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ANNUAL REPORT

BENCHMARKING LEAK DETECTION IN THE DIGITAL AGE

A Comparative Analysis of Methods in 2023

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Executive Summary

Leak detection technology has evolved significantly since the days of diving rods and listening sticks. Handheld correlators led the way to fixed-based continuously active acoustic systems which gave way to satellite inspection technology.

This benchmark report compares these various methods to help utilities make informed choices. Both quantitative and qualitative metrics are used, including leaks found per crew day, leaks found per mile inspected, and cost per leak found, as well as capital and operational expenses, flexibility, turnaround time, testing frequency, complexity, and performance.

With the detection and repair of leaks in potable water systems becoming increasingly critical due to supply shortages resulting from overuse and climate change, traditional point-to-point leak inspections often fall short, frequently overlooking clustered leaks within water systems. In contrast, satellite-based leak detection technology excels at identifying high-density leak areas, leading to more efficient crew deployments and higher returns on investment.

This approach reduces real water losses, conserves energy, and lowers greenhouse gas emissions. Therefore, utilities can optimize their leak detection efforts by adopting these innovative approaches, contributing to sustainability, resource preservation, and environmental conservation. This benchmark report can be a valuable resource for utilities seeking to enhance their leak detection strategies.

Introduction

As water scarcity becomes a pressing concern worldwide, proactive leak detection programs have become crucial. These programs are now at the forefront of water management strategies, combating challenges related to aging infrastructure, rising energy costs, and water affordability.

According to the 2018 Utah State University report titled 'Water Main Break Rates in the USA and Canada: A Comprehensive Study,' which surveyed over 300 utilities and covered 200,000 miles (321,869 km) of pipelines, break rates have increased by 27% in just six years since the previous study. As of 2018, there were 14 breaks per 100 miles per year (9 breaks per 100 km per year), with cast iron and asbestos cement pipes experiencing an alarming 40% increase in break rates over the same six-year period. As pipes age, their susceptibility to breaks tends to rise, exacerbating the situation.

Furthermore, the escalation of energy prices directly impacts water supply costs, encompassing treatment and pumping expenses. Baseline tap water costs about $5.00 per 1000 gallons (1.50 EUR per cubic meter) and rises proportionally with usage, reaching over $10 per 1000 gallons. Notably, water rates in the United States have been steadily increasing at an annual rate of 5% since the early 2000s.

This paper explores the latest leak detection technologies, offering a comparative analysis of advanced methods for 2023 and beyond.

Advancing Water Sustainability Through Loss Reduction

Water utilities are facing a growing need to curb real water losses from their systems. The 2021 City Water Optimization Index Report reviewed water systems in 51 cities and found that over half of them experienced non-revenue water levels of at least 25%, with a dozen cities facing non-revenue water (NRW) levels of over 40%. Many of these cities are situated in high water stress regions. According to the United Nations, a territory that withdraws 25% of its renewable freshwater resources is classified as 'water stressed.' Moreover, projections from the World Resources Institute for 2040 indicate that this problem is expected to worsen. According to the Economist Intelligence Unit, 44 countries are projected to confront either 'extremely high' or 'high' water-stress levels by 2040.

