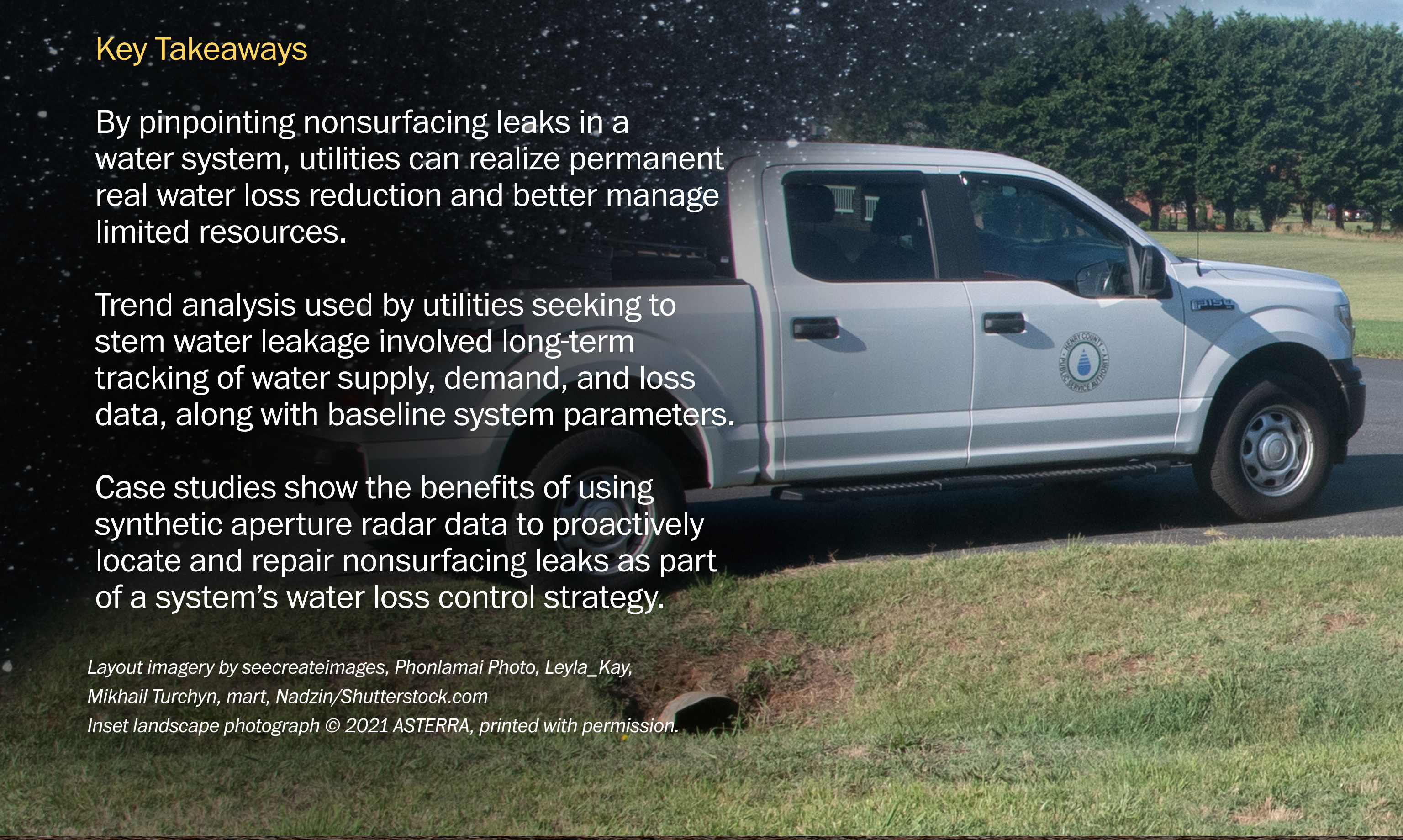
MANAGING NONSURFACING LEAKS:

The Key to Real Water Loss Reduction

Paul Gagliardo



Key Takeaways

By pinpointing nonsurfacing leaks in a water system, utilities can realize permanent real water loss reduction and better manage limited resources.

