In its breadth of audit review, the WL TAP identified common opportunities to improve water loss assessment throughout the state. Though important for the accuracy of water audit results, the following practices are not commonly practiced:

- Testing and calibrating source meters
- Prorating consumption to align sales volumes with the audit period
- Testing customer meters to inform estimates of apparent loss

As utilities look to improve their understanding of water losses, more engagement with instrument inaccuracy and in-depth data review are good places to start.

FIGURE 3 Distribution of validity grades



CURRENT INDUSTRY PRACTICE TRENDS REVEALED

The distributions of specific data validity grades reveal trends in industry practices that affect the water audit. The assignment of a specific data validity grade (DVG) requires that the urban water supplier meet or exceed all of the grade's criteria. When this grade assignment convention is consistently applied through level 1 validation, limiting factors and industry trends surface.

For example, before validation (considering the pre-validated audits of wave 2), DVGs for Volume From Own Sources input concentrated above 6 from a possible range of 0 to 10. In the process of level 1 validation, verification of the DVG criteria for this input often focused on the extent and frequency of meter testing. To receive a grade of 6 or higher for the Volume From Own Sources input, a supplier must volumetrically test or electronically calibrate its meters annually.

Figure 3 shows that after validation, the most commonly assigned grade for the Volume for Own Sources input is 5, revealing that most suppliers do not perform annual volumetric testing or electronic calibration on their source meters.

Another trend surfaces in the distribution of DVGs for the Customer Metering Inaccuracy input. To receive a grade of 4 or higher, a supplier must proactively conduct accuracy tests for a portion of its customer meter stock. After validation, most suppliers received a DVG of 3 (Figure 3). These suppliers likely do not conduct any proactive customer meter tests, and the Customer Meter Inaccuracy input must be estimated.

Figure 3 also shows another operational practice trend in the distribution of DVGs for the Average Operating Pressure metric. To receive a grade of 6 or higher, a supplier must collect pressure data within a zone, not just at the zone's boundaries, to calculate an average. This requires pressure-logging throughout the distribution system. Most suppliers received a 5 or less after validation, indicating that field-pressure data collection is limited.

All three of these trends—lack of source meter calibration/testing, lack of customer meter testing, and limited pressure data collection—directly affect water audit results. These trends serve as important qualifications on data sources and the resulting certainty of the audit results.

Overarching take-aways from the level 1 validated audits are summarized as follows:

- The WL TAP eliminated instances of incomplete audits and reduced the number of outlier audit results.
- The WL TAP provided consistent application of the DVG criteria.
- Common DVG assignments reveal common operational practices that directly affect water audit results (i.e., lack of proactive meter testing).
- Though the WL TAP improved many audits, level 1 validation often only identifies sources of inaccuracy and cannot correct for all uncertainty in water audits.

QUALIFICATIONS OF WATER AUDIT RESULTS

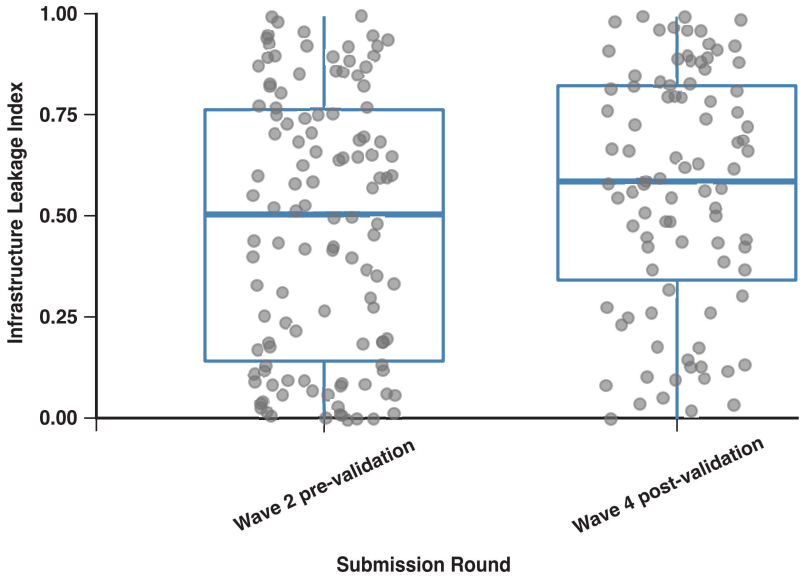
Data validity score (DVS) significance. The process of assigning a DVG for each input in the audit is an important opportunity to discuss practices around data management and instrument accuracy. The conversation and the resulting grade assignment often revealed areas for better data collection and management.

Though it is tempting to conclude that a higher composite DVS implies better audit data, the final data set challenges that interpretation. Consider the 12 audits that show negative losses after level 1 validation, which undoubtedly contain errors that could not be resolved in the level 1 validation review. These audits show DVS ranging between 41 and 77. In the end, the DVS communicates the level of engagement in data review and instrument accuracy testing, but looking at the DVS alone as an indication of audit accuracy is not appropriate.