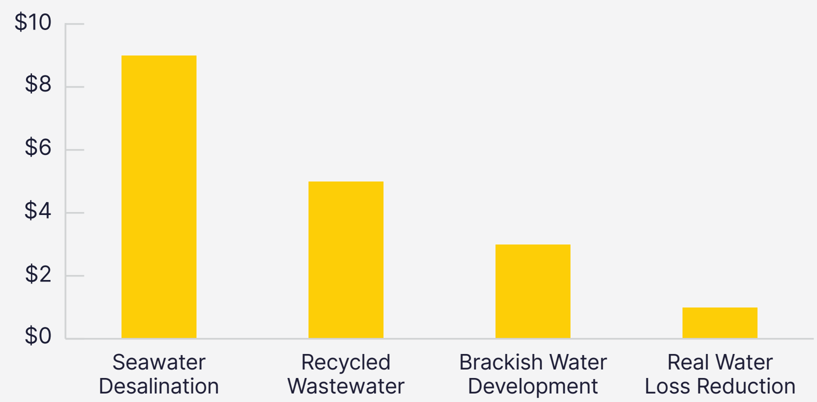
The need for water utilities to address real water losses aligns closely with the United Nations Sustainable Development Goals (SDGs) and holds significant environmental implications for water sustainability. Reducing real water losses promotes responsible and efficient water use, achieving Goal 6, which aims to ensure clean water and sanitation for all. Additionally, it contributes to Goal 13, which aims to combat climate change by reducing the amount of potable water lost to leaks as droughts and heatwaves intensify and by minimizing the amount of energy used and the CO2 emitted to process water that replaces what is lost. Consequently, mitigating real water losses plays a critical role in securing a sustainable water future for cities worldwide.

The Cost-Effective Approach to Water Loss Reduction

While reducing real water losses can help water utilities address increasing non-revenue water levels, this approach is often overlooked when utilities seek additional water supply. When the current supply source is marginalized and cannot be increased, utilities usually consider alternatives like developing and treating off-spec water, recycling wastewater, or resorting to seawater desalination.

However, these options require extensive planning and large capital investments. Reducing real water losses is not only more cost-effective but it also addresses issues sooner since it can be implemented almost immediately. The cost of seawater desalination is $9.00 per 1000 gallons (2.61 EUR per cubic meter), the cost to recycle wastewater is $5.00 per 1000 gallons (1.45 EUR per cubic meter), and the cost to develop brackish groundwater is $2.50 per 1000 gallons (0.72 EUR per cubic meter). In contrast, the cost to find and fix leaks is only $1.30 per 1000 gallons (0.38 EUR per cubic meter). Therefore, opting for real water loss reduction can optimize water management while saving resources and money.

Unraveling the History of Leak Detection Methods



Now that the importance of water loss reduction has been established, it is essential to assess the methods used today, primarily leak detection.

Most utilities will repair a leaking pipe when the water surfaces and becomes visible, as it is relatively easy to identify the leak location and conduct repairs. However, detecting and pinpointing leaks that do not surface is a more challenging task.

District Metered Areas (DMA) was one of the first methods introduced to address this issue. DMAs are segments of the distribution system separated by valves and flow meters. This allows the measurement and comparison of input flows with meter readings to determine usage. It is more common in Europe and the UK than in North America. The nighttime flows can also be measured to determine if there are leaks in the system area. By comparing input and output flows, the water balance is calculated to determine real water losses in this section of the system. If a discrepancy is noted, inspectors are sent to the field to pinpoint leak locations.

In the 1990s, the introduction of the first leak correlator became commercially available for utilities. The correlator was developed to accurately pinpoint leaks on pressurized pipes by utilizing acoustic sensors placed on both sides of a suspected leak location. The sensors collect and transmit sound data to a processing unit, where the noises are correlated and the time difference it takes for the noise to travel is calculated, enabling precise leak location identification. Initially, these were handheld units used by leak inspectors out in the field.

In the 2000s, another significant innovation was developed—fixed-based acoustic sensors. These sensors are capable of performing the same task as the correlator, but without the need for an operator. They are permanently installed throughout the pipe network and continuously collect data. The data is then transmitted back to a central location for detailed analysis.

In the 2010s, software-based solutions emerged. Software-based solutions are purely analytical. They rely on data obtained from the utility regarding pipe age, pipe type and break history. They also use open-source data related to local factors such as soil type and other environmental and geological data. These are analyzed using an AI-based algorithm to determine the likelihood of failure.

Another groundbreaking advancement was introduced at the same time which leverages synthetic aperture radar (SAR) technology from satellites to remotely detect the presence of potable water underground.