Trend analysis used by utilities seeking to stem water leakage involved long-term tracking of water supply, demand, and loss data, along with baseline system parameters.

Case studies show the benefits of using synthetic aperture radar data to proactively locate and repair nonsurfacing leaks as part of a system's water loss control strategy.

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Linear underground assets, which include transmission and distribution mains and service lines, are the backbone of North America's drinking water system, a true engineering marvel of the 20th century. However, many miles of pipeline are older than their design life, and in its latest report (2021 Report Card for America's Infrastructure), the American Society of Civil Engineers (ASCE) gave US drinking water systems a grade of C-minus (on a scale of A to F). The ASCE 2021 Report Card also reported an average leakage rate, or real water loss, at approximately 16%, with 39 billion gallons of water delivered each day and a loss rate of 6 billion gpd.

A comprehensive study published in 2018, *Water Main Break Rates in the USA and Canada*, reported a 27% increase in main breaks between 2012 and 2018—from 11 breaks per 100 miles to 14 breaks per 100 miles. The utility survey also found that approximately 0.8% of the pipe mains are replaced each year, resulting in a 125-year life requirement from an asset that has a 50-year design life. Asset management tools aid in capital planning for pipe replacement projects, but budgets are limited, and such projects have lengthy lead times.

Leaking pipes can be repaired at lower cost and in a timelier fashion if the leaks can be pinpointed within the system. This can be challenging because many leaks do not surface; however, utilities have several approaches to identify and quantify the extent of leakage in their systems, and on the basis of this information they can develop proactive solutions that meet their unique needs. The basic approach includes the following steps:

- Collect water supply, delivery, usage, and loss data
- Use various technologies to identify and repair nonsurfacing leaks in pipes
- Compare system results with known benchmarks, and document performance before and after the intervention
- Determine the cost–benefit ratio of these interventions

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Henry County Public Service Authority

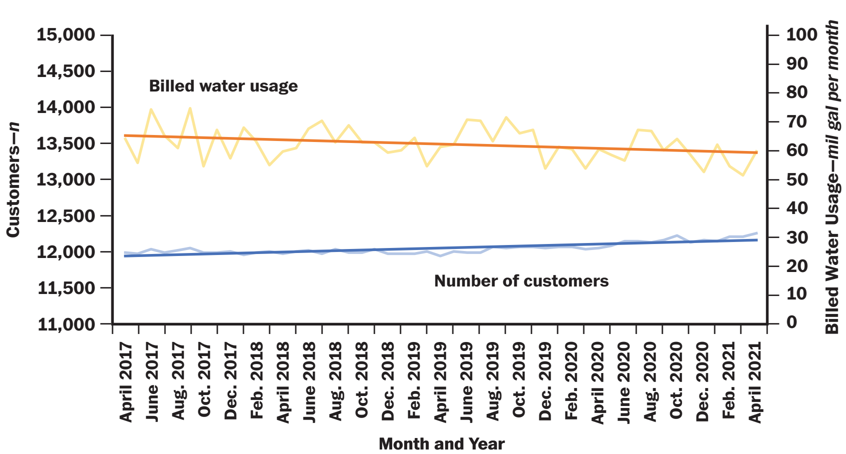
Henry County Public Service Authority (PSA) in Virginia is an example of a water utility that has followed these steps. Henry County PSA is a small utility located in south central Virginia. Its system is made up of 372 miles of pipelines and serves approximately 12,000 connections.

Since 2017, Henry County PSA has been collecting and analyzing its water distribution data. Table 1 presents the raw data that is collected and used to calculate other system parameters.

Henry County PSA's system has been in steady state for the previous four-year period. The number of customers has remained the same as has the amount of customer billed water usage, as shown in Figure 1. There have been no major changes in system operating pressures, plant losses, flushing volumes, tank losses, or fire protection usage. Only 20 miles of new pipe mains have been added to the system during this period.

