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Water Loss Reduction Techniques

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The USA uses over 450 billion gallons of water every day.

About 30 billion gallons per day is taken by public water supply systems.

Therefore, the US daily average of treated water pumped by those systems is **over 90 gallons per person per day.**

The Water Industry is at a Crossroads

Every two minutes, there is a water main break, and an estimated 6 billion gallons of treated water is lost each day in the U.S. alone (NRW?)

Some Definitions

Leaks	Slow growing failure causing significant water loss over time with minimal change in pressure. Typically caused by corrosion, successive over-pressure and ground movement.
Bursts	Rapid failure causing local pressure drop and high volume of water loss quickly. Typically caused by transients and ground movement but can also form when a small leak causes damage to pipe and surrounding soil structure.
Over-Pressure	Operation of a pipeline above minimum viable pressure causing unnecessary leakage and stress on infrastructure.
Transients	Fast moving pressure surges causing excess stress on infrastructure.

Non-Revenue Water Components

❖ Always attempt to break down NRW volume into it's 3 main components

- Unbilled authorized consumption
- Apparent Losses
  - Unauthorized consumption
  - Systematic customer meter error
- **Real Losses (leakage and overflows)**

❖ Well-managed direct pressure systems should have low apparent losses

Where do most Real Losses Occur?

➢ Most people automatically assume that the largest volume of real losses arises from main bursts, because of their visibility

➢But in reality the largest components of annual real losses, in most utilities, are consistently shown to be attributed to:

- Background leakage
- Long-running unreported leaks and breaks
- Long-running reported leaks which the utility does not repair in a timely manner

Types of Leakage Reduction

Utility Value	Acoustic Monitoring	Pressure Monitoring	Flow Monitoring	Pressure Control
Find slow growing leaks	✓	✗	✗	✗
Find bursts	✗	✓	✗	✗
Find Household leaks	✗	✗	✓	✗
Decrease break rate	✗	✗	✗	✓
Improve Speed / Quality of Repair*	✓	✓	✓	✗
Decrease Real Losses	✓	✓	✗	✓
Decrease Unavoidable Losses	✗	✗	✗	✓
Extend asset life	✗	✗	✗	✓

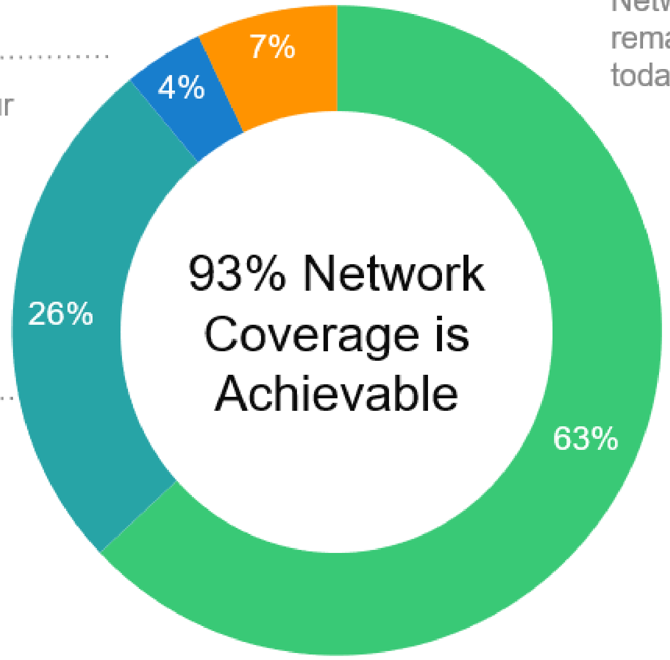
Using Modern Technology we can almost reach 100% Coverage

7% Undetectable

Network anomalies that remain undetectable with todays technology roadmap.

4% Flow Monitoring

Network anomalies that occur within households or commercial businesses. Frozen pipes, service leaks, burst water tanks etc.



26% Pressure Monitoring

Network anomalies that are detectable by pressure / transient monitoring. Bursts that are rapid caused by surges or catastrophic failures.

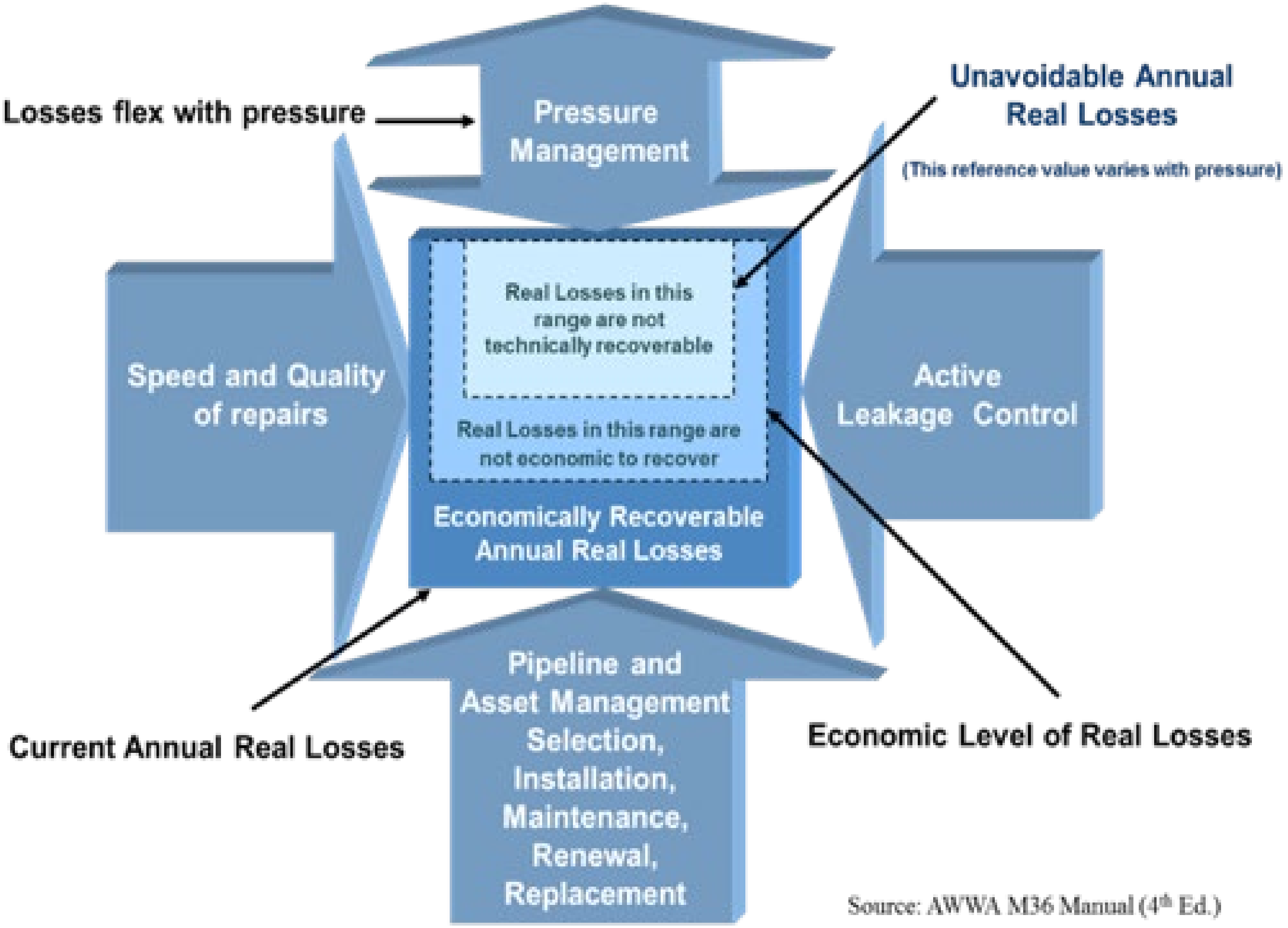
63% Acoustic Monitoring

Anomalies detectable by acoustic technology. Leaks that are slow growing: joint or corrosion based.

Minimizing Real Water Loss

Real Loss Control Actions

- Speed & Quality of Repairs
- Pressure Management
- Active Leakage Control
- Asset Management



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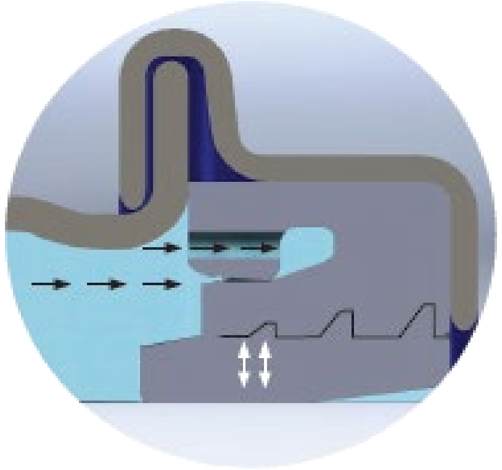
Speed and Quality of Repairs

Benefits of Repairing Pipe

- Improved operational efficiency.
- Lowered water system operational costs.
- Reduced potential for contamination.
- Extended life of facilities.
- Reduced potential property damage and water system liability.
- Reduced water outage events.
- Improved public relations.

Pressure Assisted Gaskets

- Dual sealing process which includes the mechanical sealing done by the bolt but additionally seals using the positive water pressure to hydraulically seal the gasket.



Restraint Systems Have Changed

- Reduce “point loading” of the pipe by using a gripping system instead of wedges.
- Offers even distribution around the entire circumference of the pipe.
- Gripping systems engage as the pipe try’s to angularly pull out due to pressure changes and ground movement.

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Nuts and Bolts “DO” Matter

- NASA invented MAG Tech
- MAG Technology – Molecular Anti Galling
  - Zinc Impregnated
  - Eliminates the need to grease
  - Can be re-used

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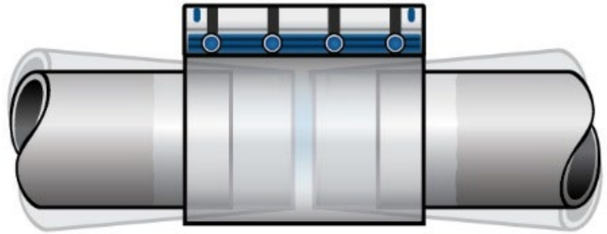
2 in 1 Products Stainless Steel Coupling

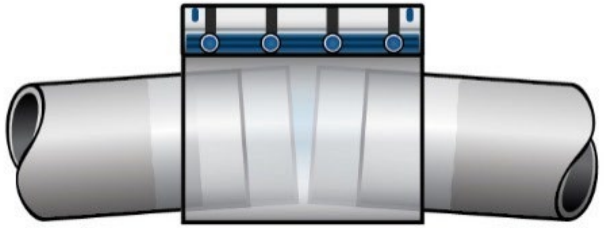
- Products that can be used as a coupling or as a wrap around clamp. This allows for smaller inventories which in turn saves you money.

Versa – Stainless Steel Wrap Around Coupling

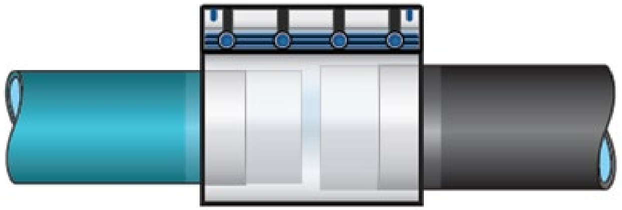
Join 2 pipe as a coupling



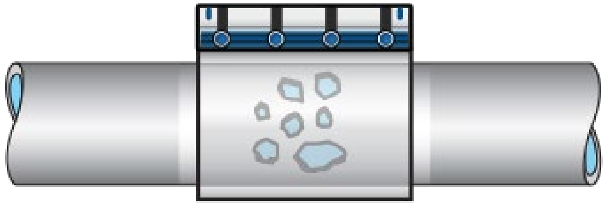
Join 2 pipes with an angle



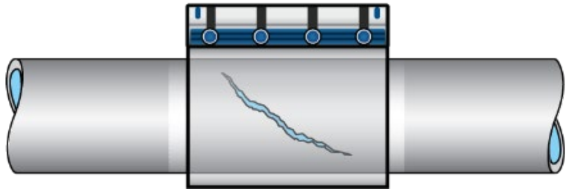
Join 2 pipes with different O.D



Repair holes



Repair Cracks



JOIN IT OR

REPAIR IT

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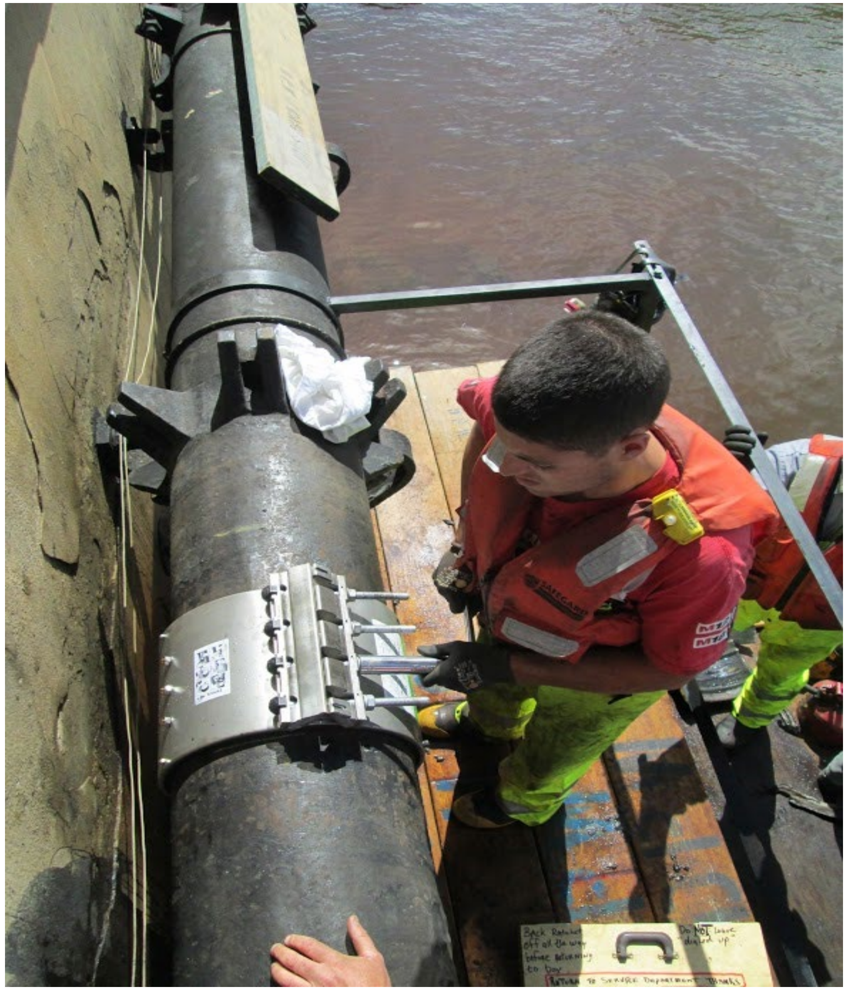
Applications: 78" Irrigation Pipe Repair

New Applications Available: HYMAX Versa Encapsulation:

- Encapsulates Couplers
- PVC, Galvanized Pipe, HDPE
- Great for Rural PVC Pressure Pipe

Fort Mason Bridge, San Francisco



One Size Fits All

DI

CI

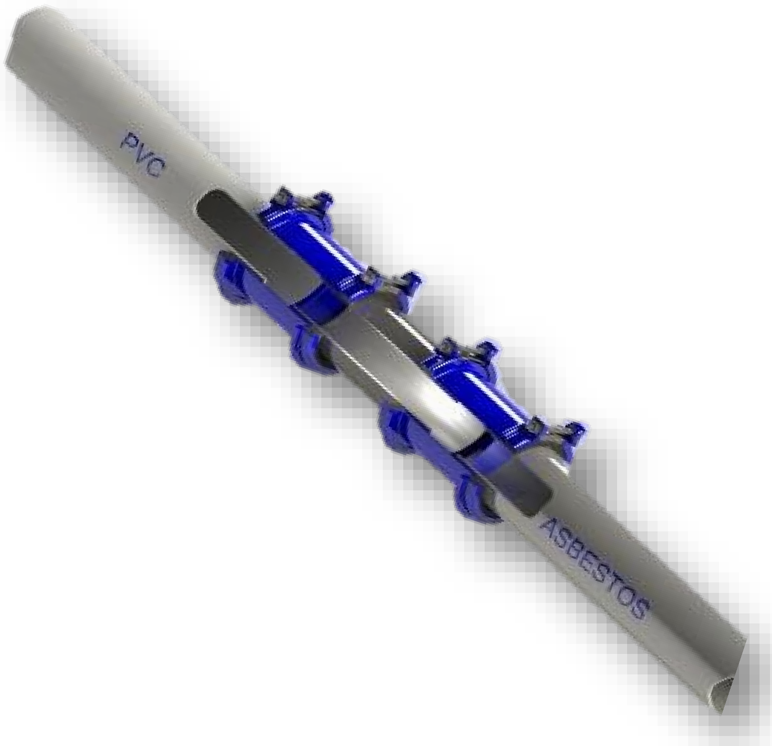
Steel

PE

PVC

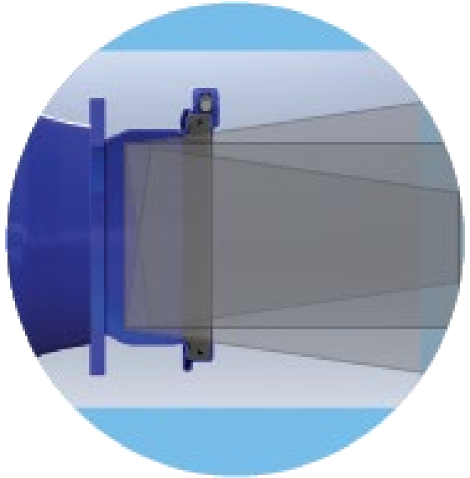
AC

GRP



Dynamic Deflection

- Angular Dynamic Deflection
- Allow for four degrees of deflection on either side.
- Deflection provides a “cushion” from ground movement and supports joints upstream and down stream to avoid future breaks.



