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Acoustic Monitoring Minimizes Water Loss and Risks of Pipeline Failures

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Presentation Outline

• Water Loss Basics
• Acoustic (Leak) Monitoring Overview
  ▶ Current Approaches
  ▶ Need for Technological Improvements
• EchoShore-DX Monitoring Technology
• Case Studies: American Water
• Transmission Main Monitoring
Optimizing Water Systems
*NRW, Energy, Pressure, and Pipe*

Older pipe networks:
- Leak more (background leakage)
- Leak quieter (more difficult to find)
- Have higher risk of catastrophic failure

Reference: AWWA M36

*Figure 5-1* The four-pillar approach to the control of real losses
Acoustic Leak Correlation Analysis  
**Principle of Operation**

1. Bracket the leak with two sensors  
2. The leak sound propagates in both directions  
3. Correlator measures the time difference to reach each of the sensors to determine the exact leak location
## Distribution Mains Monitoring

### Current Technologies and Approaches

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMAs</td>
<td>Volume of water entering an area is compared against volume of water billed</td>
<td>Quantified NRW in an area</td>
<td>Dead zones; Crews required to locate leak(s)</td>
</tr>
<tr>
<td>Sounding Survey</td>
<td>Leak pinpointing using acoustic listening technologies</td>
<td>Location pinpointing</td>
<td>Experience required; Labour intensive.</td>
</tr>
<tr>
<td>Noise logging</td>
<td>Single-channel using acoustic loggers. Often ‘lift &amp; shift’ arrangement</td>
<td>Ability to survey large distances quickly.</td>
<td>Limited performance; Crews required for deployment &amp; data collection</td>
</tr>
</tbody>
</table>

→ High false positive rate  
→ Leaks identified, but location is still labour intensive  
→ Reliant on specialized labour

Current technologies focus on improving a manual process. Still an exercise in ‘hunting’.
# Distribution Mains Monitoring

## Next Generation Tech and Approaches

<table>
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<tr>
<td>Multi-Parameter analysis</td>
<td>Multiple parameters, including pressure and flow, from a larger area model the network</td>
<td>Improved leak identification</td>
<td>Secondary indicators only; No direct LD</td>
</tr>
<tr>
<td>Permanent correlation</td>
<td>Mesh network of acoustic correlation sensors installed throughout the network</td>
<td>Detects and locates leaks. Tracks leaks over time</td>
<td>Reliant on accurate piping data</td>
</tr>
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New information available allows utilities to:

→ Find leaks before customers *as standard practice*
→ Monitor leaks in the repair queue *as standard practice*
→ Notify customers of repairs/disruptions early *as standard practice*
The Need for Permanent Monitoring

Early detection of leaks is vital for water distribution systems, with the ability to identify system failure points:

- Mitigate impact customer levels of service
- Minimize water loss
- Extend asset life
- Schedule and prioritize repairs on an informed, proactive basis
- Minimize the risks of catastrophic failures
Consortium Formed 2009
Next-Generation Fixed Monitoring System

Innovation Overview

- In 2009, 4 companies started a collaboration on the development of fixed leak detection technology for water distribution systems: American Water, City of Ottawa, Echologics, and Sustainable Development Technology Canada.
- After a series of successful developmental field trials, the first commercial system, known as EchoShore-DX, was installed in Charleston, West Virginia in 2014. This technology drastically improved the way that water main leaks are identified, prioritized, and repaired.
System Components & Layout

- Antenna
- High Sensitivity Sensor
- Integrated processor, radio, and battery
EchoShore DX – Project Parameters

Project Scoping Requirements:

→ GIS Data for the geographic area to be monitored
→ Pipe material, pipe diameter, hydrant locations
→ Network propagation study to determine network infrastructure reqs

