Lessons Learned in Conducting Acoustic Leak Detection Surveys on Water Distribution Systems at 12 Military Installations

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Presentation Overview

- Benefits of a Leak Detection / Location Program
- Summary of Available Leak Detection / Location Methods
- Case Study of Acoustic Leak Detection Surveys at 12 Military Installations

Ref: www.times-news.com
Benefits of Leak Detection / Location

- Increase level of service
- Bolster water conservation initiatives
- Reduce operating and repair costs
- Reduce liability due to damage caused by leaks
- Shift repairs from “Emergency” to “Scheduled”
- Improve compliance with regulatory programs and mandated goals
- Avoid being a headline
Definitions

**Leak Detection** – The process of identifying the presence of a leak within a water system without locating the position of the leak

**Leak Location** – The process of identifying the position of a leak within a water system (a.k.a. leak pinpointing)
Leak Detection / Location Methods

Multitude of Methods Available

- Visual Observations
- Records Review
- Flow Monitoring
- Acoustic Technologies
- Thermal Imaging
- Electromagnetic
- Chemical
## Visual Observations

<table>
<thead>
<tr>
<th>Description</th>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Best Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspected leaks are reported to the water utility by employees and customers.</td>
<td>▪ No specialized equipment or training required</td>
<td>▪ May require additional methods to locate leaks</td>
<td>Detecting and sometimes locating visible leaks when other methods are not economically feasible or warranted</td>
</tr>
<tr>
<td>Typically includes saturated or green areas over pipes, leaking aboveground appurtenances, water surfacing in streets, water in valve boxes or vaults, and dry weather flow in storm sewers.</td>
<td>▪ Effectiveness is independent of pipe size and material</td>
<td>▪ Unable to identify underground leaks unless they surface</td>
<td></td>
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<tr>
<td></td>
<td>▪ Opportunity for community engagement and education</td>
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*Ref: www.parkrecord.com*
## Records Review

<table>
<thead>
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| Completion of a top down water audit comparing production data to billing records in order to estimate water loss from the system. | ▪ No specialized equipment required  
▪ Effectiveness is independent of pipe size and material  
▪ Able to provide estimated quantity of water lost due to leakage | ▪ Requires robust customer meter data  
▪ Production and customer meter errors reduce accuracy of leakage estimates | Detecting and quantifying water loss within the entire system to determine if additional leak detection / location is warranted |

### Water Balance

| Source: AWWA M36 Water Audits and Loss Control Programs |

<table>
<thead>
<tr>
<th>Volume from Own Sources</th>
<th>Water Exported</th>
<th>Authorized Consumption</th>
<th>Billed Water Exported</th>
<th>Billed Metered Consumption</th>
<th>Billed Unmetered Consumption</th>
<th>Non-Revenue Water</th>
<th>Revenue Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Supplied to System</td>
<td></td>
<td>Unbilled Authorized Consumption</td>
<td>Unbilled Metered Consumption</td>
<td>Unbilled Unmetered Consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Losses</td>
<td></td>
<td>Apparent Losses</td>
<td>Unauthorized Consumption</td>
<td>Customer Metering Inaccuracies</td>
<td>Systematic Data Handling Errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Real Losses</td>
<td>Leakage and Overflows at Utility’s Storage Tanks</td>
<td>Leakage on Transmission and/or Distribution Mains</td>
<td>Leakage on Service Connections</td>
<td></td>
<td></td>
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</tbody>
</table>
# Flow Monitoring

<table>
<thead>
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</table>
| Comparing permanent or temporary meter data to expected consumption rates to quantify water loss. | - Effectiveness is independent of pipe size and material  
- Can determine leakage district by district or customer by customer  
- Limited system access required | - Installation of permanent meters may be cost prohibitive  
- While temporary meters are less expensive, installation requires care and expertise to ensure accuracy | Detecting and quantifying leaks district by district or customer by customer to prioritize leak location by other methods |

Ref: www.ultrasonic-flow.com
Acoustic Technologies

Sounds typically generated by leak

- Water exiting pipe
- Water impacting bedding & circulating in cavity

Propagated Along Pipe: 500 – 800 Hz

Propagated Through Ground: 20 – 250 Hz
### Listening Rods / Sticks

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<tr>
<td>Simple steel rod with earpiece at one end that detects leak sounds propagated along the pipe. Used at hydrants and valves to detect leaks in the area.</td>
<td>- Low cost of equipment</td>
<td>- Requires extensive operator practice to use effectively</td>
<td>Detecting leaks on metallic pipes near hydrants and valves</td>
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<tr>
<td></td>
<td>- No mechanical or electronic components</td>
<td>- Requires frequent testing points</td>
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<tr>
<td></td>
<td></td>
<td>- Difficult to locate position of leaks</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Limited effectiveness on non-metallic pipe</td>
<td></td>
</tr>
</tbody>
</table>