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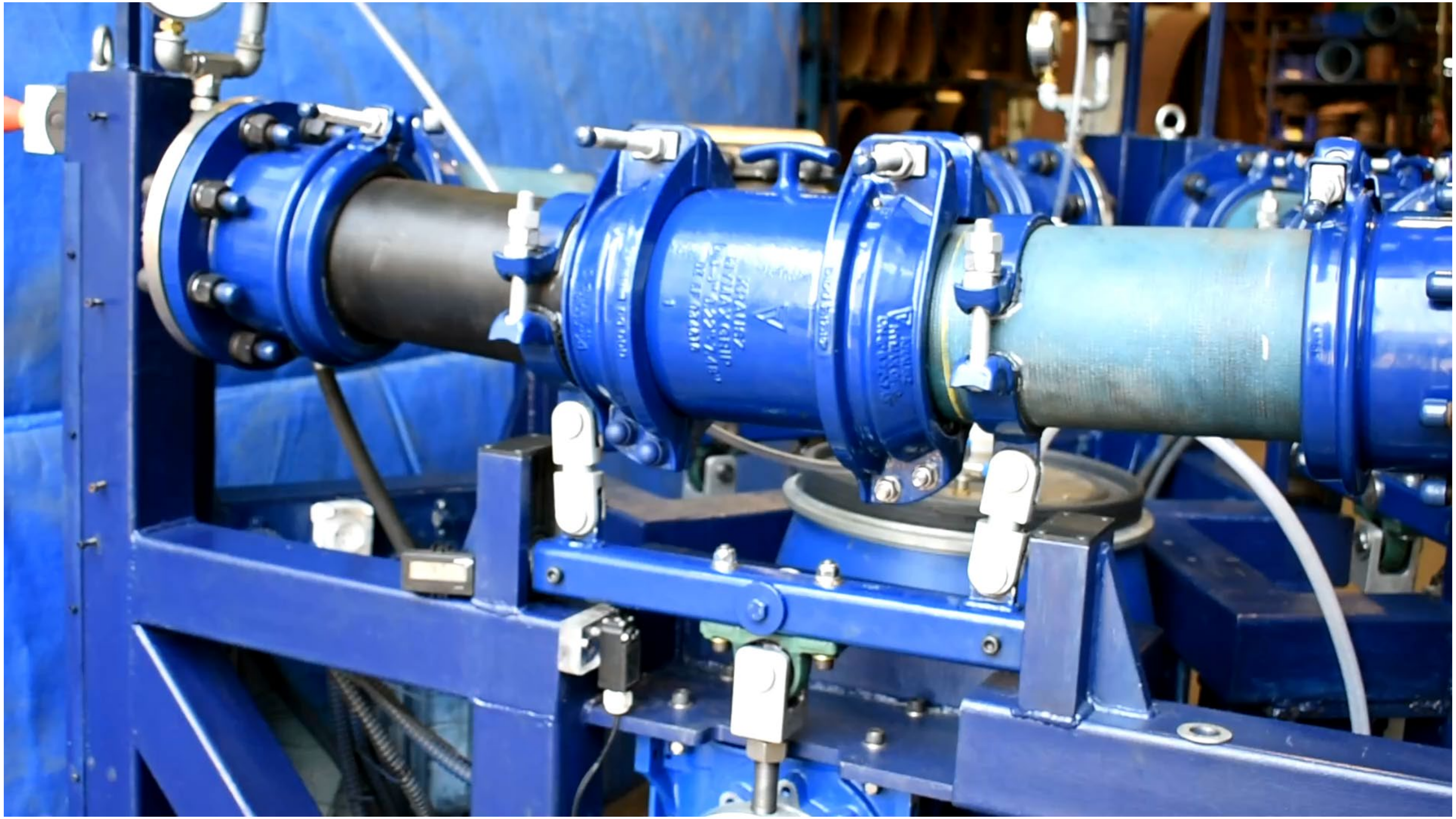
Dynamic Deflection Testing



HYMAX GRIP SwivelJoint

HYMAX GRIP SWIVELJOINT can connect and restrain two pipes at any angle from 0°to 90 °

HYMAX GRIP SwivelJoint

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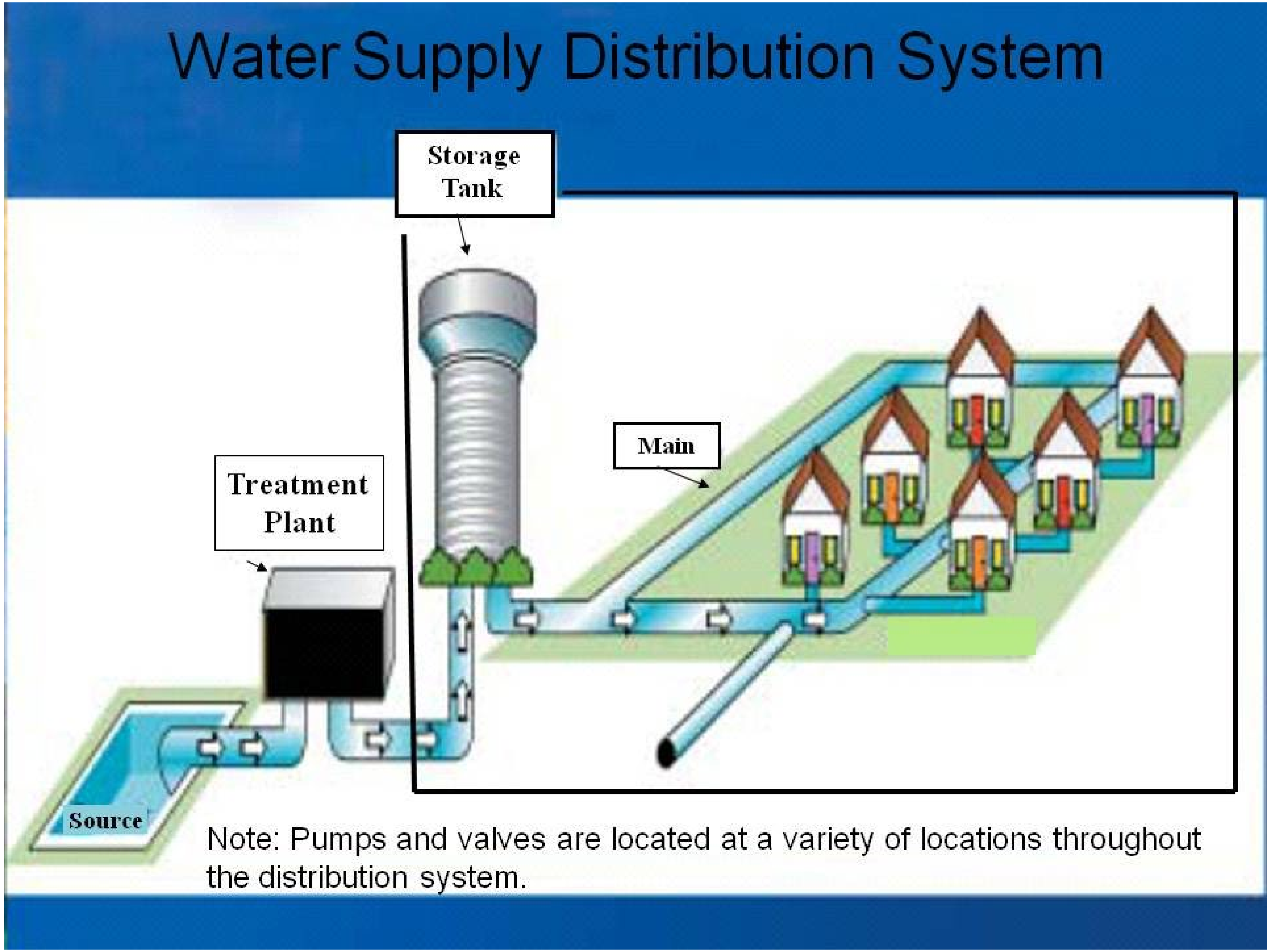
Pressure Management

Hydraulic Fundamentals



Hydraulic Fundamentals (cont.)

- An operator does not have to be a water engineer but should be aware of relationships among water volume, velocity, flow and pressure.

- It is helpful to review some of the fundamental principles of hydraulics – "*the study of fluids at rest and in motion*"

Fluid Statics - Rest

Fluid Dynamics - Motion

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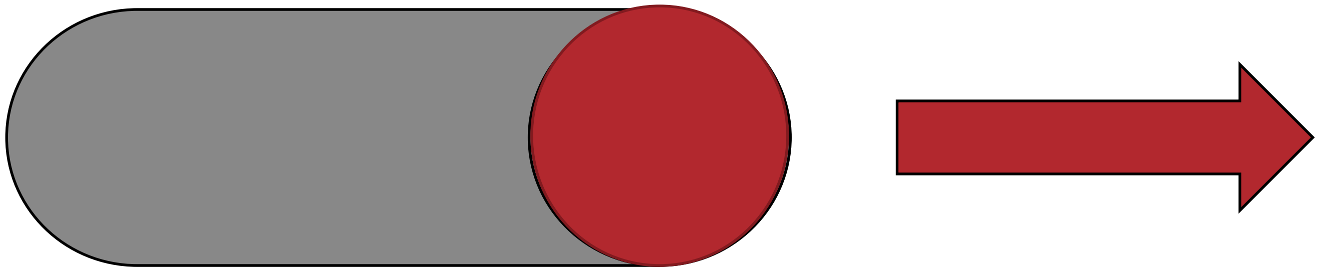
Flow

- Flow is expressed in units of volume divided by time: cubic feet per second, cubic meters per second, gallons per minute, or million gallons per day.

- The basic flow equation is Q = A x V
    - The "A" stands for the cross-sectional area of the flowing stream of water. The "V" in the formula stands for the velocity of flow (speed at which the water is moving) and is usually expressed in feet per second (ft/sec or fps).



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Pressure Head

- In a tank that is not airtight, the only pressure exerted is by the weight of water. This is known as pressure head. The deeper the water, the greater the pressure

- It depends only on the water depth, not on the volume of the tank.

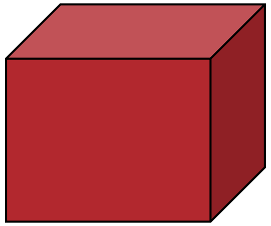
- Pressure head is commonly expressed either as head (feet of water), or as pressure (pounds per square inch or psi).

- A cubic foot of water weighs 62.4 pounds.

If 144 square inch columns exert a pressure of 62.4 pounds, then a single square-inch column exerts a pressure of:

62.4 pounds/144 square inches = 0.433 pounds per square inch or 0.433 psi

Head of one foot of water exerts a pressure of 0.433 psi.



12 Inches x 12 Inches

Pressure Head Example

If we have tank height of 60 ft

Pressure gauge would read:

60 x 0.433 = <u>25.98 psi</u>

60 / 2.31 = <u>25.98 psi</u>

1 Foot of water column = .433 p.s.i.

2.31 Feet of water column = 1 p.s.i.

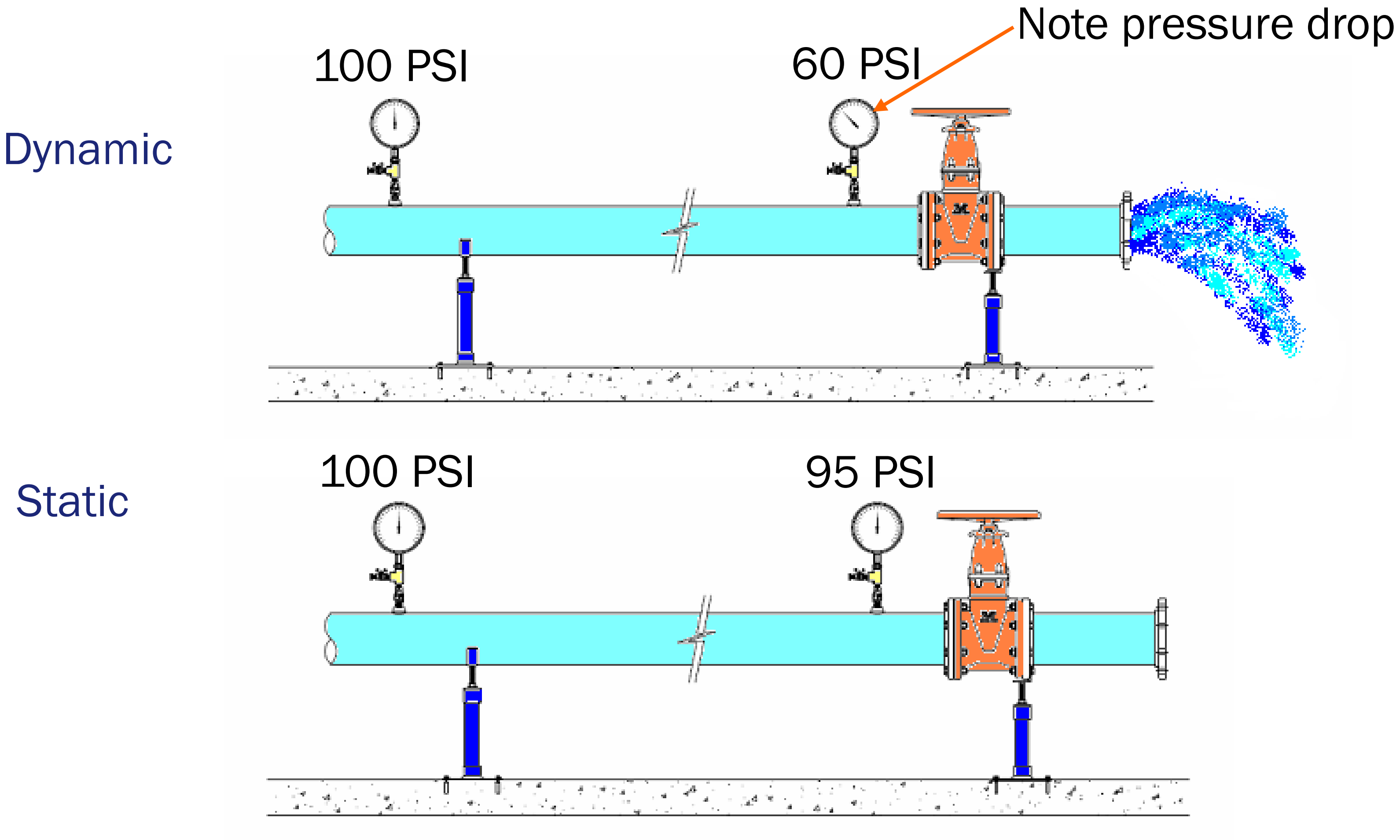
Operating Pressure

When a pipeline is flowing there will always be pressure drop. This is due to many factors, some are…

- the size of the pipe
- the age of the pipe (roughness of the inside)
- how much water is going through the pipe
- how many fittings or bends are in the pipe
- length of pipe

The pressure we see on the gauges during a flowing condition is known as operating pressure or dynamic pressure

Dynamic to Static Operating Pressure – Cause & Effect



What is the First Thing That Comes to Your Mind?