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<th>Operating Parameters</th>
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<tr>
<td>Maximum Mi.Echo Node Spacing</td>
<td>1,500 ft. for non-plastic pipe materials</td>
</tr>
<tr>
<td></td>
<td>A site specific survey is required for plastic pipe materials</td>
</tr>
<tr>
<td>Pipe Diameter</td>
<td>Up to 12” diameter (300 mm)</td>
</tr>
<tr>
<td>Pipe Material</td>
<td>Cast Iron, Steel, Ductile Iron, Asbestos Cement, PCCP, PVC, PE, and other plastics</td>
</tr>
<tr>
<td>Battery life</td>
<td>5 years</td>
</tr>
<tr>
<td>Liquid Temp</td>
<td>33°F to 100°F (0.5°C to 38°C)</td>
</tr>
<tr>
<td>Ambient Temp</td>
<td>-27°F to 130°F (-33°C to +55°C)</td>
</tr>
</tbody>
</table>
EchoShore DX - System Description

System comprised of a series of nodes and radio infrastructure:

Network of interconnected nodes monitors a service area
EchoShore DX - User Interface

- Leverages existing functionality of Mi.Host
- Graphical and visual display of system status
- Leak events geospatially positioned within water infrastructure

Advanced leak detection integrated with Mi.Host interface
EchoShore DX – How it Works

Nodes form the leak detection network

System-wide leak detection and correlation on initialization

Baseline background noise level excludes existing leaks

EchoShore-DX will identify and locate existing leaks
EchoShore DX
Secondary Leak Detection at Server Level

Multi-Channel Leak Detection:
1. Leak groups identified
2. Correlation data files from the leak group are obtained
3. Correlations on all node pairs in the leak group are performed

Server-level intelligence increases LD probability and conserves radio bandwidth & battery life
EchoShore DX – Operational Experience

**AMERICAN WATER**
Uniontown, PA

- **Coverage:** 0.5 mi² (approx.) [1.3 km²]
- **Total Nodes:** 18
- **Pipe:** 4” – 12” Mostly DI [mixture of pipe types]
- **Service Start:** June 2013
- **Experience:** First installation site. Field validation, including multiple successful leak simulations. First true leak to be found.

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**Ottawa, Canada**

- **Coverage:** 1 mi² [2.5 km²]
- **Total Nodes:** 84
- **Pipe:** 4” – 12” Mostly CI [mixture of pipe types]
- **Service Start:** Sept 2013
- **Experience:** Incrementally larger pilot installation, full DMA. Found 2 leaks to date, none missed, no false positives.
EchoShore DX – Operational Experience

**AMERICAN WATER**
Liberty, PA

Coverage: 0.6 mi² [1.4 km²]
Total Nodes: 43
Pipe: 4” – 12” DI and CI
Service Start: Jan 2014
Experience: Second engagement with American Water. First leak found was monitored over 4 weeks and was fast progressing. Total of 3 leaks found, including an OB.

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**AMERICAN WATER**
Metro Chicago, IL

Coverage: 1 mi² [2.5 km²]
Total Nodes: 79
Pipe: 4” – 12” Mixed metallic
Service Start: Aug 2014
Experience: Third engagement with American water. Project driven by high cost of wholesale water, elevated leakage rate during change of season. Found 1 leak to date.
Permanent Monitoring: Case Study

West Virginia American Water

Service Area: 10 mi², Average Production 25 MGD
Total Nodes: 386, approximately 5 mi² of network coverage
Pipe: 4” – 12” DI and CI
Service Start: Dec 2014
Experience: 4th installation at American Water. 11 leaks found in the first month and 45 leaks in the first 5 months of operation, 40 of which had not yet surfaced prior to repairs. Credited with 2.3 MGD of water loss reduction. Phase 1 of multiple phased deployments.