Between April 2017 and April 2019, the real water loss percent rose from 22% to 32.3%, the real water loss volume per connection

Henry County PSA Customers and Billed Water History



PSA—Public Service Authority

Figure 1

per day from 53 to 85 gpd, and the real water loss volume from 18.9 to 30.5 million gallons per month. Figure 2 shows the real water loss trend over this two-year period.

The real water loss shown in Figure 2 was calculated primarily from the finished water and billed water usage raw data. The month-to-month values vary because the billed water meter readings do not align exactly with the beginning and ending of each month, while the finished water volumes are exact monthly values. Over this period, an increasing trend in greater water loss is apparent, nonetheless.

Henry County PSA did not have a proactive leak detection program during this period, but it responded to surfacing leaks via work orders. Annually, between 12 and 15 main breaks per 100 miles of pipe were identified over this period, which was consistent with the previous benchmark range of 11 to 14 breaks per 100 miles. The real water loss continued to increase while all surfacing leaks were repaired as they were identified; consequently, managing nonsurfacing leaks is the way to reduce real water loss.

Analyzing 20 of ASTERRA's projects returned an average of 80 nonsurfacing leaks per mile, independent of nonrevenue water (NRW) percent and system size. This is almost six times the number of surfacing main breaks that an average system experiences. The number of nonsurfacing leaks is based on the volume of real water loss in a system and uses an average of 3.2 gpm per leak. This value was developed from an analysis of a cohort of 1,858 traditional boots-on-the-ground (TBOTG) leak detection projects performed by Utility Services Associates between 2009 and 2018. This database was used to develop performance metrics for traditional leak detection methodologies that included data on each individual project, including the number of leaks found, type of leak, and estimated leak size. Figure 3 shows the breakdown of leaks found by

Henry County PSA Water System Data Parameters

Raw data	Raw water Finished water Plant losses Total customers Billed water usage Bulk water usage Flushing volume Tank losses Stolen water Fire protection volume Length of water mains Work order leaks
Calculated parameters	Total authorized usage Nonrevenue water—volume and percent Unbilled authorized consumption Unidentified real water losses Real water loss per connection per day Loss per length of main