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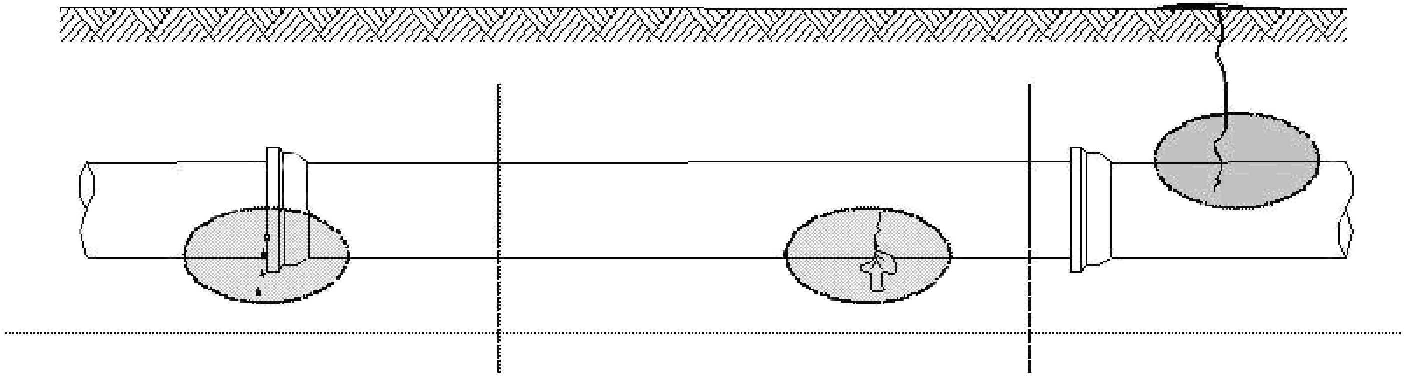
Break Frequency Reductions – Pressure Management

- Lower pressures potentially mean lower break frequencies.

- Break frequencies are generally higher at night time or off peak times when pressures potentially rise (dynamic to static pressure condition)

- Pipe breaks mean leakage but also have the associated cost of repairs as well – How much money does this cost your utility each year?

Pressure Management



Background Leakage

Un-reported and un-detectable using traditional acoustic equipment.

Tools

- Pressure stabilization
- Pressure reduction
- Main and service replacement
- Reduction in the number of joints and fittings
- Proactive leak detection

Un-reported leakage

Often does not surface but is detectable using traditional acoustic equipment.

Tools

- Pressure stabilization
- Pressure reduction
- Main and service replacement
- Adding sensors to detect underground assets
- Proactive leak detection

Reported leakage

Often surfaces and is reported by the public or utility workers.

Tools

- Pressure stabilization
- Pressure reduction
- Main and service replacement
- Optimization of repair time
- Proactive leak detection

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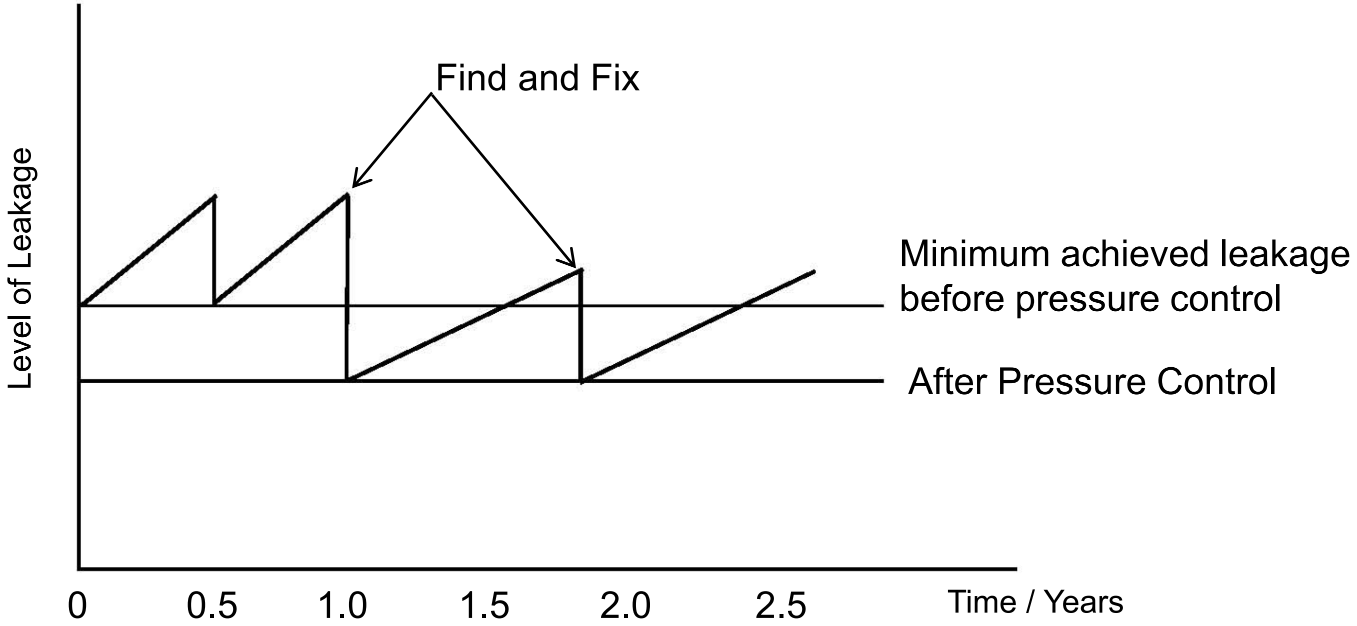
Pressure Management Benefits

- <u>Lower Operating Pressures - </u>Leakage Volume Reduction
- <u>Lower Operating Pressures - </u>Decrease in New Break Frequency



The rate of rise of unreported leakage is also reduced, leading to fewer economic interventions to find unreported leaks

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DMA – What is it?

- Established to have smaller zones of control in a utility distribution network
- Consists of a meter and pressure reducing valve (PRV) controlling pressure & measuring flow, or a single METERING Valve providing both functions controlling pressure and measuring flow
- Meter allows you to measure flow into a district and by comparing flow out of the district (metered customers) you have leakage (barring commercial losses and unbilled/unauthorized usage)
- PRV then is adjusted for that zone specifically with reduction in pressure resulting in reduction of leakage
- <u>1% reduction in pressure results in 1.15% reduction in lost water approximately.</u>

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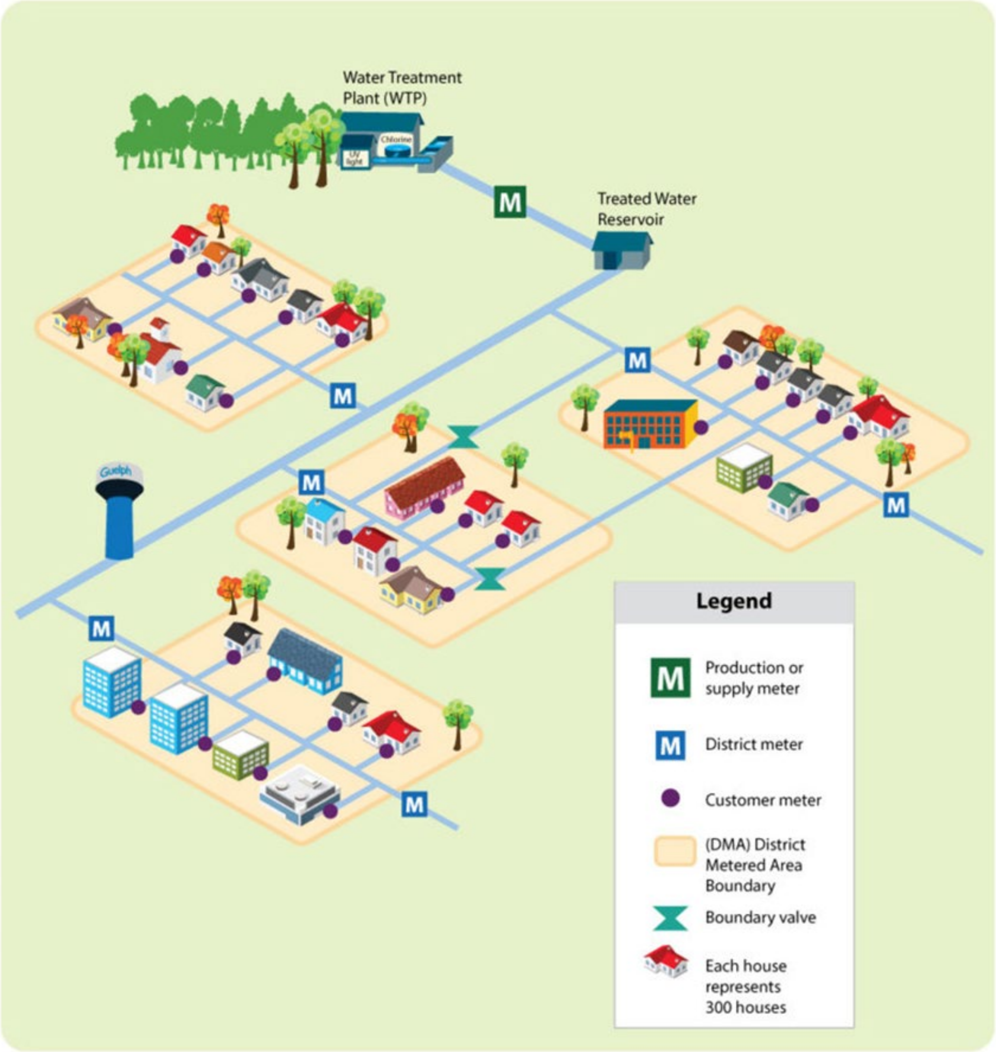
DMA Overview



Flow Based Pressure Management –

Reduction in max pressure based on demand reduces new breaks significantly as well as reduces NRW

10 psi reduction in max pressure results in a minimum 6% water loss reduction

20 psi = 14% reduction in water loss

30psi = 23% reduction in water loss

Primary Advantages of Establishing DMAs

- Better pressure optimization over a smaller zone of control
- Lower water losses - Financial savings
- Run times of leaks are typically shorter as they are easier to identify
- Active leakage control is easier
- The areas within the network are more defined, smaller and more manageable

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Actual DMA - PRV & Metering Station Pre - Installation

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Pressure Management

Time Based PRV's – Two Set Points

- One pilot set for low flow (night flow)
- One pilot set for high flow (day flow)
- Solenoid used to switch between pilots – daytime and night time demand pressure settings
- Local simple electronic timer or SCADA – (power availability is required)
- Caution on fire flows which must be calculated into night flow set points

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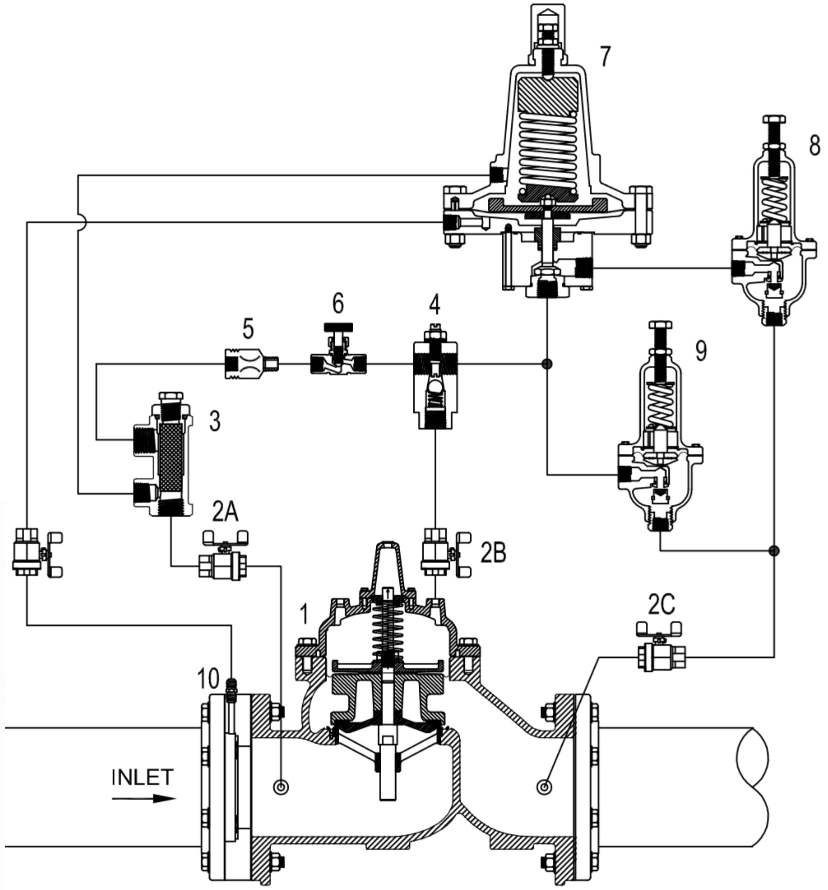
2 Step Pressure Management Valve

- The 2 Step PMV is a standard PRV with 2 additional pilots and a minimal restriction in line.