Another 1.5 MGD of water loss was recovered from a 36" PCCP main leak, that was picked-up by the DX system through ground vibration.
Permanent Leak Detection in Practice

*Leak Progression to Failure (almost) – Liberty PA*
Permanent Leak Detection in Practice

*Leak Progression to Failure (almost) – Liberty PA*

![Graphs showing leak progression over time](image)

Origin → +2 weeks → +4 weeks

Dave Hughes: “...a time bomb defused”; 5 gpm leak paid for the system
The Need for Permanent Monitoring  
**Case Study: New Jersey American Water**

In 2007, New Jersey American Water deployed its first automated leak reporting system in Irvington, Maplewood and West Orange. Approximately 3,500 sensors have been placed on service pipelines with some connected to AMI. All return acoustic information to the vendor’s software that interpreted the leak noise and, through a computer cloud, the data is available to our staff.
New Jersey American Water
Automated Leak Reporting Experience

The daily return of data found many leaks and provided advantages over traditional leak detection approaches, e.g., listening surveys, but this technology still has many limitations, including:

- Too many false positives that resulted in time consuming investigations without finding leaks;
- Difficulties detecting leaks through multiple materials, commonly found with old repair sites where plastic pipe was inserted to replace deteriorated iron or steel pipe;
- Inability to characterize a leakage noise to determine leak size; and
- Despite a historic profile of acoustic sound, resources were required to interpret the data.
New Jersey American Water

Largest, Multi-System Deployment

- New Jersey American Water deployed 1,000 leak logger nodes
- Target water systems
  - Regulatory driven, e.g., Delaware River Basin Commission
  - High water loss combined with high cost of water
- Six systems in New Jersey
  - Belvidere
  - Frenchtown
  - Irvington
  - New Egypt
  - Pemberton
  - Washington
- Business cases showed net savings in Year 1
New Jersey American Water
Major Leak – Washington Township

• Leak was located 1,900' from logger on a 16" DIP transmission main
• Leak was on a disintegrated plastic Tap-to-Curb (TTC)
• NJAW estimated the leak at 80-100 gpm
• Leak was not surfacing anywhere, but the water was only 18" below ground when excavated
The Need for Permanent Monitoring

Transmission Networks

Top Risks Identified by Water Utilities

1. Emergency Repairs & Damage From Bursts
2. Water Loss Management
3. Pressure Management

Not all transmission main segments carry the same level of risk
Acoustic Behavior of Trunk Mains

What Makes Transmission Main Leak Detection Difficult

- Most leak detection equipment is designed for distribution mains, and fails on large mains
- Large mains transmit different frequencies
- Large mains have more ambient noise (traffic, water flow)
- Sound attenuates faster in large mains
- Fewer appurtenances available
The Acoustics of Leak Noise

INFRA SOUND

below 20 Hz

20 Hz to 20,000 Hz

ULTRA SOUND

over 20,000 Hz

Human Optimum

150mm Cast Iron Pipe

150mm PVC Pipe

1200mm Cast Iron Pipe

200 - 4000 Hz

200 - 1000 Hz

10 - 50 Hz

10 - 80 Hz
Commercially Available Technologies

- **Invasive technologies** have proven successful at finding leaks, but
  - Operational Challenges (flow, velocity, off-takes)
  - Extensive civil works required
  - Require highly trained operators in the field
  - Expensive

- **Standard Correlators** are less effective with increasing main size
  - Unable to detect and isolate low frequency leak noise
  - Closer access points needed, but fewer points available
  - Require highly trained operators in the field
Transmission Main Leak Detection: 108” Concrete 2,627’ Between Sensors

Utility: East Bay Municipal Utilities District
Project Location: California, USA
Project Timeframe: September 2010
Pipeline Diameter: 108”
Correlation Plot Number: 3
Material: Concrete
EchoShore TX
System Components & Layout

Monitored Transmission Main

Node 1
½ mi.
Node 2
½ mi.
Node 3

Antenna
Power Source
Processor & Comm. Hardware
Hydrophone

Node 1
Node 2
Node 3
EchoShore TX

Network Architecture

A network of interconnected nodes monitors a service area.