The Satellite Imagery Leak Detection (SILD) technology has the remarkable capability to “see” up to 2 meters below the surface, and its functionality remains unaffected by weather, foliage, or hardscape. Its patented algorithms can efficiently analyze extensive pipeline networks, pinpointing the most probable leak locations. Additionally, the SILD technology is pipe material and size agnostic. It works well on metal or plastic pipes and pipes of all sizes.

Exploring Leak Detection Techniques: Pros and Cons

The water industry's focus on leak detection has spurred a surge in products and services from new companies. Each of these approaches has its own pros and cons. These offerings can be broadly categorized into the following groups.

Handheld Acoustic Correlators (Traditional Boots-on-the-Ground)

Handheld acoustic correlators, deployed by traditional BOTG (Boots-on-the-Ground) inspectors, are essentially enhanced versions of the century-old listening stick. They operate on the principle that a leak in a pressurized pipe generates a noise that travels a certain distance along the pipe. These correlators are connected to listening points like valves or fittings to collect readings. Unlike single-point acoustic devices, correlators use two acoustic listening systems, placed on either side of the leak, to pinpoint its location based on the acoustic signal strength observed at each device.

Pros:

This cost-effective and minimally invasive technique is commonly used in conjunction with other leak detection methods to precisely identify the leak's exact location.

Cons:

This fully manual process heavily relies on the expertise of human operators for successful detection. Due to its labor-intensive nature, covering an entire service area in a single year becomes challenging or even impractical for utilities. In many cases, it can take 4 to 5 years to inspect the entire system using this approach. Moreover, ensuring proper training for leak detection personnel and obtaining high-quality acoustic devices are critical factors for achieving accurate results.

Correlating Continuous Acoustic Monitoring (CCAM)

Correlating Continuous Acoustic Monitors (CCAM) or fixed base acoustic systems are also sound sensors or correlators, but unlike BOTG methods, they consist of a set of equipment that is permanently or semi-permanently mounted to the pipes or attached to hydrants. These systems continuously collect data and transmit it to a central location for analysis, enabling operators to be alerted to leaks over time. In some cases, the equipment is moved to another region of the system after a specified time, following a “lift and shift” program.

Pros:

CCAM is a non-invasive approach and can be monitored remotely. The equipment sensitivity and data analytics are improving, which will increase performance.

Cons:

CCAM comes with a significant capital cost. Typically, it is focused on monitoring specific areas of the distribution system for long-term observation and is not easily or inexpensively relocated. The installation of permanently fixed leak detection devices requires battery power to operate the sensors and backhaul data to a central processing platform, limiting the productive life of these systems. Additionally, the units have a battery life of 5-6 years, requiring periodic maintenance and replacement.

District Metered Area (DMA)

DMAs with flow meters, or virtual DMAs, aim to analyze flows during minimum consumption periods, usually at night, to differentiate legitimate consumption from leakage within the DMA. When discrepancies are identified, leak detection activities are initiated to locate and repair these leaks. This can be achieved either physically through pipe modifications and flow meters or virtually through modeling and the establishment of a virtual twin program.

Pros:

Smaller DMAs tend to be more cost-effective and easier to model, making them a favorable option in certain cases.

Cons:

The implementation of DMA leak detection can be costly, especially if significant modifications are required to isolate an area for accurate input and outlet flow measurements.

Tethered or Floating Systems

Tethered or floating devices are acoustic/sound sensors deployed within a pipe through an opening, such as a hydrant, by BOTG personnel. As they are pulled through the pipe, they can triangulate leaks and identify gas pockets caused by leaks using acoustic signals.

Pros:

These devices can be easily removed via the tether or further downstream using nets or natural exits. Apart from leak detection, these systems are also utilized for condition assessment studies, employing ultrasonic or video tools to collect data.

Cons:

These systems are invasive and may require a special access point to be constructed for launching and recovery, depending on their size.

Software-Based Condition Assessment Solutions

Software-based condition assessment tools are predictive systems that employ proprietary artificial intelligence or open-source algorithms to analyze pipe systems and forecast future failure risks. These advanced algorithms are trained using historical break data, along with information on pipe age, type, soil conditions, and other parameters collected from the utility. It is important to highlight that these tools are primarily designed for condition assessment and asset planning, rather than specifically identifying likely leak locations.