- It automatically controls between 2 downstream pressure set points depending upon system demand, (not time)

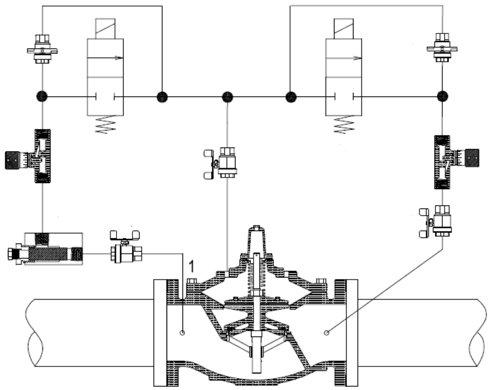
- Flow Based Pressure Management



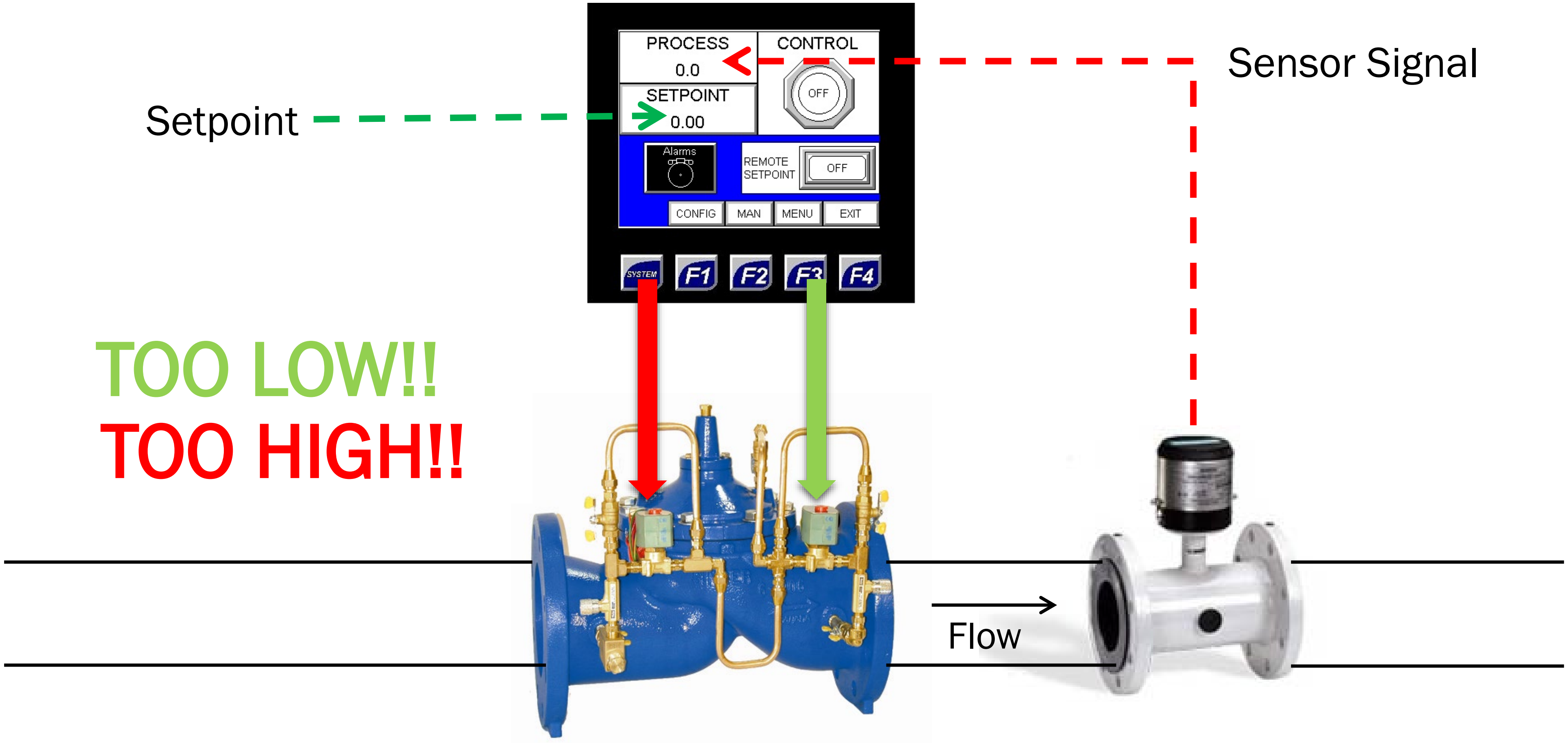
Model 2PR-630

Electronic Pressure Management

- Dual Solenoid Control
- Solenoids are energized or de-energized to position the valve
- Power failure results in failure option,
  - Fail Closed
  - Fail Open
  - Fail Last Position
  - Fail to redundant hydraulic back up
- Continuous adjustments of flow based on changing pressures – Flow Modulation

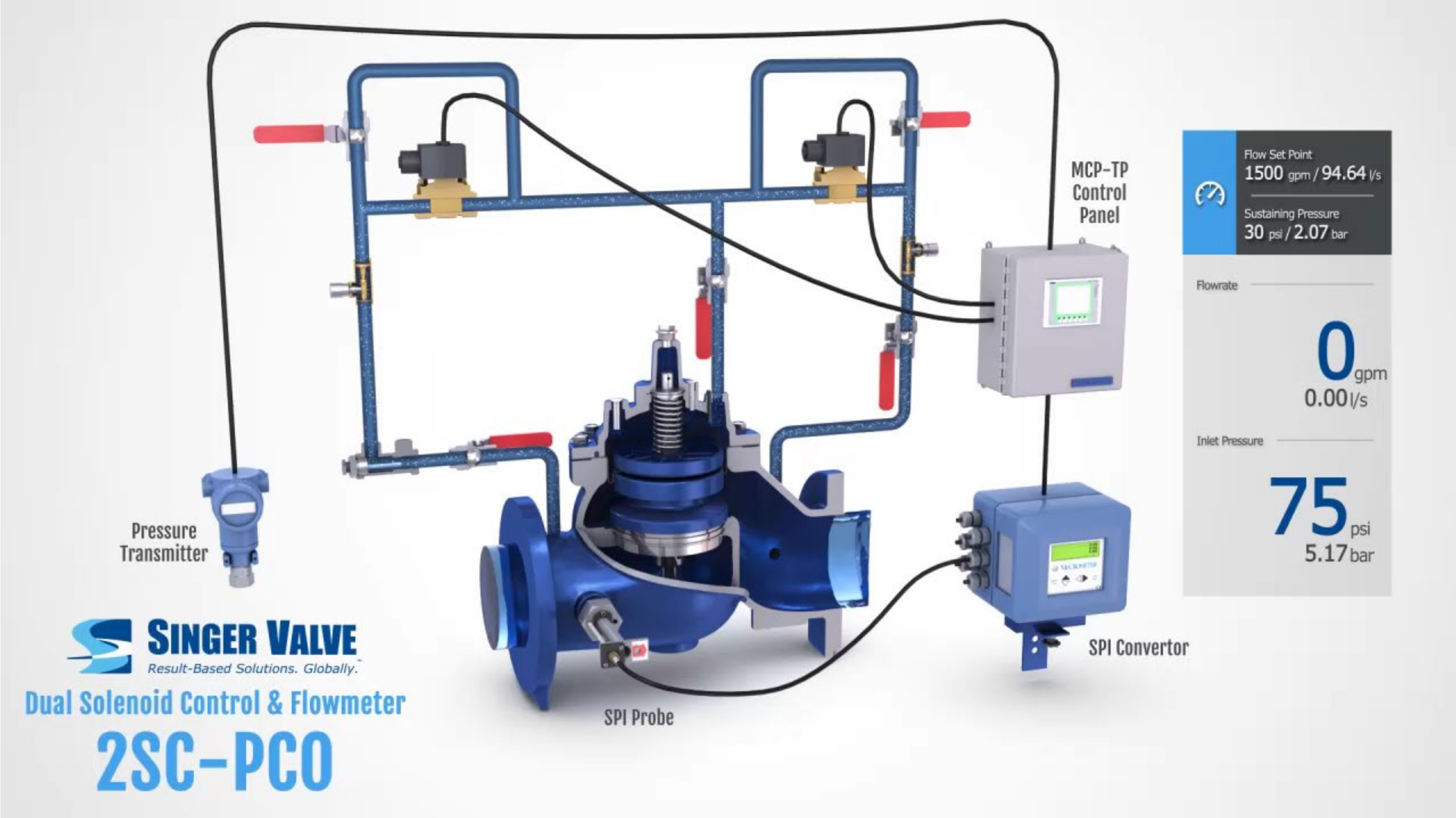


Electronic Flow Control



Example: Flow Based Pressure Management

Electronic Valve Example



What if you don't have power to the vault?

Single Pressure

Bi-directional flow

Triple Pressure

Bi-directional flow

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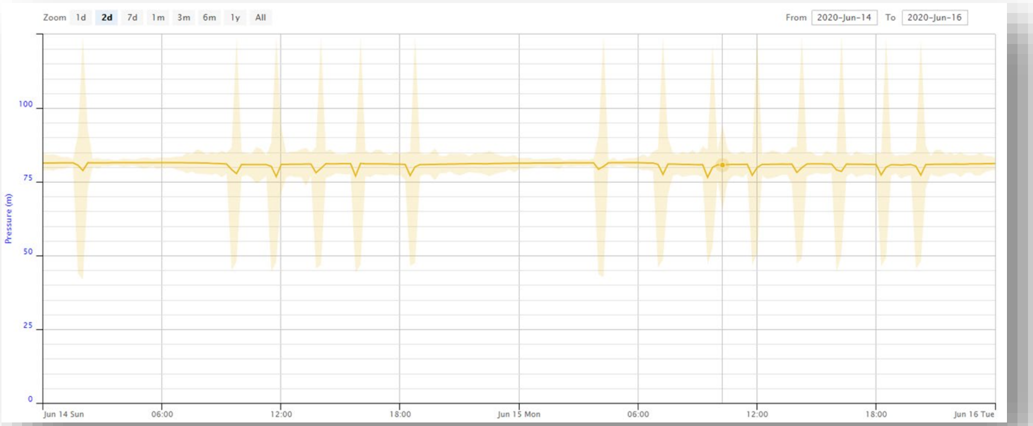
Loggers collect uniquely valuable information

For Transient Detection at 1Hz:

- Mean
- Max
- Min
- Standard deviation



For PRV Monitoring:

- Inlet & Outlet Pressures
- Control Chamber Pressure for Performance Evaluation

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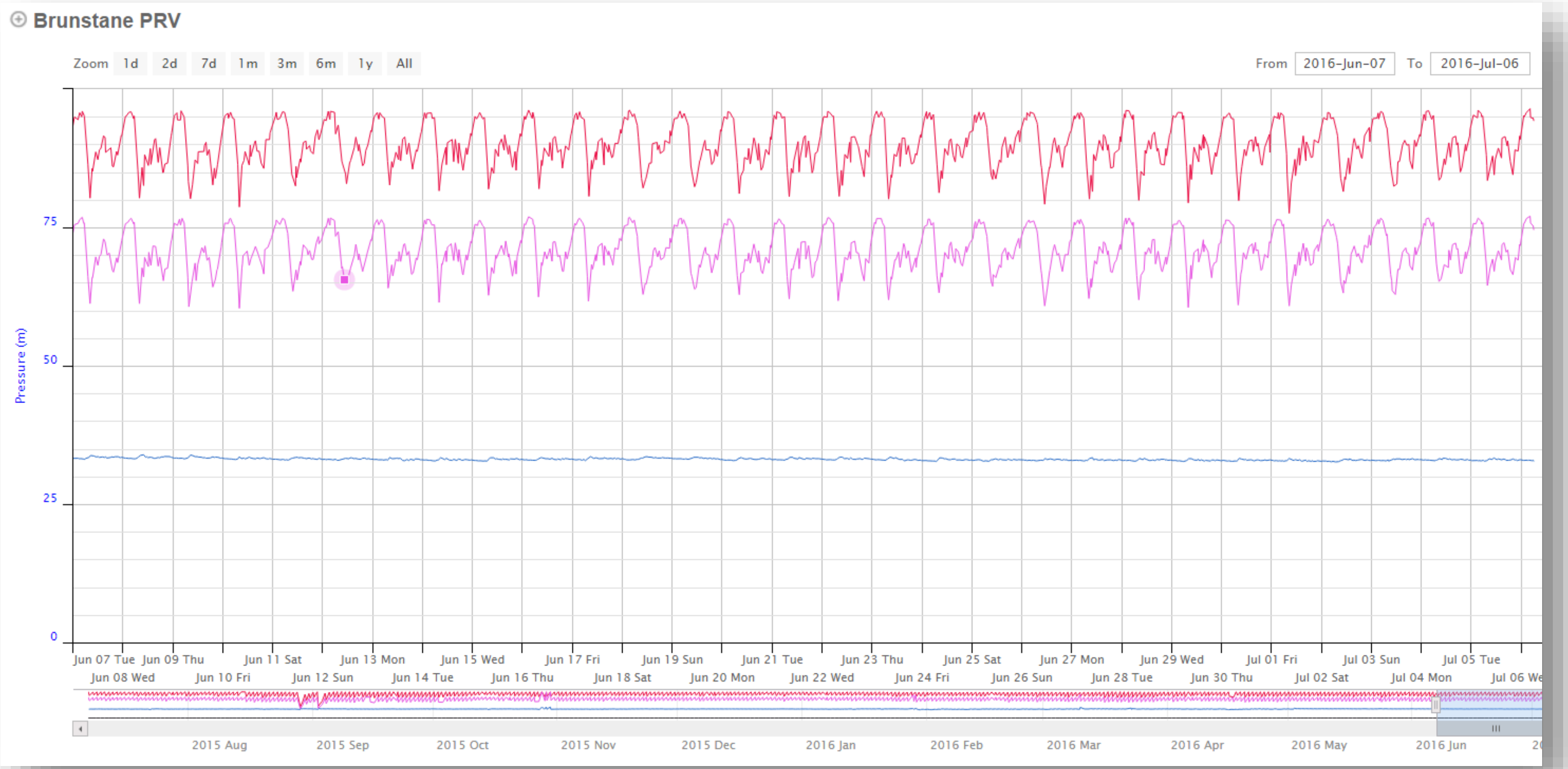
PRV Condition – PRV working well



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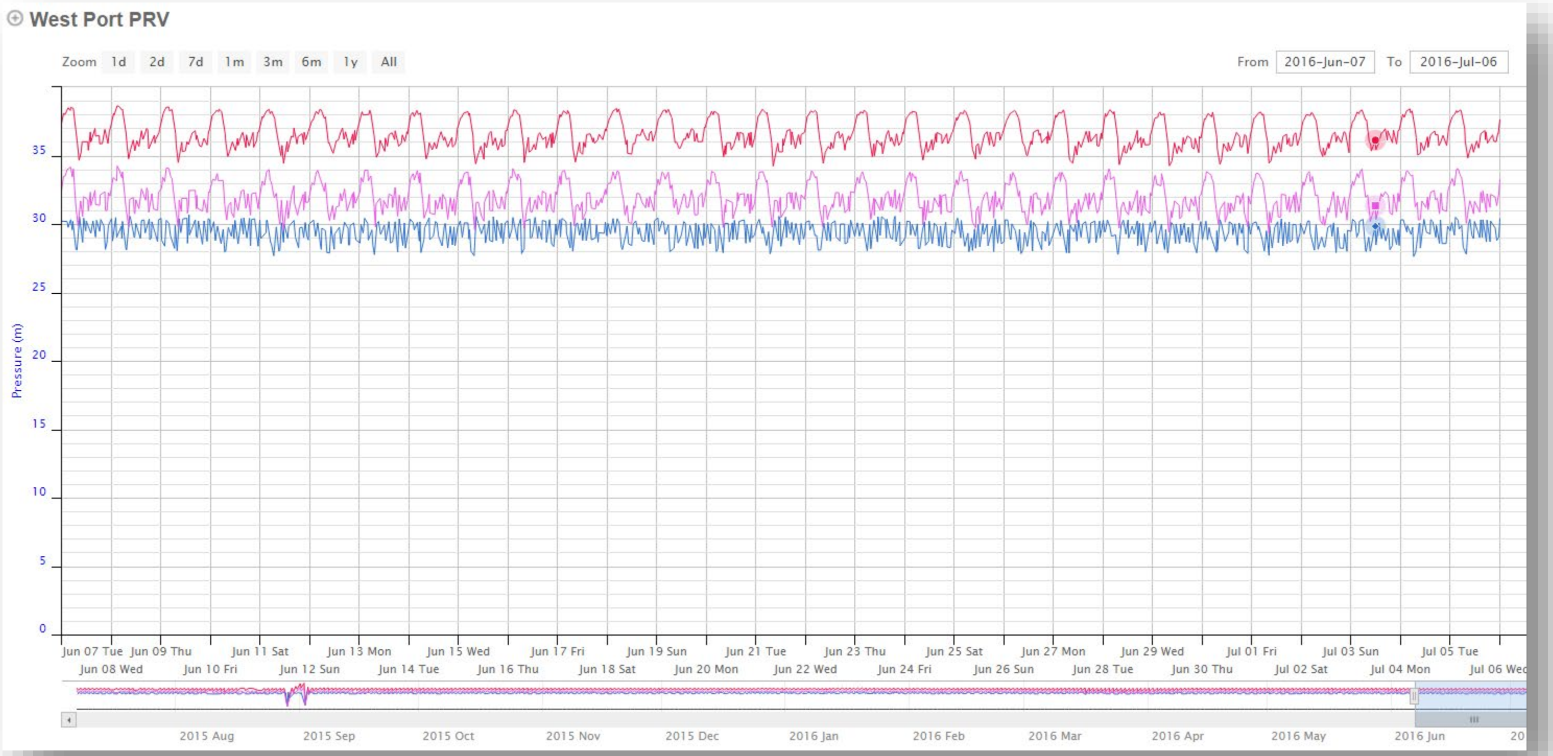
PRV Condition – unstable PRV outlet pressure



The downstream pressure is unstable due to insufficient upstream pressure during higher demand periods. The downstream set point can not be met.