PSA—Public Service Authority

Table 1

Real Water Loss Per Month Before Intervention

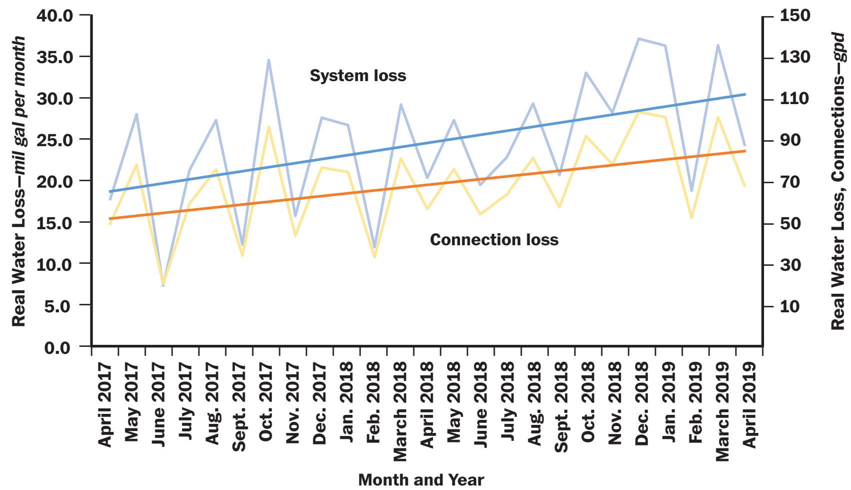


Figure 2

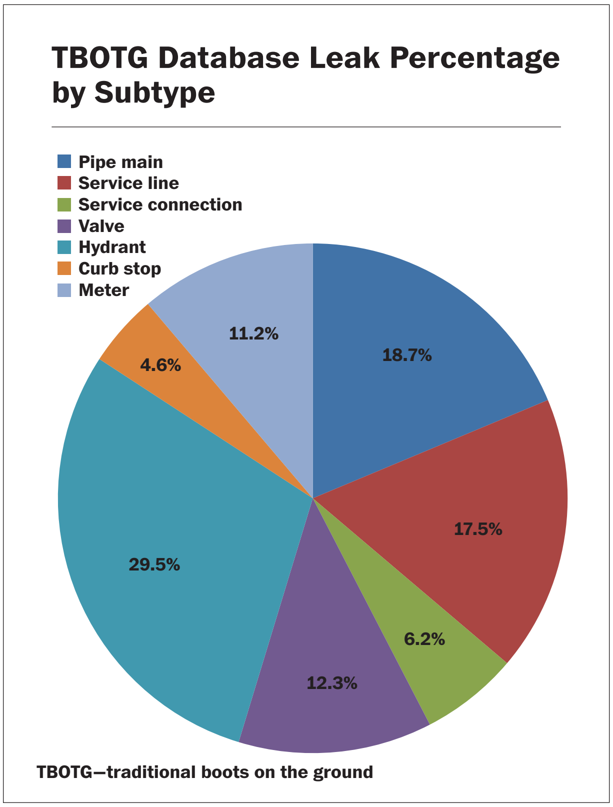


Figure 3

subtype. Customer-side leaks are not included in this analysis, as they do not contribute to NRW.

The leak sizes estimated by this cohort of projects are lower than those suggested by AWWA Manual M36, *Water Audits and Loss Control Programs* (fourth edition). Both sets of data are listed in Table 2. M36 did not report on the size of leaks from curb stops or meters. There are typically many more nonsurfacing leaks than surfacing main breaks, so to have a lasting reduction of real water loss, these hidden leaks must be found and repaired.

In the first quarter of 2019, Henry County PSA retained an external service provider (ASTERRA/Utilis) to provide leak pre-location service that employs a process using synthetic aperture radar (SAR) to locate subsurface leaks of potable water from space. Water sources, such as leaking pipes, lakes, or swimming pools, reflect electromagnetic waves both below and above ground level. Microwave radar is emitted from a satellite and used to detect the signature of wet soil underground with a potable water indication.

Every material has inherent electric properties, a dielectric constant creating an identifying marker; SAR data can be used to distinguish between different backscatter properties. Drinking water–saturated soil has a specific signature in SAR data that can be isolated to find potable water leaks. To identify the water-related backscatter, all other signals (e.g., electromagnetic noise reflection) are filtered or removed from the scan. The result is a geographic information system–based map showing points of interest (POIs) that are likely potable water pipe leaks. This map of POIs and associated likely leaking locations (LLLs) is then used to direct the TBOTG field inspection teams to confirm and pinpoint the leak location.

The POIs are the centroid of an LLL zone within which the field crews focus their attention. The LLL zone stretches up to a 300-foot radius from the POI. All pipes within the LLL zone, typically 1,100 linear feet, are inspected for leak noises using acoustic devices. All the listening points (e.g., meters, valves, curb stops, hydrants) within the LLL zone are usually accessed to search for leak noise. With the SAR system, the imaging does not locate the point in the pipe that is leaking but instead senses the leak's result—wet subsurface soil. Twenty-six percent of the time, an LLL exhibits more than one leak. Fully 60% of all the leaks found in North America pursuant to the satellite pre-location direction were nonsurfacing leaks.

> **There are typically many more nonsurfacing leaks than surfacing main breaks, so to have a lasting reduction on real water loss, these hidden leaks must be found and repaired.**

Duarte, Calif.

A study funded by the California Energy Commission and published in June 2021, *Demonstrating Innovative Leakage Reduction Strategies*, analyzed the performance of satellite-directed leak detection and correlating continuous acoustic monitoring technology. In a study conducted at the California American Water system in Duarte, Calif., a satellite survey of the entire 100-mile system was performed each month for a period of 12 consecutive months. The satellite survey identified more than 500 POI/LLLs during the study period.

Only 29% of the POIs were field inspected by the TBOTG crews because of resource constraints. Overlapping POIs were identified pursuant to the monthly scans, which resulted in the observation of leak clusters. One such cluster is shown in Figure 4. These clusters uncovered both spatial and temporal patterns in the evolution of leaks in this system.