Pros:

The software's predictive capabilities enable utilities to proactively address potential issues and optimize their maintenance strategies for system resilience. Not only does it require less capital investment, but it can identify the sections of pipe with the highest likelihood of failure. Additionally, it is less intrusive as it uses readily available information about the system and its environment.

Cons:

Most systems do not have a complete data set for their pipe network. Missing data must be interpolated to complete the analysis. It is difficult to prove analysis efficacy due to long-term prediction horizon.

Satellite Imagery Leak Detection (SILD)

Satellite Imagery Leak Detection is a new technology that leverages satellite imagery and advanced data analytics to remotely identify leaks. From space, this technology can find areas in the pipe network with a high density of leaks so that pinpointing activities can be efficiently deployed

Pros:

The technology works completely remotely and can survey large amounts of land area and pipeline length in a single satellite pass. It can detect likely leak locations and minimize the area that a field crew must physically inspect thereby increasing productivity, efficiency and rate of leaks pinpointed. The technology increases value proposition by identifying more leak locations than other technologies.

Cons:

There are a limited number of satellites that observe Earth using SAR. Field leak crews are still required to pinpoint leaks, and the efficiency of leak detection depends on the proficiency of these field crews.

Comparing Leak Detection Methods: Unassisted BOTG Versus SILD-Guided Approach

This comparative analysis explores the performance difference between traditional unassisted BOTG leak detection methods that inspect pipes randomly and SILD technology which pinpoints likely leak locations. This investigation aims to showcase the efficiency contrast between these methodologies, shedding light on the remote earth observation technology transformative impact on leak detection.

Traditional unassisted boots-on-the-ground (BOTG) leak detection efforts are customarily carried out by inspecting pipelines from one end to the other at random as assigned by the utility. This point-to-point method is usually carried out by retained contractors or in-house crews. Leaks are pinpointed using acoustic equipment by accessing listening points along the pipeline route. These listening points include meters, curb stops, valves, hydrants, and any other physically available appurtenance.

The SILD solution surveys many miles of pipeline with a single scan. Leveraging proprietary algorithms and a GIS-based map, the technology pinpoints likely leak locations, focusing on the 5-10% of the total surveyed area that necessitates proactive attention. Subsequently, field crews are deployed to these pinpointed areas for physical inspection, using the same acoustic equipment as the traditional methodology, but maximizing the efficiency of leak detection efforts.

When comparing and evaluating these methods, establishing a performance benchmark is critical to compare results accurately. Both the utility and the solution provider should conduct comprehensive benchmarking analyses. Utilities can benchmark the performance of their current technology to assess its technical efficacy and value proposition, serving as a baseline for comparing alternative approaches. Similarly, technology providers can benchmark the performance of their solutions against traditionally used methods. However, a benchmarking analysis requires standardized performance metrics to ensure fair comparison among alternative technologies. This can present challenges when a new technology performs the task in a fundamentally different manner than the traditional methodology. In such cases, defining appropriate metrics becomes crucial to accurately assess the effectiveness of the innovative solution.

The traditional unassisted BOTG leak detection method can be compared to the SILD method using the following metrics.

- Leaks Found per Crew Day
- Leaks Found per Mile Physically Inspected
- Miles Inspected per Crew Day
- Listening Points per Mile Accessed
- Percent of Leaks Non-Surfacing
- Cost per Leak Found

There are an adequate number of traditional unassisted BOTG projects to analyze and calculate a valid performance metric for this methodology. Two unique traditional leak detection contractor databases were reviewed in this analysis. The first is comprised of 1858 projects conducted in North America between 2009 and 2018, while the second database encompassed 289 projects from 2017 to 2021 (for a total of 2147 projects). Together, these databases identified and pinpointed a total of 18,784 leaks.