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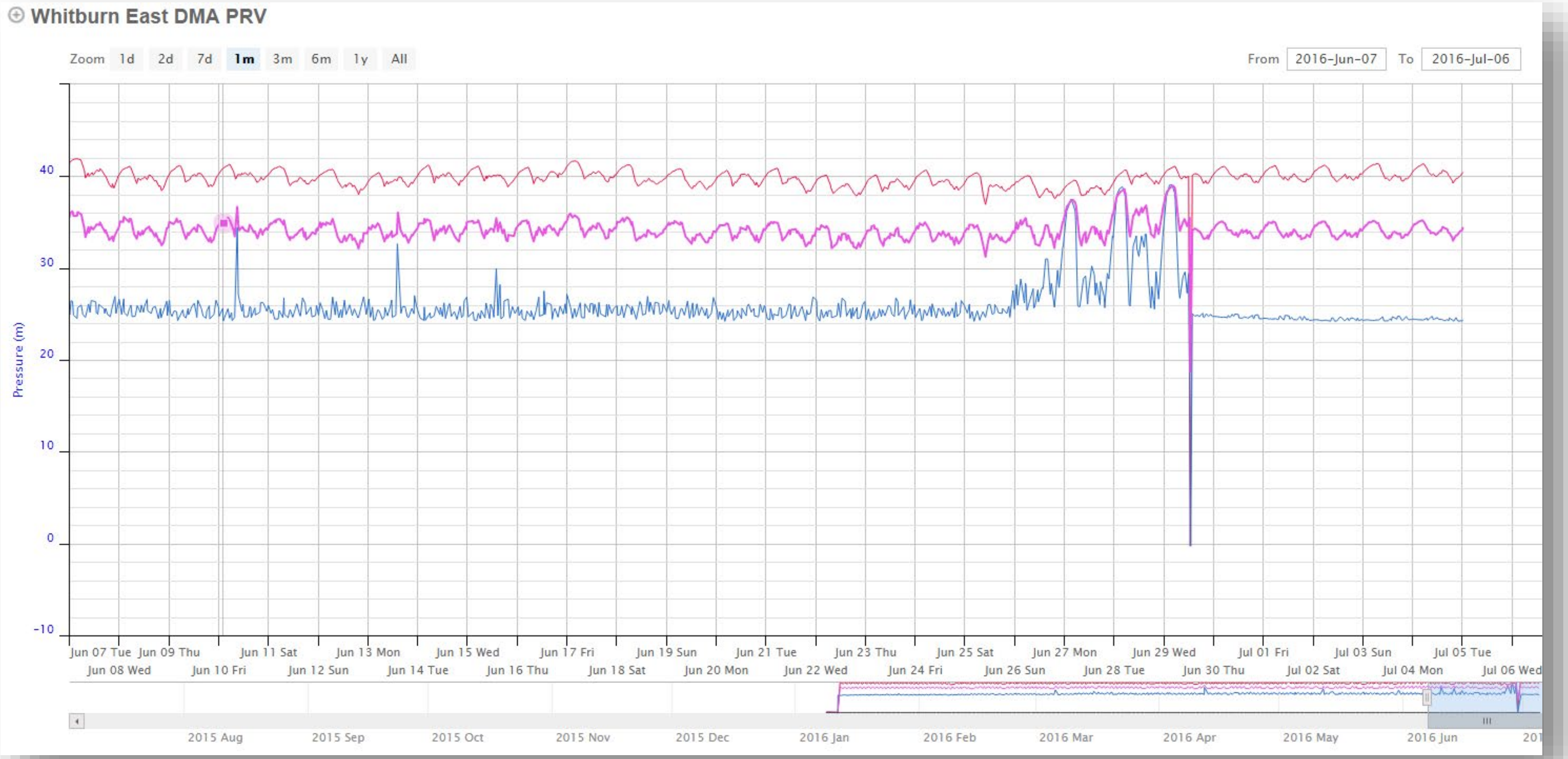
PRV Condition – Debris in the PRV



From 27th June it is clear that something is preventing the PRV from closing sufficiently at low flow; likely to be debris under the diaphragm. This caused downstream pressure to climb.

50
50

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The future of control valves

PRV

Monitored PRV

+

Control
Logger

Remotely controlled PRV

+

Advanced pilot valve (APV)

Automatically optimised PRV*

+

Control
point logger

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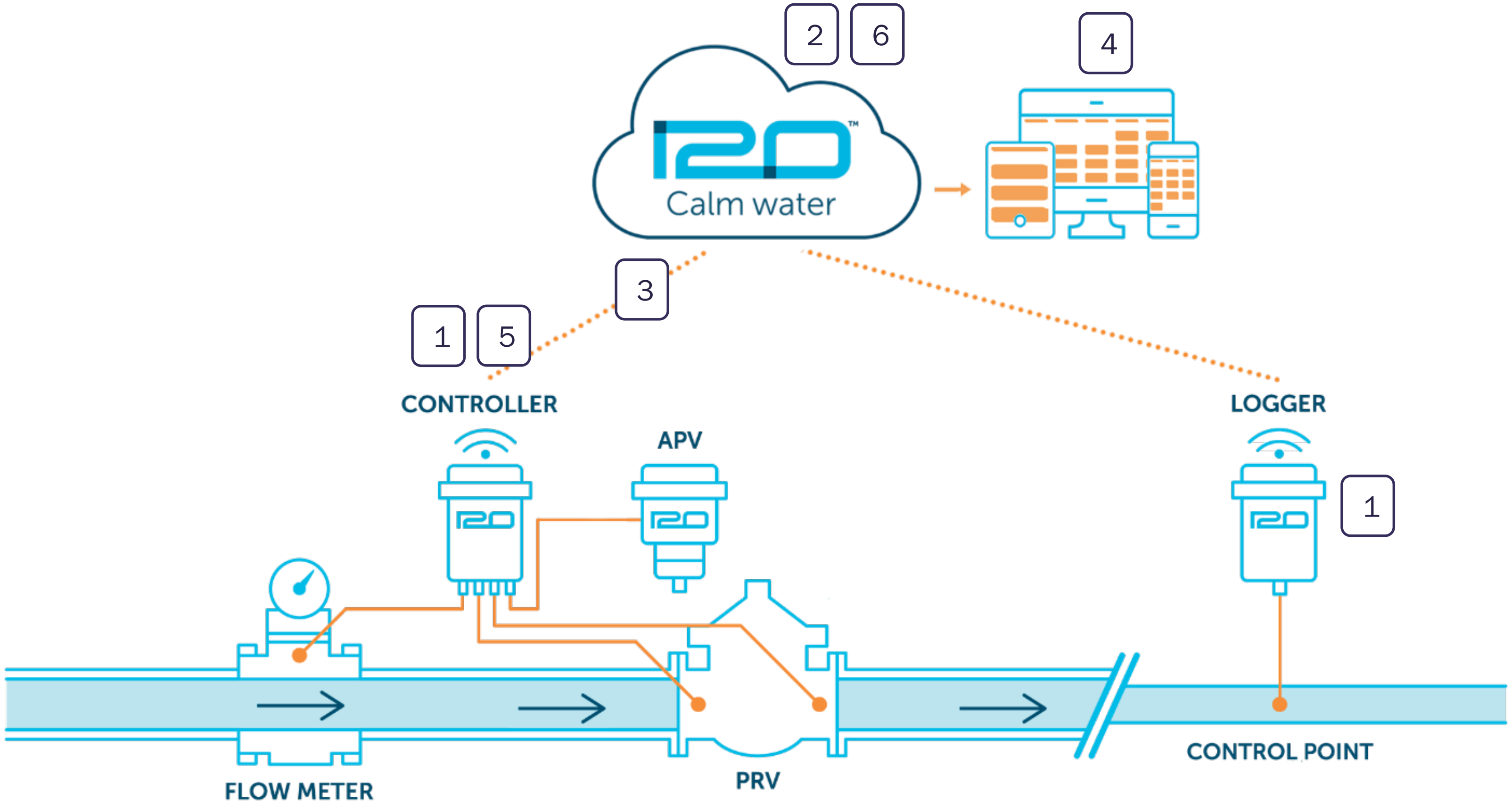
How Advanced Pressure Management works

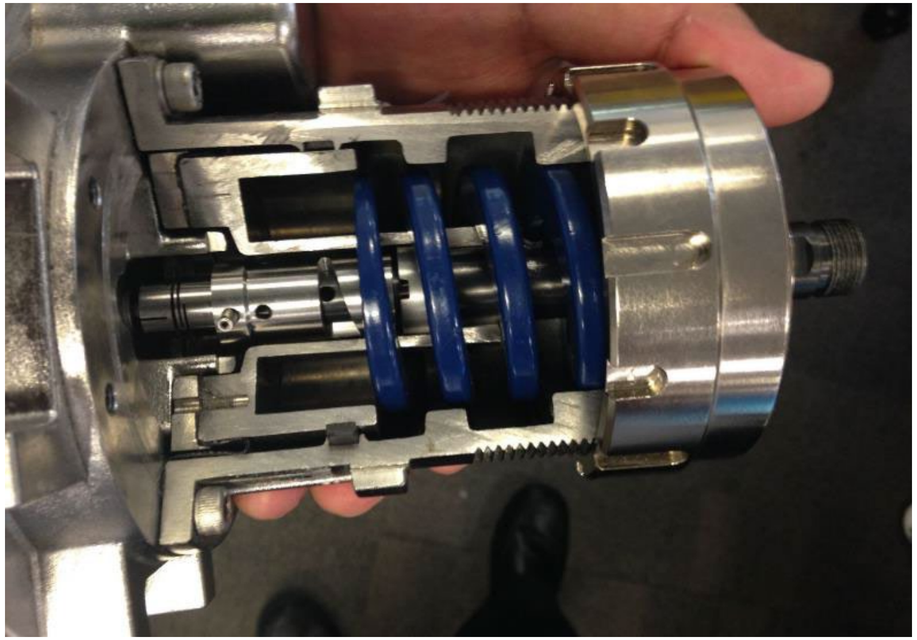
1. Flow and pressure data is recorded and sent to cloud platform
2. Flow-related head-loss curve created using algorithm
3. Head-loss curve sent to PRV controller
4. Client sets target pressure for critical point
5. Controller reads flow in real-time and instructs the Advanced Pilot Valve what outlet pressure is required
6. Pressure and flow data re-analysed each day and head-loss curve updated if necessary



PRV control has a number of control modes

- Fixed downstream pressure
- Flow modulation using water company-defined outlet pressure table
- Automatic optimisation using outlet pressure table created by system algorithm
- Scheduling function for each and all control modes
- Ability to mix modes at different times
- Ability to schedule at least 1 year in advance

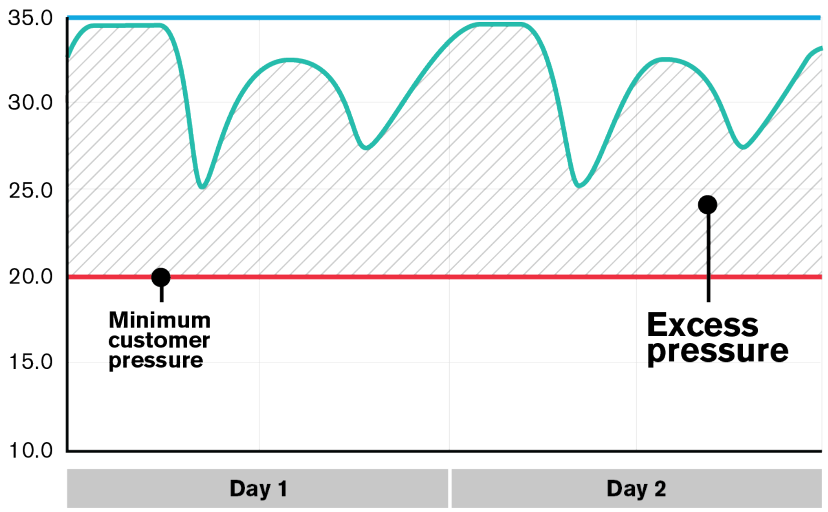
The Advanced Pilot Valve (APV) is usually installed in parallel with the existing pilot and delivers precise and smooth pressure changes



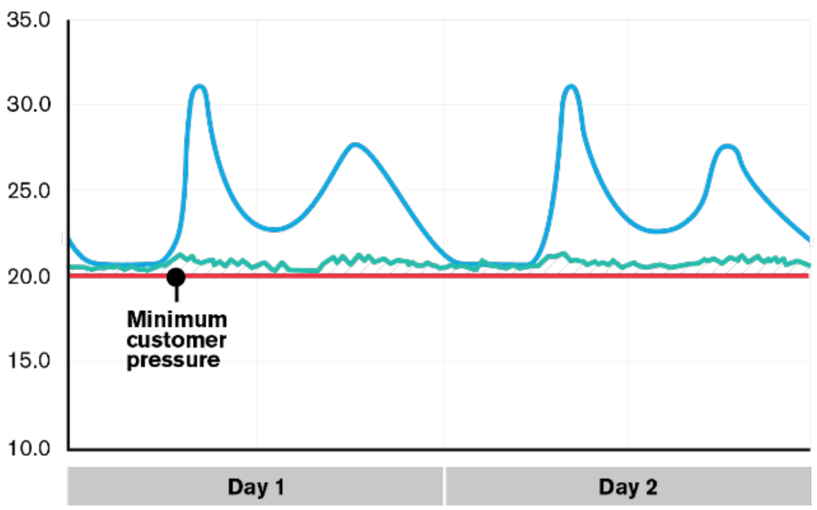
- The i2O control system uses a dedicated pilot valve – a high precision patent protected device designed for continuous actuation, providing precise and smooth control, and minimising battery power required to drive it
- Pressure can be set to reduce gradually over a defined time period to minimise customer complaints with minimum effort
- Ability to select control sample period to allow for unusual zone profiles
- Tunable fine control parameters to ensure the optimal settings for each zone

Advanced Pressure Management is used to reduce over-pressure which in turn reduces leakage, bursts and open-tap demand.