The temporal relationship between identifying POIs and finding leaks is also shown in the timeline. POIs were identified months prior to leaks being found or surfacing, which implies that the ASTERRA satellite technology can successfully pre-locate nonsurfacing leaks many months before they surface, and results such as this are what helped this technology receive AWWA's 2021 Innovation Award.

SAR Analysis of Henry County PSA

Two satellite surveys of the Henry County PSA service area were conducted in the spring of 2019. The subsequent field inspection programs were executed between April 2019 and December 2020 by Henry County PSA crews. A total of 311 leaks were found through field inspection of all the 684 POI/LLLs identified by the satellite imagery. Of the 311 leaks found within these POI/LLLs, 52 were on the customer side of the meter, 107 were found via work orders, and 152 were found by investigation of the TBOTG leak detection crews. The work order leaks were surfacing leaks. Of the 152 leaks found by the TBOTG crews, 17 were surfacing and 135 were nonsurfacing.

Real water losses found by this program equaled 1.03 mgd on the basis of a total of 259 NRW leaks being identified; this was based

Estimated Leak Flow Rate by Subtype

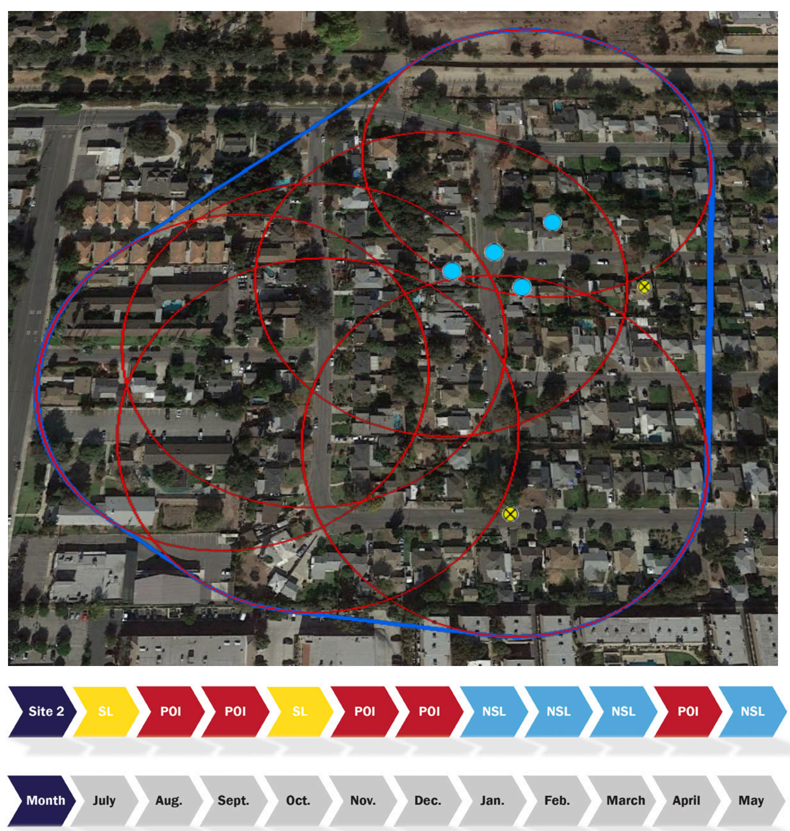
	Main	Service Line	Service Connection	Valve	Hydrant	Curbstop	Meter
TBOTG	9.0	3.3	1.6	6.7	1.0	0.7	0.4
M36	10.4	6.9	6.9	6.9	3.5	NIC	NIC

M36—AWWA Manual M36, NIC—not included, TBOTG—traditional boots on the ground

Flow rate is measured in gallons per minute.

Table 2

Leak Cluster Map and Associated POI, SL, and NSL Timeline



LLLs—likely leaking locations, NSL—nonsurfacing leak, POI—point of interest, SL—surfacing leak

Red circles show the individual POI/LLLs, blue lines show POI cluster areas, purple lines show overlap of POI cluster areas with individual POIs, blue dots show nonsurfacing leaks, and yellow markers show surfacing leaks.