The performance metrics from one SILD provider is based on 880 projects completed worldwide between 2016 and 2022, covering regions such as North America, Europe, Latin America, the Middle East, Africa, New Zealand, Australia, Great Britain, Ireland, Asia, and Japan, and identifying a total of 87,324 leaks during this period.

Leak Detection Program Performance Metrics

	Traditional Unassisted BOTG	SILD-Guided
Number of Projects	2147	880
Number of Leaks Found	18,784	87,324
Leaks Found per Crew Day	1.3	5.5
Leaks Found per Mile Physically Inspected	0.3	3.4
Miles Inspected per Crew Day	3.9	1.5
Listening Points per Mile Accessed	35	135
Percent Non-Surfacing Leaks	90%	80%
Average Leak Size	3.2 gpm	4.5 gpm
Cost per Leak Found	$1250	$700

The SILD technology excels in identifying pipeline areas with higher concentrations of leaks, as leaks are not evenly distributed throughout the system. This is evidenced by the leaks found per mile inspected and the leaks found per crew day metrics. Notably, the SILD projects average 1.5 miles (2.4 km) of pipeline inspected per crew day, while the traditional approach covers 3.9 miles (6.3 km) per day.

Additionally, SILD project crews averaged 135 listening points per mile (84 per km), compared to 35 per mile (22 per km) in traditional projects. Best practices recommend accessing all possible listening points available during BOTG inspections, maximizing the number of acoustically observed leaks within the inspected zone. However, this detailed approach may slightly reduce the miles of pipeline inspected on each crew day due to increased inspection time per listening point.

Evaluating Alternative Leak Detection Methods

The traditional unassisted BOTG method has a wealth of recorded data, making it suitable for a data-based comparison to the SILD methodology, while other leak detection methods have relatively limited publicly available performance data.

One of these methods includes fixed base correlating continuous acoustic monitoring (CCAM) systems that are permanently installed in selected pipe sections by the utility. These systems continuously monitor the pipeline section, and upon detecting a leak, a field crew is dispatched with correlators to pinpoint the leak's location for repair. Given the fundamental difference of the fixed base system as a continuous monitoring program, it necessitates the development of modified performance metrics to enable a comparative analysis with other leak detection methods.

In one study, SILD technology was evaluated side-by-side with a fixed base acoustic leak detection system over a year-long period. The comparison was made possible as both systems were monitored and operated for the same duration of 12 months, covering an identical 100-mile service area. Each technology autonomously identified Points of Interest (POI) related to potential leaks and promptly reported them to the utility. Subsequently, BOTG field leak inspectors were dispatched to the identified areas for leak pinpointing. During the study, the SILD detected and pinpointed 117 leaks, while the CCAM technology identified 20 leaks within the same time period. This study showed the ability of SILD technology to find more leaks within a given area within a given time. The quicker leaks can be detected and repaired, the larger the value proposition regarding water loss reduction and money saved.

In a UK-based study, a comparative analysis was conducted to evaluate leak detection performance using DMAs against SILD remote observation technology. The study involved surveying and inspecting the same DMA areas, and the results revealed an increase in the leak detection efficiency when the SILD technology was employed. Specifically, the leak per crew day metric increased by 700%, rising from 0.4 leaks per day to 2.8 leaks per day. This performance improvement demonstrates the effectiveness and potential of the SILD technology in optimizing leak detection efforts.

As additional data becomes publicly available, the performance and value proposition of the SILD technology can be further refined and explored, validating its potential as a more cost-effective and efficient leak detection solution.

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Qualitative Analysis of Leak Detection Technologies

Due to the limited availability of public data for conducting a quantitative analysis of these emerging technologies, a qualitative approach is used to compare the available options. The comparison will be based on a set of parameters that help assess the effectiveness and suitability of the technological solutions.

Capital Cost

The capital cost of equipment required to implement the solution.

Operations Cost

The cost of labor, truck roll, supervision, and data backhauling to implement the solution.

Performance

The ability of the solution to detect leaks using a performance metric such as leaks found per day, leaks found per mile physically inspected, leaks found per 100 miles (100 km) per year, or dollars (euros) per leak found.