- Node 1
- Node 2
- Node 3
- Node 4

Cellular Network

Internet

Echologics Servers

Secure VPN

API Client

User Interface

Monitored Transmission Main
EchoShore TX

*Installation: In-Chamber Arrangements*

- Permanent monitoring in Canada, DN1500 (60") concrete lined steel pipe
- Permanent monitoring in Singapore, DN700 (28") steel pipe
- Permanent monitoring in USA, DN900 (36") AC pipe
- Permanent monitoring in USA, DN600 (24") concrete pipe
24 hour leak detection cycle
• Time-synced acoustic data capture
• Upload to central server and processed
• Results passed to UI or SCADA

Autonomous
• Automated correlation peak selection
• Reporting

On-Demand Functionality
• User can force unscheduled data capture
• Manual correlation

Time between leak detection surveys reduced from years to hours
EchoShore TX
Expandable Functionality

Core functionality is **acoustic leak detection**

Upgrades include:
- **Water hammer** detection
- **Tamper** detection, and other acoustic anomalies

- **Pressure/Flow**
- **Temperature**
- **Chlorine**
- Other Customer Requirement

Opportunity to expand from advanced leak detection to customized pipeline monitoring
NIST Smart Cities Global Challenge

• White House initiative to showcase Smart City Technologies
  ▶ Mueller, AT&T and IBM are participating vendors for water sector
  ▶ Las Vegas, Los Angeles and Atlanta are participating cities
• June 1st/ 2nd Presentations at NIST in Washington D.C.
• Technology engagements consist of EchoShoreTX in conjunction with AT&T wireless communications and IBM Visual Dashboard
• Vendor/ Client Benefits
  ▶ Echologics secures EchoShoreTX contracts, national media exposure, senior client contact
  ▶ Participating cities gain national exposure as Smart City
Smart Cities Challenge

Operational Experience

Project: Las Vegas, NV
Pipeline: 36” Asbestos Cement
Objective: Leak monitoring
Monitoring Start: April 2015

Project: Atlanta, GA
Pipeline: 20” Ductile Iron
Objective: Leak, pressure monitoring
Monitoring Start: April 2015

Project: LADWP, CA
Pipeline: 36” Concrete Lined Welded Steel
Objective: Leak monitoring
Monitoring Start: May 2015
Nevada Center of Excellence

- **Purpose:** State initiative to foster job growth
- **Mission**
  - Showcase adoption of water technology at Las Vegas Valley Water District
  - Attract water technology company investment and jobs
  - Jointly develop leading water technologies
- **Echologics/Mueller participation benefits**
  - Office space and conference room facilities
  - Joint marketing for hosting visiting utilities and political delegations
  - Test site for any “bleeding edge” technologies
    - Example: EchoShore TX on Las Vegas Strip
      - [https://www.youtube.com/watch?v=drl=youtu.be](https://www.youtube.com/watch?v=drl=youtu.be)
  - State funding for hiring of required personnel
  - Formal promotion of LVVWD as leading case study/reference
EchoShore – Mobile

Utility performs the field work

Monitored Transmission Main

Node 1

Node 2

Node 3

Antenna

Power Source

Processor & Comm. Hardware

Hydrophone

760m

760m
Permanent Monitoring Solutions

- **Reduces Non-Revenue Water** with early leak detection
  - Average leak goes undetected for up to 9 months
  - Many leaks never surface
- **Monitor leak progression** to determine urgency

- **Minimize risks of catastrophic bursts** by fixing leaks early
  - Liabilities $1M+ considering collateral damages
  - Avoid bad publicity and customer dissatisfaction
- **Saves repair costs**
  - Lessen the extent of pipeline (asset) damage
  - Reduce the number of emergency (overtime) repairs
  - Minimize wasted capital associated with *false positives*
- **Improve the safety of field personnel** by eliminating the need for traffic controls during leak investigations