Figure 4

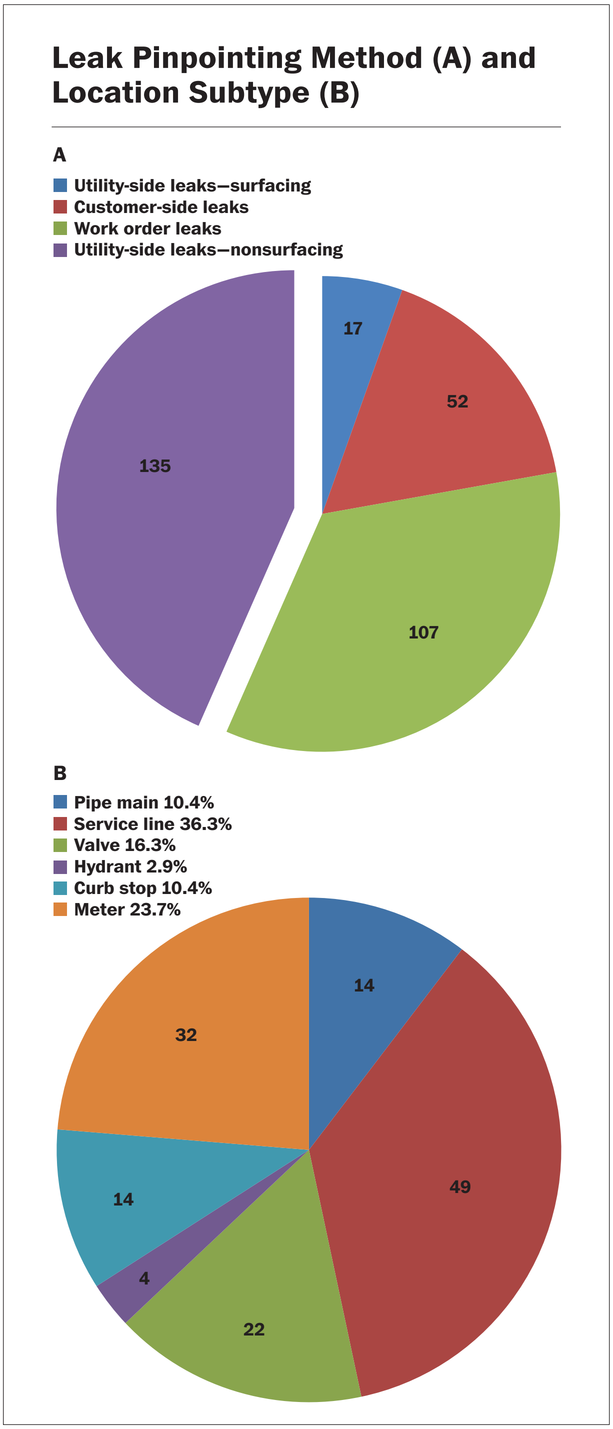


Figure 5

on all utility side leaks found within the POI/LLL areas, including leaks found via work orders. Customer-side leaks are not included in the real NRW loss analysis.

Following the discovery and repair of leaks through this approach, the system's real water losses have declined from 30.5 million gallons per month in late 2019 to 24 million gallons per month in April 2021.

Leaks found through work orders were not found during the normal course of field inspections pursuant to the POI/LLL list delivered to Henry County PSA but were located within the POI/LLL zone identified by the satellite image.

Out of the 152 utility side leaks found by directed field inspection, 135 were nonsurfacing. The nonsurfacing utility side leaks were categorized by subtype as follows:

- 14 on pipe mains
- 49 on service lines
- 22 on valves
- Four at hydrants
- 14 at curb stops
- 32 on meters

Figure 5 shows the breakdown of leak data by method (part A) and location (part B). Note that these are leaks that would not have been found except for the satellite program.