Ref: [www.pollardwater.com](http://www.pollardwater.com)
## Geophones

<table>
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</table>
| Mechanical listening device placed on ground surface above pipelines to locate leaks via sound propagated through the ground. Operates similar to a stethoscope | - Low cost of equipment  
- No electronic components  
- Can be used with metallic and non-metallic pipe  
- Able to locate the position of leaks, but can be time consuming | - Requires extensive operator practice to use effectively  
- Requires frequent testing points  
- Requires access along the pipe corridor | Ground microphoning to locate leaks on metallic and non-metallic pipe in problematic areas |

Ref: plumbinginfo.org
**Hydrophones**

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| Piezoelectric accelerometer with an amplifier that transfers leak sounds to headphones. Used at hydrants and valves to detect sounds that propagate along the pipe. | ▪ Moderate cost of equipment  
▪ Noise filters and amplifiers aid user in detection leak sounds  
▪ Can be used with metallic and non-metallic pipe  
▪ Able to be used as a ground microphone to locate leaks, but can be time consuming | ▪ Requires extensive operator practice to use effectively  
▪ Difficult to locate position of leaks | Detecting leak areas on metallic and non-metallic pipe <16" diameter; ground microphoning to confirm leak locations |
## Leak Noise Correlators

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| Listening devices placed on each side of a suspected leak and transfer data to computer processor to calculate the location of a leak relative to location of the sensors. Used at hydrants and valves to locate leaks that propagate sound along the pipe. | ▪ Moderate cost of equipment  
▪ Can be used with metallic and non-metallic pipe  
▪ Able to quickly and accurately locate the position of leaks, including inaccessible routes when the approximate area is known | ▪ Typically requires factory training  
▪ Requires accurate pipe diameter, material, and configuration data | Quickly locating leaks on metallic and non-metallic pipe <16“ in problematic areas |

Ref: [www.utsleak.com](http://www.utsleak.com)
### Leak Noise Loggers

**Description**
Listening device and digital recorder placed in the system to record leak sounds over an extended period of time for later analysis. Used at hydrants and valves to detect leak sounds that propagate along the pipe.

**Strengths**
- Moderate cost of equipment
- Can record leak sounds over extended period without on-site operator
- Data from multiple noise loggers can be used with correlator processors to pinpoint leak locations

**Weaknesses**
- Typically requires factory training
- Requires correlation processor to locate position of leaks

**Best Use**
Long term leak detection monitoring on metallic and non-metallic pipe <16"; Leak locating in problematic areas (when used with additional loggers and correlation processor)

Ref: www.pollardwater.com
### Inline Acoustic Leak Detectors

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</table>
| Free-floating or tethered sensor installed in the pipe and moves with the flow to locate leaks. | - Can test long segments of large diameter pipe with few access points  
- Some sensors can be equipped with cameras to provide asset condition information | - More expensive equipment; generally requires trained contractor  
- Line may need to be depressurized during installation  
- Sensor may become stuck or lost | Detecting and locating the position of leaks on metallic and non-metallic transmission mains >12" |

Ref: www.puretechltd.com
# Fiber Optics

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</table>
| Fiber optic cable installed inside the length of the pipe to detect leak sounds and locate their location. | ▪ Can test long segments of large diameter pipe with few access points  
▪ Highly accurate in detecting and locating water leaks  
▪ Possible to conduct long term monitoring of identified leaks  
▪ Capable of detecting breaks in pre-tensioning wires in PCCP pipe | ▪ Expensive equipment; typically owned and operated by contractor  
▪ Line may need to be depressurized and/or dewatered during installation | Long term leak detecting, locating, and monitoring on critical, large diameter, PCCP transmission mains |

Ref: [www.puretechltd.com](http://www.puretechltd.com)
**Thermal Imaging**

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| Infrared meters or photography used to identify temperature differences at the ground surface caused by leaked water. | ▪ Does not require access to system appurtenances  
▪ Can quickly identify areas for further investigation | ▪ Expensive equipment; typically owned and operated by contractor  
▪ Leaks may not be identified if temperature difference is not large enough or is masked by groundwater  
▪ Interference may be caused by nearby utilities in densely developed areas | Detecting and locating leaks on metallic and non-metallic transmission mains in rural areas |

Ref: www.thermalimaging.co.uk
Electromagnetic

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<tr>
<td>Ground Penetrating Radar (GPR) unit used over pipeline to identify voids,</td>
<td>▪ Moderate cost of equipment</td>
<td>▪ Requires extensive operator practice to use effectively</td>
<td>Confirming location of leaks identified via other methods on metallic and non-metallic pipes</td>
</tr>
<tr>
<td>water pockets, and/or ground disturbance created by leaks.</td>
<td>▪ Can be used with metallic and non-metallic pipe</td>
<td>▪ Ability to locate leaks is dependent on pipe bedding and groundwater conditions</td>
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<tr>
<td></td>
<td></td>
<td>▪ Requires access along the pipe corridor</td>
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</table>