BEFORE: fixed outlet pressure at the PRV with over-pressure in the network



AFTER: varying outlet pressure with minimal viable pressure for customers



PRV outlet pressure

Control point pressure

Minimum viable pressure

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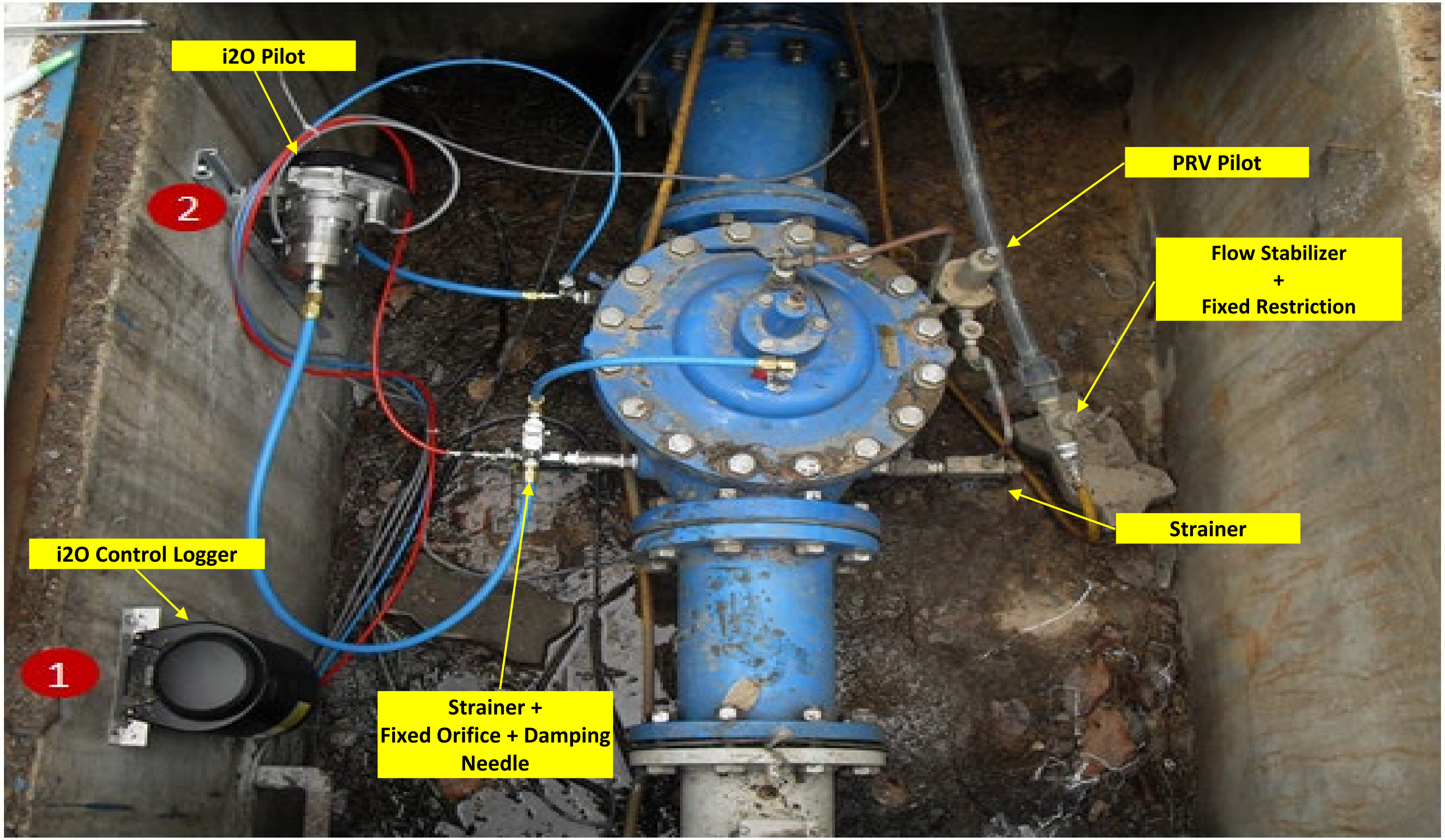
Typical Installation



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Active Leakage Control

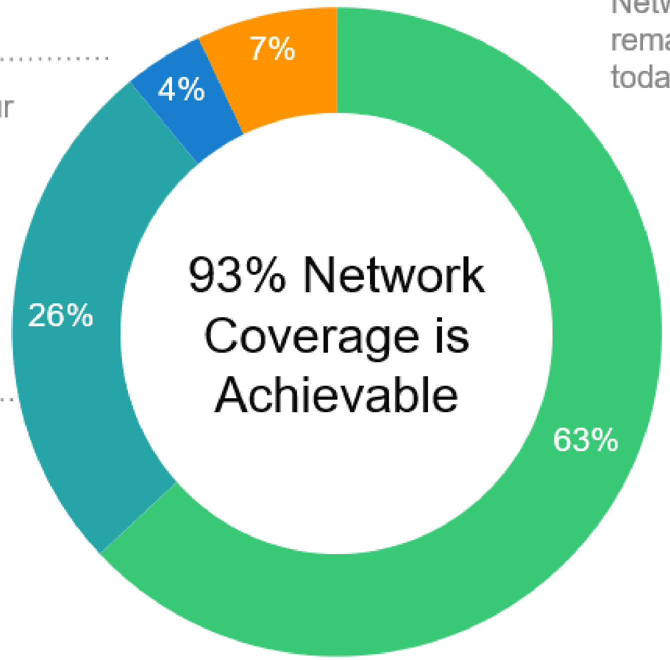
Acoustic, Pressure and Flow Monitoring are Complementary Tools for Leak Detection

4% Flow Monitoring

Network anomalies that occur within households or commercial businesses. Frozen pipes, service leaks, burst water tanks etc.

26% Pressure Monitoring

Network anomalies that are detectable by pressure / transient monitoring. Bursts that are rapid caused by surges or catastrophic failures.



7% Undetectable

Network anomalies that remain undetectable with todays technology roadmap.

63% Acoustic Monitoring

Anomalies detectable by acoustic technology. Leaks that are slow growing: joint or corrosion based.

Leak Detection Methods

- **External Acoustic Methods: Distribution Systems**
  - Sounding
  - Listeners
  - Correlators
  - Systems
    - Loggers
    - Fixed correlating
- **External Acoustic Methods: Transmission Systems**
  - Correlators / hydrophones
- **Internal Acoustic Methods**
  - Tethered hydrophone
  - Free swimming hydrophone
- **Non-Acoustic Methods**
  - Gas Tracer
  - Ground Penetrating Radar
  - Thermography
  - Low-voltage Conductivity
  - Satellite

Leak detection is primarily used to find sources of water loss

Also used as a pipeline performance indicator:

- Failure analysis
- Prioritize pipes for inspection
- Prevent breaks

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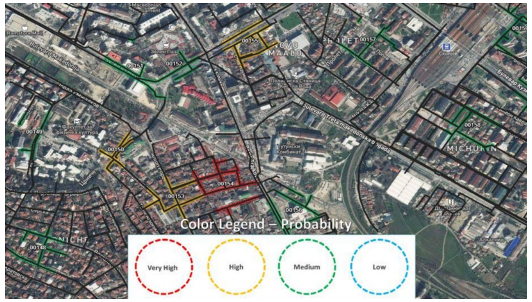
Satellite

Technology Description

- Microwave images acquired from satellites
- Images are analyzed for potable water signature
- An entire network can be analyzed at once



Applicable Pipelines

- All pipe diameters
- All pipe materials
- Applicable 3’ - 10’ depth

Analysis Output

- GPS coordinates of leak areas
- Categorized likelihood of leak

Limitations

- Urban areas
- Clay, swampy soils
- 300’ radius accuracy
- Bends, restrictions
- 1,000’ distance

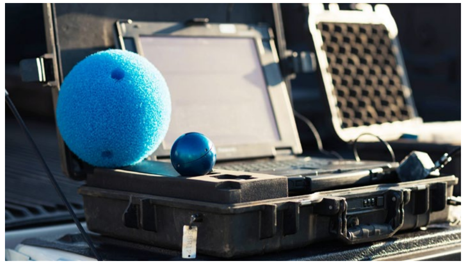
Typical Economics

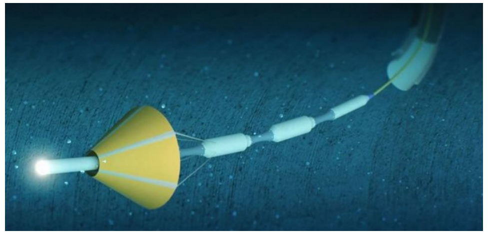
	Transmission	Distribution
Minimum project	$12,500	
Inspection Cost	$420/mile	
Site Preparation	$0	

Internal Acoustic Leak Detection

Technology Description

- Free-swimming or tethered equipment
- Flow carries tool through pipeline during inspection
- Hydrophone listens for leak sounds as tool travels





Applicable Pipelines

- Distribution/Transmission
- Cast Iron, Ductile Iron
- Asbestos Cement
- Steel, Concrete
- PVC, PE
- 6” and greater pipe diameters

Analysis Output

- Locations of leaks
- Visual inspection (if camera on tool)
- Gas pockets

Limitations

- Pipe access for launch/retrieval
- Flow velocity
- Bends, restrictions
- Valves
- Pre-cleaning
- Tool disinfection

Typical Economics

	Transmission	Distribution
Mobilization Cost	$25,000	$25,000
Inspection Cost	$12,000/mile	$12,000/mile
Site Preparation	~$2,500/mile	~$4,000/mile

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External Acoustic Leak Detection

Technology Description

- Sounding survey – techs listen (aurally) for leaks using listening tools.
- Correlation survey – techs use correlators and FFT analysis to locate leaks

Applicable Pipelines

- Distribution/Transmission
- Cast Iron, Ductile Iron
- Asbestos Cement
- Steel, Concrete
- PVC, PE
- All pipe diameters (<16” most common)

Analysis Output

- Locations of leaks

Limitations

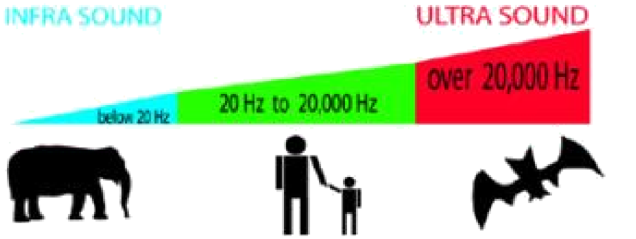
- Labour intensive
- Skilled labour required
- Subjective (sounding)

Typical Economics

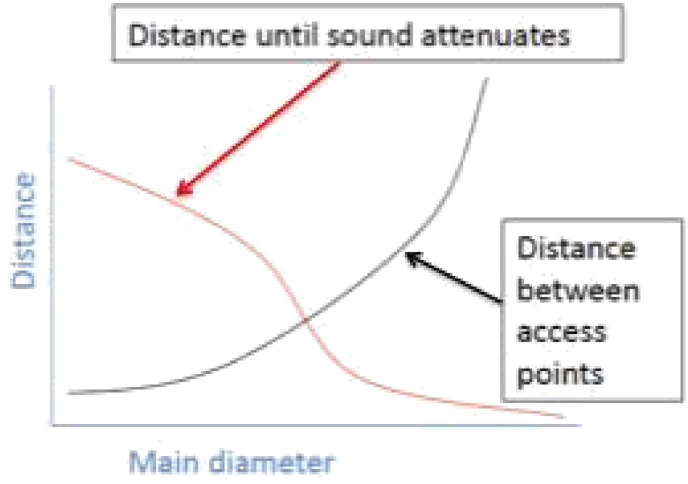
	Transmission	Distribution
Mobilization Cost	$n/a	$n/a
Inspection Cost	$10,000/mile	$300/mile
Site Preparation	$3000/pothole	$n/a

Leak Noise Basics: Size (& Type) of Pipe Matters

- Small leaks vibrate at higher frequencies; large leaks at lower frequencies
- Larger pipe will not carry sound as far as smaller pipe made of same material
- Leaks from metal pipe generate more noise that travels farther than leaks from cement or plastic pipes
- Transitions in pipe materials (with clamps and couplings) muffle leak noise



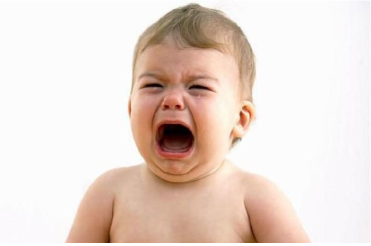
Human Optimum	200 - 4000 Hz
150mm Cast Iron Pipe	200 - 1000 Hz
150mm PVC Pipe	10 - 50 Hz
1200mm Cast Iron Pipe	10 - 80 Hz



Frequency Examples

Human Male Voice: 125 – 2000Hz

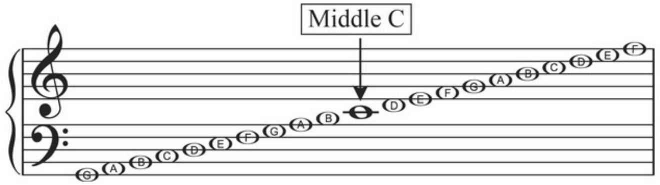
Human Female Voice: 250 – 5000Hz



Baby Crying: 1000 – 5000Hz

Music- Middle C Note: 256Hz

Music- Middle A Note: 440Hz



Typical ¾” copper pipe leak: 400 – 2000Hz

Typical Cast Iron or Ductile Pipe: 200 – 800Hz

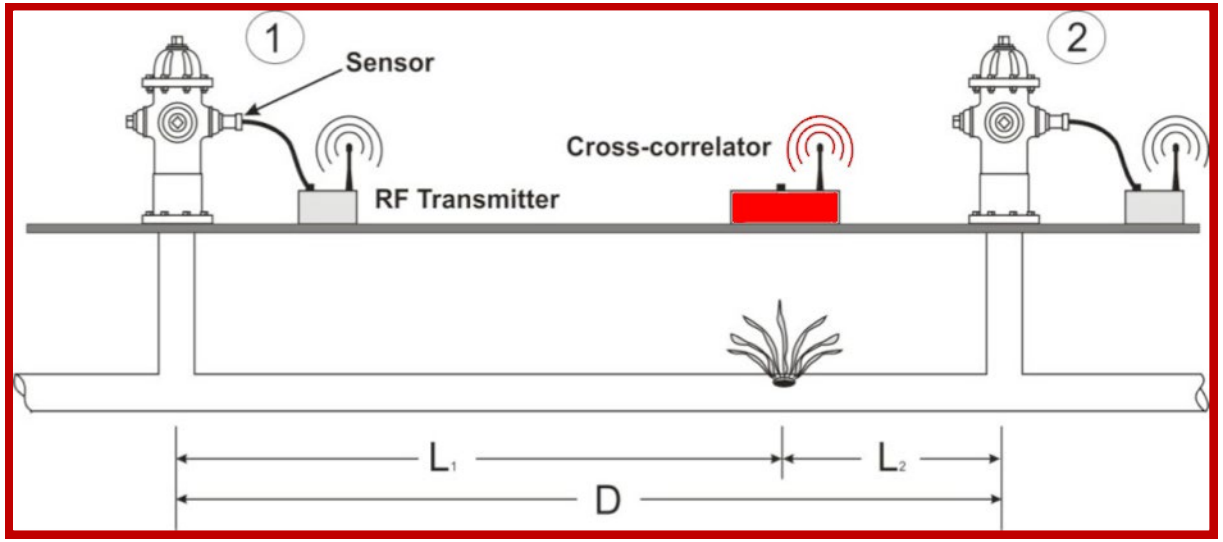
Harmonic of a Cat Purr: 50Hz

Typical 6” PVC Pipe: 5 – 30Hz

How Do Correlators Work?