Following the discovery and repair of leaks through this approach, the system's real water losses have declined from 30.5 million gallons per month in late 2019 to 24 million gallons per month in April 2021. The real water loss per connection per day declined from 85 to 66 in this same period, as shown in Figure 6.

The 135 nonsurfacing utility-side leaks accounted for 462 gpm, or 665,000 gpd, of real water loss. This is the volume of real water loss that would not have been identified by historical methods such as work order identification of surfacing leaks. This volume is consistent with the reduction seen in Figure 7 of 600,000 gpd based on the no-project alternative. The no-project alternative is the case in which no leak detection intervention is deployed and the increasing trend of real water loss continues; it's estimated this would have resulted in a real water loss of 42 million gallons per month in April 2021. The actual loss rate following this program was only 24 million gallons per month, a virtual reduction of 18 million gallons per month or 600,000 gpd. The TBOTG database leak size corresponds more closely to the real loss reduction calculated than does the estimated loss rate figures based on AWWA M36, which estimated that the nonsurfacing, utility-side leaks found at Henry County PSA would have resulted in 650 gpm of real water loss, or 935,000 gpd.

Benchmarking to Improve Water Loss Control

Utilities should track water supply, treatment, delivery, usage, and loss data so they can benchmark their performance and determine when interventions are required. This information is also