Testing Frequency

The time it takes to survey or inspect the entirety of a utility's distribution system.

Flexibility

The ability of a solution to easily change the focus of the survey or inspection to alternative sections of a distribution system.

Invasiveness

The level of intrusion a solution has on the pipe system.

Turnaround Time

The time it takes from solution implementation until results are obtained.

Weather Impacts

The impact that weather or other physical features have on the ability of the solution to perform.

Complexity

How difficult or easy the solution is to implement and the requirement of specialized knowledge.

Return on Investment

The overall value of the solution from a fiscal standpoint or a water saving perspective.

Comparing Leak Detection Technologies: Performance, Flexibility, and ROI

	Software-Based Condition Assessment	Floating	DMA	TBOTG	CCAM	Satellite Imagery Leak Detection
Performance	Low	Medium	Medium	Low	Medium	High
Flexibility	High	Low	Medium	Medium	Low	High
ROI	Low	Low	Medium	Low	Medium	High

The above table offers a comprehensive comparison of various leak detection methods, each evaluated across different attributes. SILD ranks high across various categories, showcasing notable performance, flexibility, and return on investment (ROI) in comparison to other leak detection methods.

Comparing Leak Detection Technologies: Costs, Efficiency, and Impact

	Software-Based Condition Assessment	Floating	DMA	TBOTG	CCAM	Satellite Imagery Leak Detection
Capital Cost	Low	Medium	Medium	Low	High	Low
Operations Cost	Medium	Medium	Low	Medium	Low	Medium
Testing Frequency	Low	High	High	High	High	Low
Invasiveness	Low	High	Medium	Low	Low	Low
Turnaround Time	Medium	Low	Low	Medium	Medium	Low
Weather Impact	Low	High	Low	Medium	Low	Low
Complexity	High	High	Medium	Low	Medium	Low

The above table demonstrates an additional comparison across other metrics including Capital Cost, Operations Cost, Testing Frequency, Invasiveness, Turnaround Time, Weather Impact, and Complexity. The consistent pattern of lower values highlights SILD's efficiency, signifying its ability to deliver cost savings, reduced invasiveness, quicker turnaround times, and lower operational complexities. This wealth of data serves as a standard benchmark for evaluating other leak detection technologies. It is essential for all technology providers to gather high-quality data from their projects and publish it with the client's consent and support. This will allow for an apples-to-apples comparison of technologies to determine which option is the best fit for each application.

Satellite Leak Detection: A Smart Investment for Water Utilities

SILD technology not only enhances leak detection efficiency but also delivers exceptional returns on investment (ROI) and significant cost savings for water utilities.

By identifying likely leak locations with a high concentration of leaks, SILD streamlines the deployment of field inspection crews, resulting in more leaks being pinpointed and repaired per mile inspected and per crew day. This operational efficiency translates directly into substantial savings for utilities. Moreover, SILD technology's ability to reduce water losses not only preserves this precious resource but also minimizes the need for excessive electricity generation and lowers greenhouse gas emissions. These financial advantages make SILD a smart and cost-effective choice for water utilities aiming to enhance their leak detection strategies and improve their bottom line.

The Impact of SILD Technology

SILD technology helps utilities recover lost water supply by detecting real water losses so that pipes can be repaired. The technology excels at identifying likely leak locations, concentrating on areas with a higher density of leaks. This heightened accuracy enhances the productivity and efficiency of field leak inspection crews, resulting in more effective leak detection. SILD can also inform utilities as to where to deploy other leak-detection methods such as DMAs, CCAM, or tethered solutions. By identifying areas with high leak densities, the most vulnerable pipes are located and can be prioritized for capital replacement or focused maintenance.

However, the impact of effective leak detection goes beyond water conservation; it extends to reducing unnecessary electricity generation and lowering greenhouse gas emissions. By efficiently addressing leaks, SILD plays a pivotal role in achieving water conservation goals, reducing energy consumption, and contributing to broader sustainability initiatives.

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