How it works:

- Bracket the leak with two sensors
- The leak noise takes longer to arrive a point 1 than point 2
- Correlator measures this difference and determines the exact leak location



Known parameters:

D ⟶ Total distance

V ⟶ Velocity of wave sound

Find L_1

Sensor Connection Points

Fixed Leak Monitoring

Technology Description

- Permanent or semi-permanently installed acoustic sensors.
- Sound logging for leak surveys (logging)
- Auto correlating for leak identification/monitoring

Applicable Pipelines

- Distribution/Transmission
- Cast Iron, Ductile Iron
- Asbestos Cement
- Steel, Concrete
- PVC, PE
- All pipe diameters (<24" most common)

Analysis Output

- Locations of leaks
- Frequency spectrum

Limitations

- Communications
- Sensitivity varies with pipeline access

Typical Economics

	Transmission	Distribution
Design/Install	$30,000/mi	$8,000/mi
Annual Monitor	$6,000/mi-yr	$400/mi-yr
Site Preparation	Variable	$n/a

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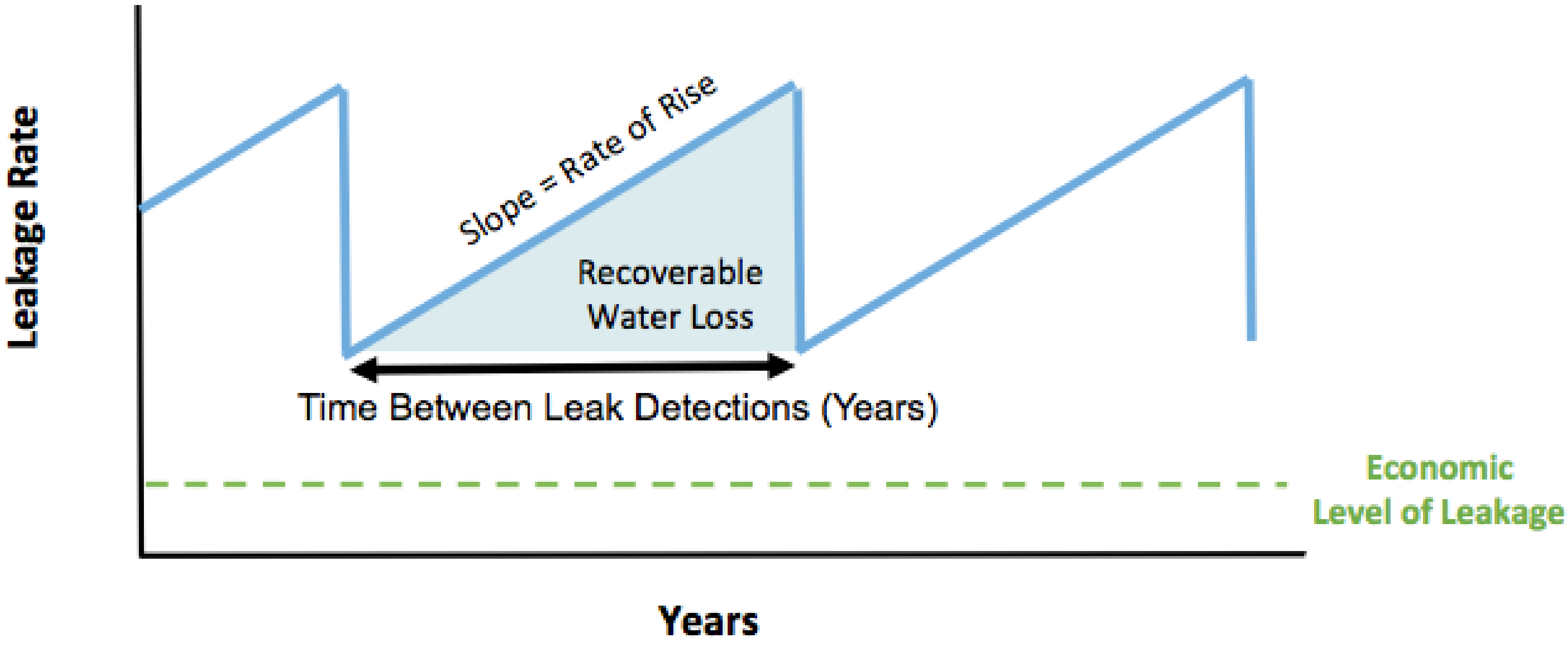
Pipeline Monitoring – What are we looking for?

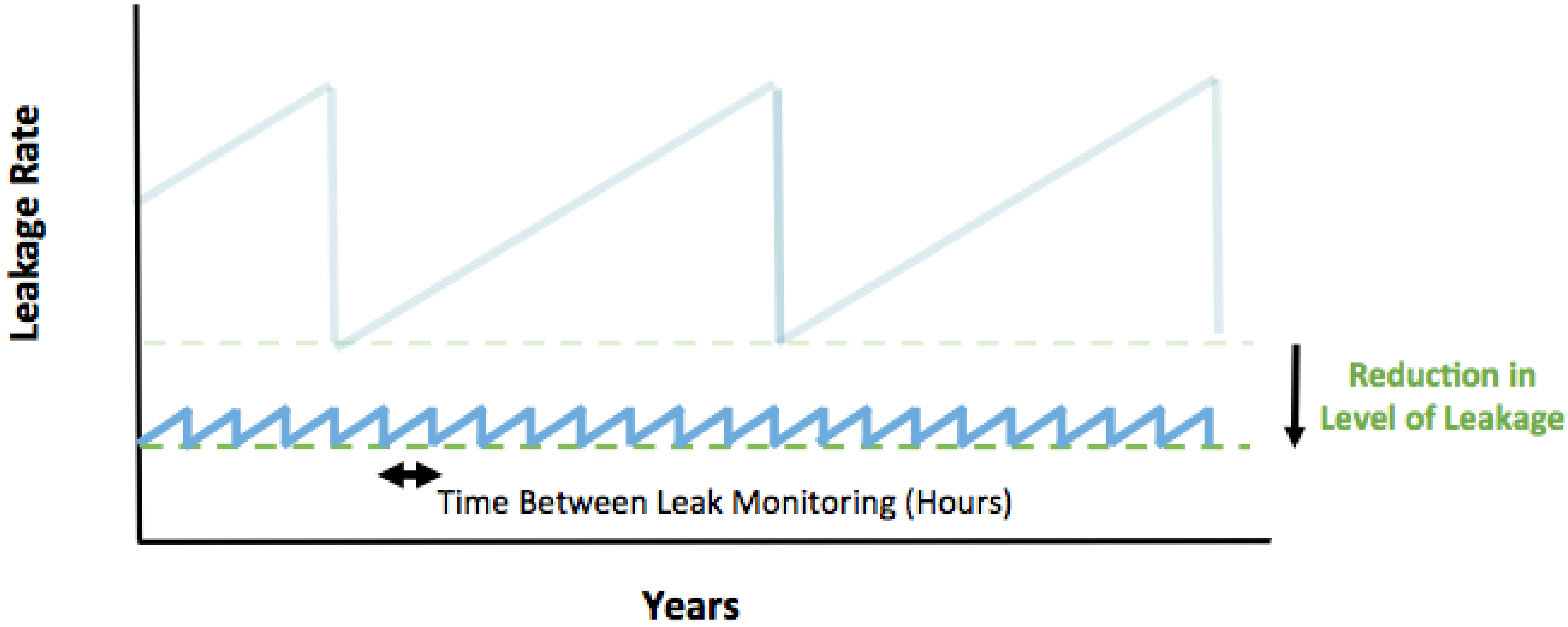
Know when this starts.

To avoid having this happen!

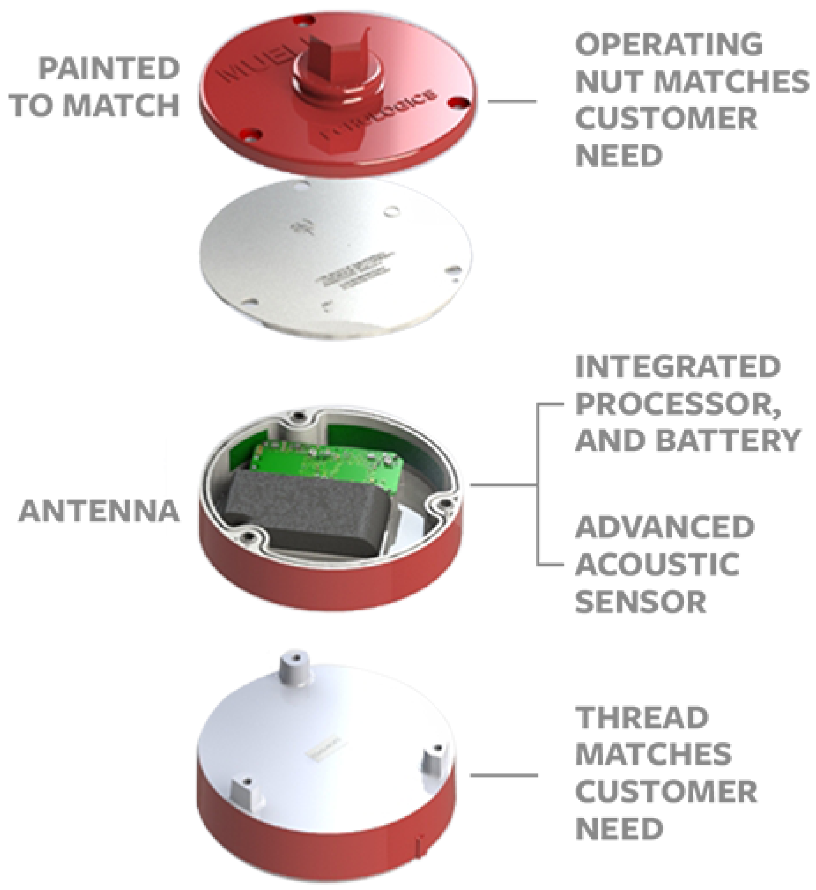
Active Leakage Control



Fixed Leak Monitoring



Seamless Integration



10-year product + battery life

Hidden in plain sight

Harmonized design

Works for both wet and dry barrel hydrants

Works over 4G LTE-M cellular network

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Pumper Nozzles or Side Caps – Adaptable!

System Advantages

Design Flexibility

- Detects Leaks on cast iron, ductile iron, steel, asbestos cement, and concrete pipe materials.
- Works on Pipe Diameters up to 24" diameter.
- Utilize existing or new fire hydrants of any manufacture

Automatic Acoustic Analysis

- Leaks automatically correlated by multiple nodes
- Leak Location identified within a few feet

Low Maintenance

- Above Ground Installation
- 10-year design life
- System Diagnostic Capabilities

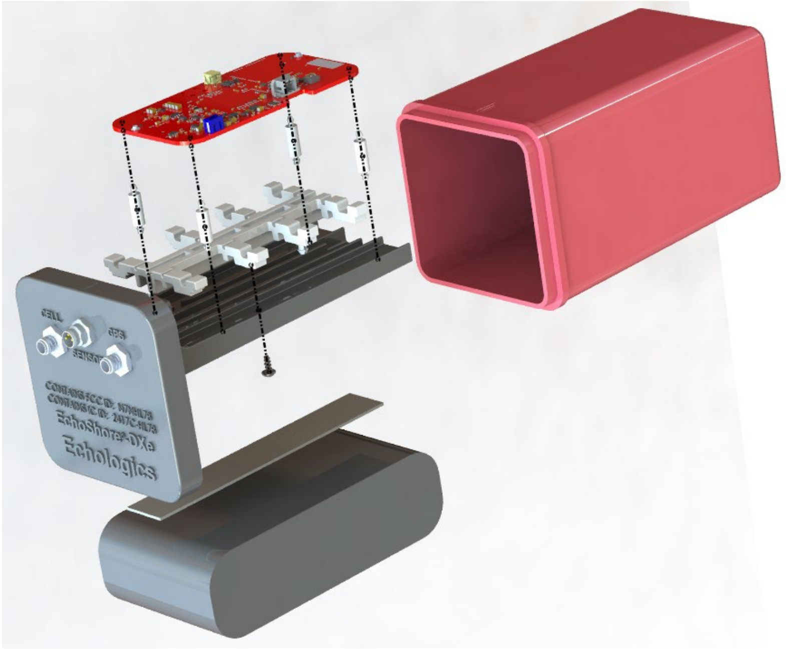
‘Install-and-forget’

EchoShore-DX sensors require no maintenance for up to 10 years.

- Versatile and rugged design
- Long distance between sensors
- Extra-long (verified) 10-year battery life

Implement EchoShore-DXe on:

- Valves
- Below-ground hydrants
- Release valves



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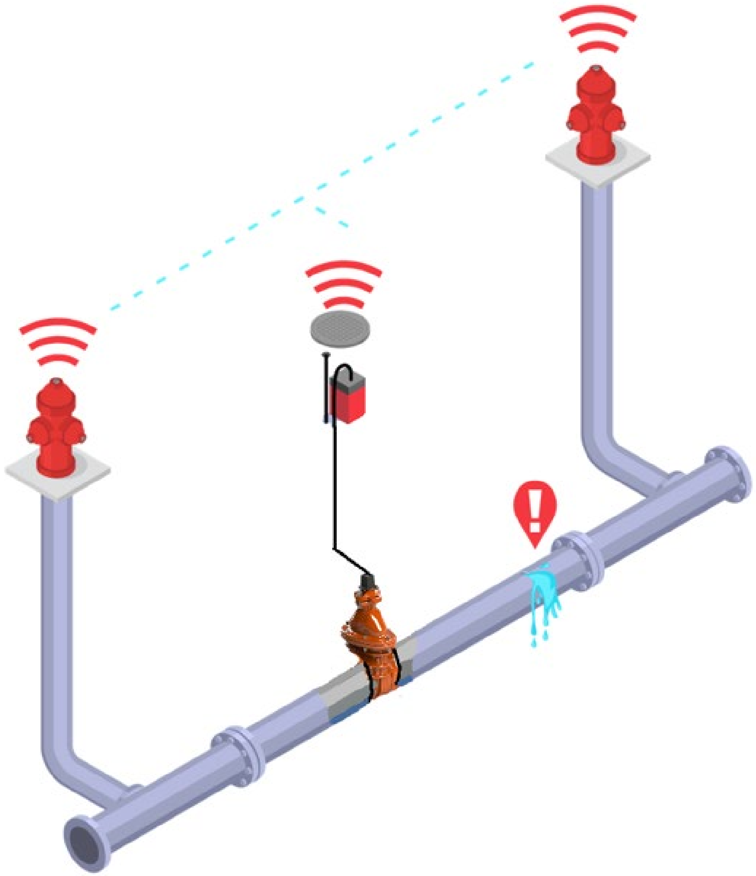
EchoShore DX

EchoShore-DX system uses sound and vibration monitoring to positively detect and locate leak acoustic patterns, preventing false alarms.



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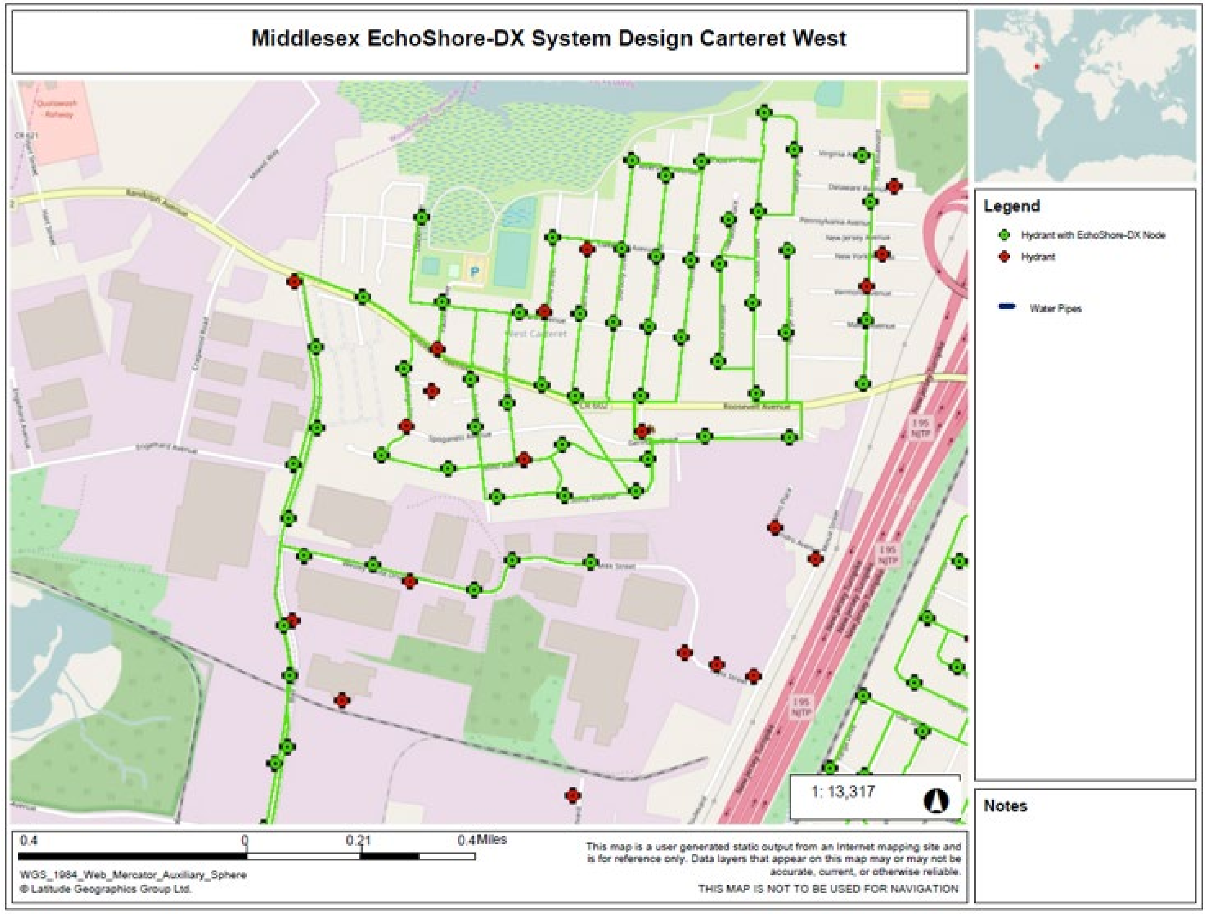
EchoShore-DX: How it Works