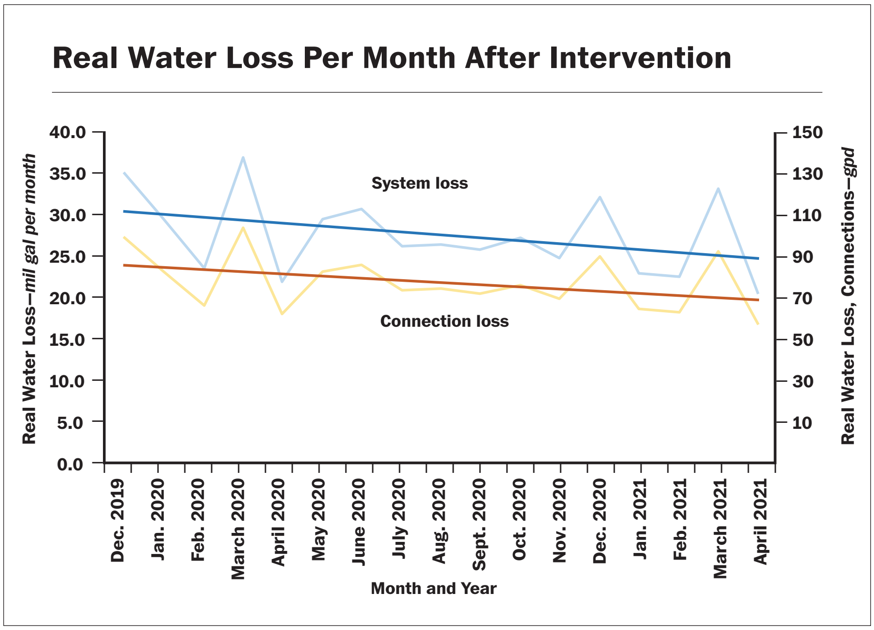


Figure 6

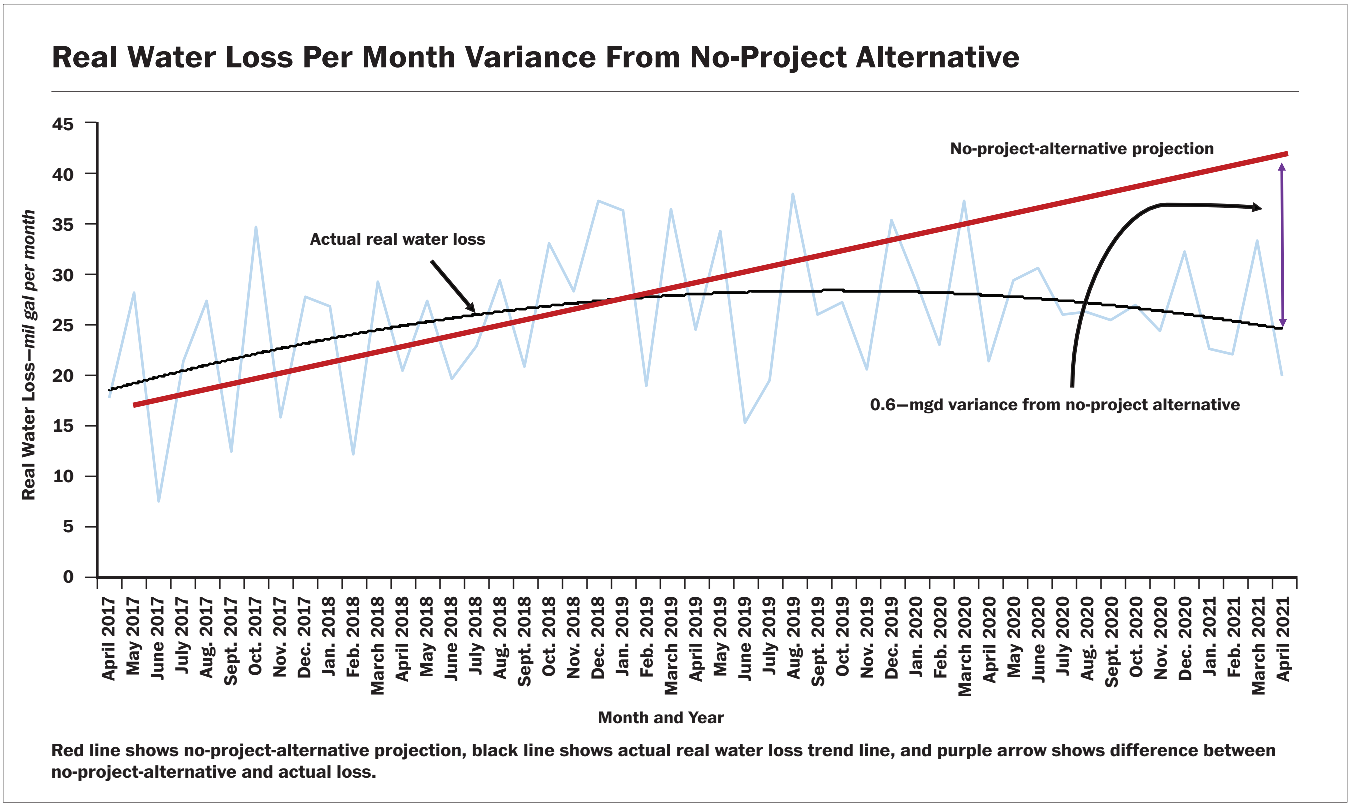


Figure 7

useful in analyzing the effect of an intervention to determine its technical efficacy and impact on real water loss reduction.

Benchmarking leak detection methodologies allows for the selection of best practices to achieve the goals of the utility. This also provides historical data against which utility performance can be compared. The detailed water loss tracking report maintained by Henry County PSA staff allows this analysis to be performed with a high level of certainty and accuracy. The conclusions validate and corroborate the trend analysis of the water loss tracking data, the leak type and size assumptions, and the nonsurfacing leak analysis.

Finding and repairing nonsurfacing leaks is imperative to lasting real water loss reduction. Technologies that can identify nonsurfacing leaks should be employed, along with accurate pinpointing methodologies, to ensure nonsurfacing leaks are found.

About the Author

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https://doi.org/10.1002/awwa.1828

AWWA Resources

- Developing Quebec's Water Efficiency Strategy. Kachani Y, Laneuville M, Jernigan W. 2020. *Journal AWWA.* 112:6:56. https://doi.org/10.1002/awwa.1519
- Control Apparent Losses to Optimize Revenue Capture. Van Arsdel JH. 2021. *Opflow.* 47:6:16. https://doi.org/10.1002/opfl.1558
- Applying Lessons Learned From Water Audits. Wrage M. 2021. *Journal AWWA.* 113:3:77. https://doi.org/10.1002/awwa.1694

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