Consecutive-year audit results. The WL TAP often worked with two audits: one year's audit in the wave 2 practice validation and a more recent audit in the wave 4 formal validation. For those suppliers that participated in both rounds of reviews, the two audits provide insight into year-to-year consistency, at least in the first few years of water audit compilation. Variation in audit results is expected from year to year because water losses are dynamic. However, large swings in audit results from year to year rarely reflect true water loss changes. Instead, consecutive audits with a dramatic change in results typically indicate that the supplier is wrestling with data source errors.

Of those 305 suppliers with two consecutive audits, 43 of them—14% of the group—showed a change in the real-losses performance indicator of greater than 15 gal/connection/day.

FIGURE 4 Distribution of ILIs between 0 and 1 before and after validation



ILI—Infrastructure Leakage Index

This serves as an important caution: it can take many years of audit compilation and refinement to develop a consistent and meaningful assessment of water losses.

Persistence of ILI below 1. An ILI below 1 suggests that the supplier's current annual real-loss volume is less than the unavoidable annual real losses modeled for the system. In other words, these audits present an exceptionally low leakage volume.

After level 1 validation, 108 audits reported an ILI below 1, and Figure 4 shows the distribution of ILI results below 1 before and after validation. For some agencies, review of summary documentation and double-checking the audit methodology changed the audit inputs to show a more realistic leakage volume. However, for many agencies reporting an ILI below 1, the process of validation did not reveal any errors in methodology or immediate corrections. In a handful of cases, application of the audit methodology (i.e., acknowledging customer meter under-registration or estimating some non-zero volume of operational use) shifted ILIs below 1 after level 1 validation.

Unfortunately, there is no way to distinguish audits that accurately report an exceptionally low leakage volume from those that are erroneous. As a measure of caution, the filtering process flags audits that present an ILI below 1 to suggest potential error. After multiple years of audit submissions and improved accuracy, the persistence of ILIs below 1 warrants further examination and research.

MOVING FORWARD

Audit validation program. The WL TAP facilitated the biggest audit-data-collection effort in California to date. Across the training and validation sessions, the WL TAP instilled a new appreciation for AWWA's water audit software and piqued interest in the benefits of water loss monitoring and management. To sustain attention and encourage water audit improvement, it will be important to maintain the following strengths.

Consistency. The first year of level 1 validations was unique because the WL TAP offered a streamlined process for all participants. In the future, efforts to standardize and maintain clear expectations of level 1 validation across different validation providers will be essential (through checkpoints like the Water Audit Validator certificate program). It will also be critical for the state to ensure that quality control measures are in place.

Transparency. The PM team emphasized the importance of transparency in the water audit process. For a water audit to be useful, the inputs must be as accurate as allowed by the data available, and the DVGs must reflect data collection and maintenance protocols as actually practiced. The PM team built trust over the course of the program to foster candid, open conversations between utility staff and the validator. These levels of transparency are critical to a validation program's success.

Learning. Participants especially appreciated that the reporting requirement was so well supported by training. In addition to the final round of audit review, the WL TAP offered opportunities for utility employees to refine their water audit expertise, consider peers' experiences, and evaluate areas for improvement. Future training sessions should encourage continued attention and care to water auditing and water loss control while also allowing new staff to get up to speed. It is important that training continue for water suppliers of all sizes.

WATER LOSS PROGRAMMING CONSIDERATIONS

Water audit best practices are being adopted across the state of California, and each utility has stepped up to assess its water loss baseline; now, practical discussions of where to improve data, how to empower proactive management, and how to cost-effectively reduce water losses can begin. With respect to these efforts, the WL TAP's experience with the first year of validations reveals important considerations for ongoing training and technical assistance.

Uncertainty remains. The first year of level 1 validated data should serve as a starting point. An accurate audit requires constant refinement and ongoing study of data sources describing production, consumption, and meter inaccuracy. Many suppliers are now identifying potential sources of inaccuracy, but data source improvement takes time.

Proactive opportunities exist. In discussions with each supplier in the validation sessions, the PM team inquired about current water loss control activities. All suppliers described programs of leak repair (responding to known failures), and many have active main-replacement programs. However, a minority of suppliers proactively survey or otherwise manage leakage. Only a quarter of the participating suppliers described any form of proactive leak detection work.

Context matters. Given the diversity of infrastructure and financial parameters across California's water suppliers, it is critical to assess each utility's water loss performance in the context of its unique operations and constraints. This is especially important to consider, as water loss target setting begins in upcoming years. SB-555 states that the performance benchmarking process will begin in 2019. Further, water loss control is a highlighted component of Executive Order B-37-16, "Making Water Conservation a California Way of Life." Especially as water loss management becomes a pillar of conservation efforts across the state, it is important that the WL TAP provide a strong foundation of training and validated water audits.

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