Ref: surveyequipment.com
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</thead>
<tbody>
<tr>
<td>Inert gas is injected into pipeline; leakage is detected by sensors at the ground surface</td>
<td>- Moderate cost of equipment</td>
<td>- Requires extensive operator training</td>
<td>Detecting and locating leaks on newly constructed pipelines prior to putting them in service</td>
</tr>
<tr>
<td></td>
<td>- Can be used with metallic and non-metallic pipe</td>
<td>- Detection can be affected by weather</td>
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<tr>
<td></td>
<td>- Requires access to few system appurtenances</td>
<td>- System typically needs to be dewatered prior to testing</td>
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<td></td>
<td></td>
<td>- System may require disinfection following testing.</td>
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</tbody>
</table>

Ref: [www.tracerelectronicsllc.com](http://www.tracerelectronicsllc.com)
Summary of Methods

**Leak Detection**
- Visual Survey
- Listening Rods/Sticks
- Water Balance
- Hydrophones
- Leak Sound Loggers
- Flow Monitoring
- Tracer Gas
- Thermal Imaging
- Inline Acoustics
- Fiber Optics

**Leak Location**
- Visual Survey
- Geophones
- Hydrophones
- Leak Sound Correlators
- Tracer Gas
- Ground Penetration Radar
- Thermal Imaging
- Inline Acoustics
- Fiber Optics
Case Study

Acoustic Leak Detection Surveys at 12 Military Installations

- Background
- Methodology
- Results
- Lessons Learned
Case Study - Background

- 12 surveys were conducted from 2009 to 2013
- Surveys covered over 4.1 million linear feet of piping
- Service populations from 5,500 to 13,800 people
- Average daily demands from 0.75 MGD to 2.0 MGD
- Executive Order 13514 mandates a reduction in water consumption intensity of 2% per year from FY 2007 baseline through FY 2020
- Engineering Technical Letter 11-22 states audible leak detection to be the preferred method of the Air Force
Case Study - Methodology

- Water system maps
- Water system pressures
- Break and repair history
- Water production records
- Water consumption and billing records
Case Study - Methodology

Standardize the Distance Between Listening Points

**Metallic Pipe**

500 foot spacing on metallic pipe

**Non-Metallic Pipe**

100 foot spacing on non-metallic pipe
Case Study - Methodology

Preparing Field Maps

Selection of Listening Points
Case Study - Methodology

• Introduce field team
• Get to know military and civilian utility personnel
• Explain the technology to base personnel
• Conduct field test of hydrophone and leak correlator
• Coordinate with escorts and security forces
Case Study - Methodology

**Progression Maps**

- Listening Point (0)
- Leak-Like Sound (1&2)
- Interference (-1)

Sounding Survey
Case Study - Methodology

Correlation Requires Accurate Pipe Data

- Location/Length
- Material
- Diameter

$$d = \frac{D - v\Delta t}{2}$$

Result 1-2

Leak Sound Correlation
Always un more than one correlation

Result 1-3

Result 1-2

Result 2-3
Inconclusive

Pod #1

Pod #2

Pod #3
Case Study - Methodology

Leak Correlation Challenges

- Pipe Tees
- Mapping Errors
Case Study - Methodology

Leak Correlation Challenges

- Pipe Tees
- Mapping Errors

Pod #1

Result 1-2

Pod #2

Leak Sound Correlation
Case Study - Methodology

Ground Microphone
Case Study - Methodology

Final Leak Map

- Listening Point
- Leak-Like Sound
- Potential Leak Locations
Leak Log & Summary Report

- Leaking component
- Leak location (map and coordinates)
- Water loss classification
- Confirmed or suspected leak
- Surface cover
- Cost estimates for repair
Case Study - Results

Leaks by Site
249 Total Leaks Identified

Base 1: 4
Base 2: 30
Base 3: 37
Base 4: 5
Base 5: 37
Base 6: 21
Base 7: 6
Base 8: 15
Base 9: 22
Base 10: 10
Base 11: 19
Base 12: 43
Case Study - Results

Identified Leaks by Appurtenance

- Hydrants: 39%
- Valves: 14%
- Service Lines: 22%
- Other: 19%
- Main Lines: 6%

Identified Leaks by Appurtenance
Case Study - Results

Other Notable Findings

- Evidence of poor pipe installation
- Poor frost proofing
- Unintentionally closed valves
- Water loss from other sources can exceed leakage (storage tanks, flushing, swimming pools)
- Map inaccuracies

<table>
<thead>
<tr>
<th></th>
<th>Valves</th>
<th>Hydrants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newly Mapped Appurtenances</td>
<td>730</td>
<td>169</td>
</tr>
<tr>
<td>Appurtenances that could not be Located</td>
<td>569</td>
<td>153</td>
</tr>
</tbody>
</table>
Lessons Learned

1. A lack of sufficient meter data prevents development of meaningful water balances

2. Pre-select sounding survey points based on pipe material to ensure proper coverage

3. Test acoustic equipment with a simulated leak at a fire hydrant

4. Revisit potential leak areas identified during the sounding survey to confirm the sounds initially identified are continuous and not due to temporary water use
5. Engage utility personnel prior to correlation to confirm system configuration, materials, and features that may mimic a leak-like sound.

6. Conduct a surface inspection of leak areas to validate location results.

7. Improve system maps with data collected during surveys.