Sophisticated planning architecture

Our planners work with you to optimize EchoShore-DX by:

- Strategically placing sensors to greatest effect
- Minimizing cost, maximizing impact



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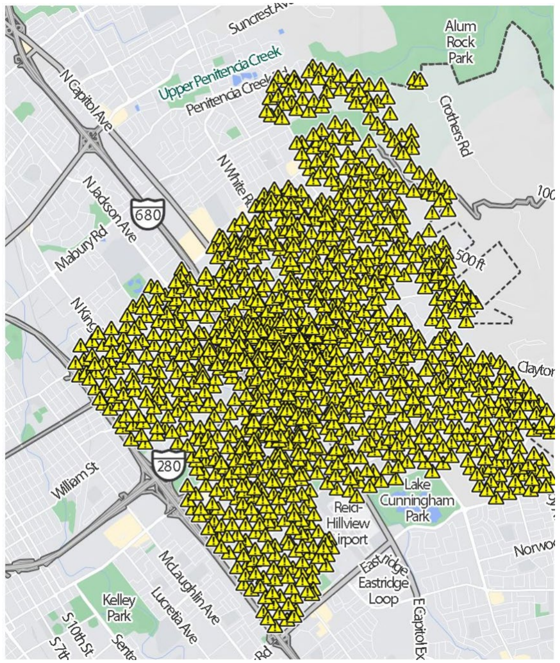
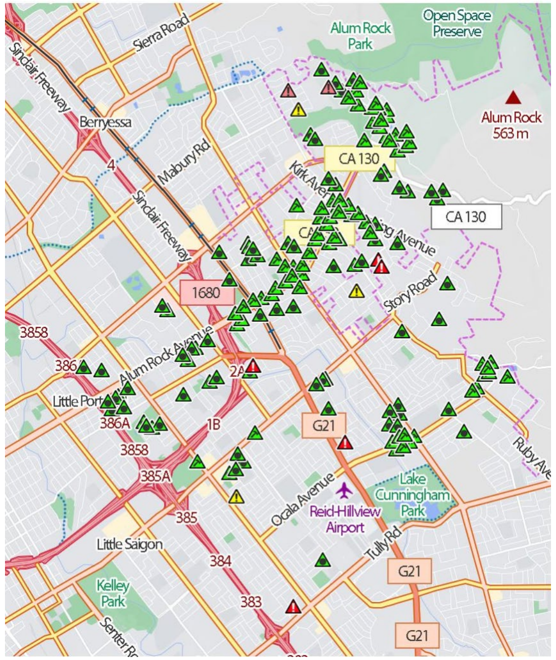
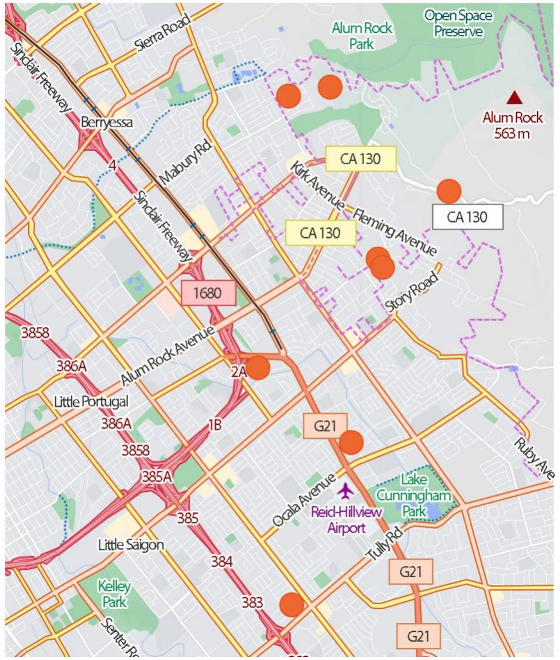
Cut through the noise







Data: 29,297 Network Noises

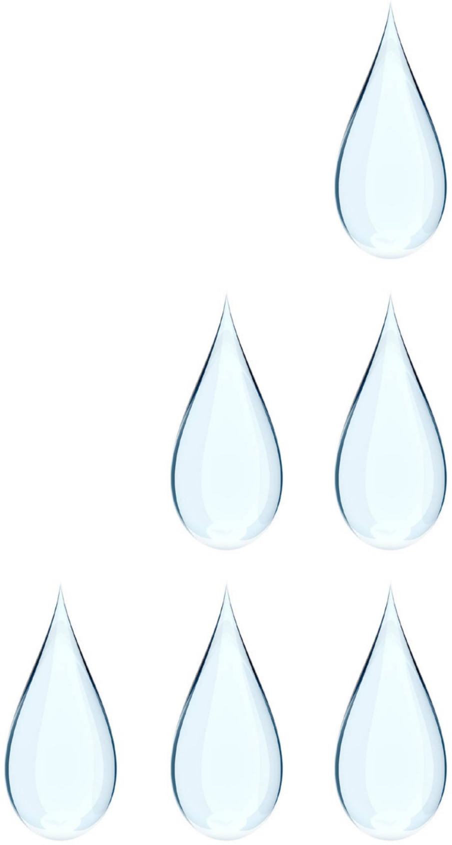
Information: 555 Persistent Noises

Insights: 8 Investigations Recommended

Leak Sizes – A Predictive Model

Leak Size:

- Predicts the potential size of a reported leak event
- Backed by Machine Learning and model trained and validated on over 1,500 reported leaks
- Provides a prediction of a small, medium or large leak



Small Flow Rate: Less than 20 Liters Per Minute (LPM) or 5 Gallons Per Minute (GPM)

Medium Flow Rate: Between 20 LPM and 115 LPM or between 5 GPM and 30 GPM

Large Flow Rate: Larger than 115 LPM or larger than 30 GPM

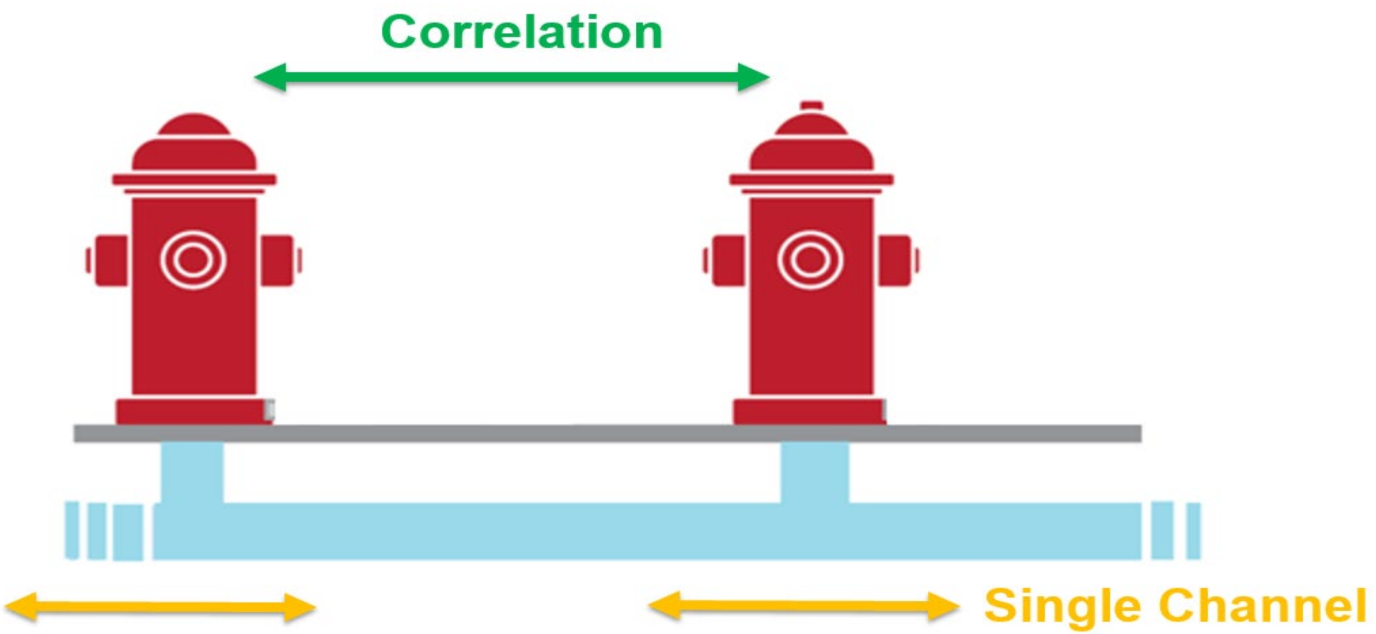
Single Channel Leak Detection

Overview:

- Single Channel leak detection monitors for changes in sound that indicate an emerging leak
- Leak notifications are generated from data from a single sensor and signal leakage at or nearby an EchoShore-DX sensor
- The Single Channel algorithm has been implemented into the Echologics monitoring tools

Benefit:

- Detects leaks that are located directly at or nearby EchoShore-DX sensors to improve correlated leak monitoring capabilities



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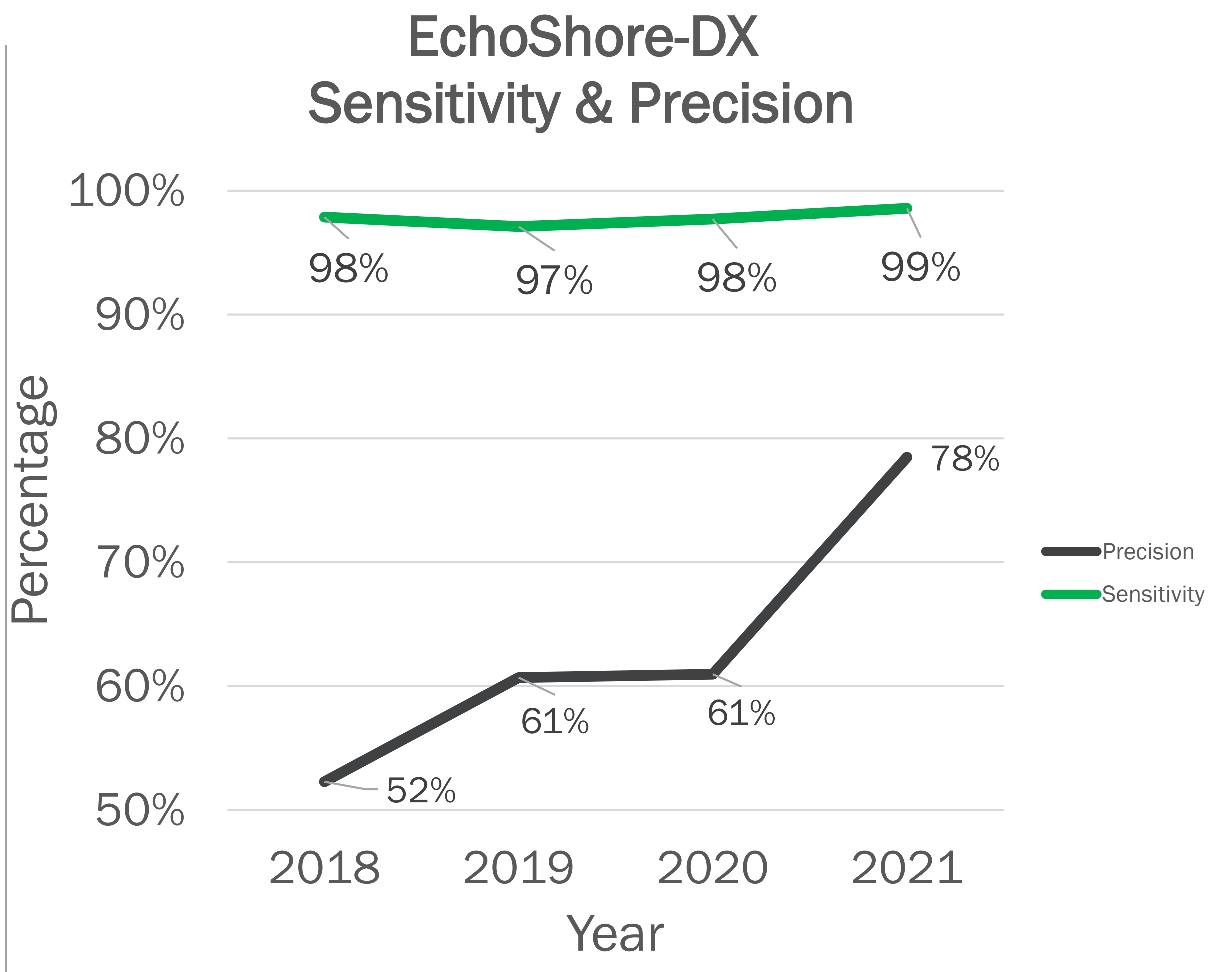
Accuracy, precision, and alerts you can depend on

EchoShore-DX is simply the best:

- 99% sensitivity.
  This means 99% of leaks are detected
- 78% of alerts result in actual leaks
- Best-in-class algorithm: Artificial Intelligence-enabled correlation
- Configurable acoustic monitoring helps locate harder to find leaks / emerging leaks



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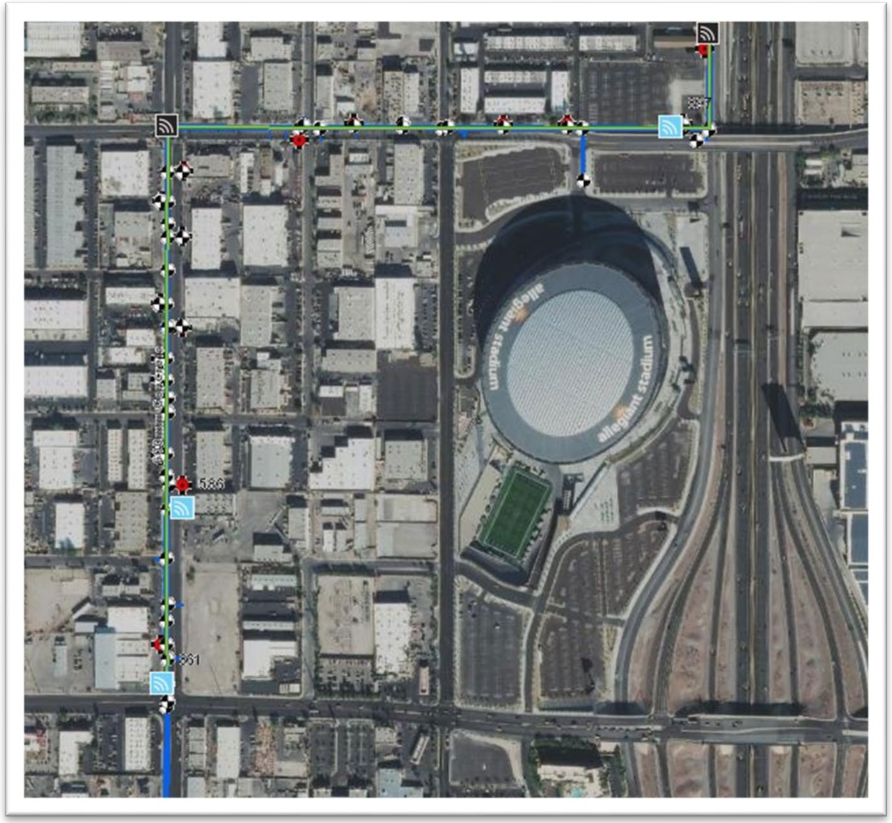
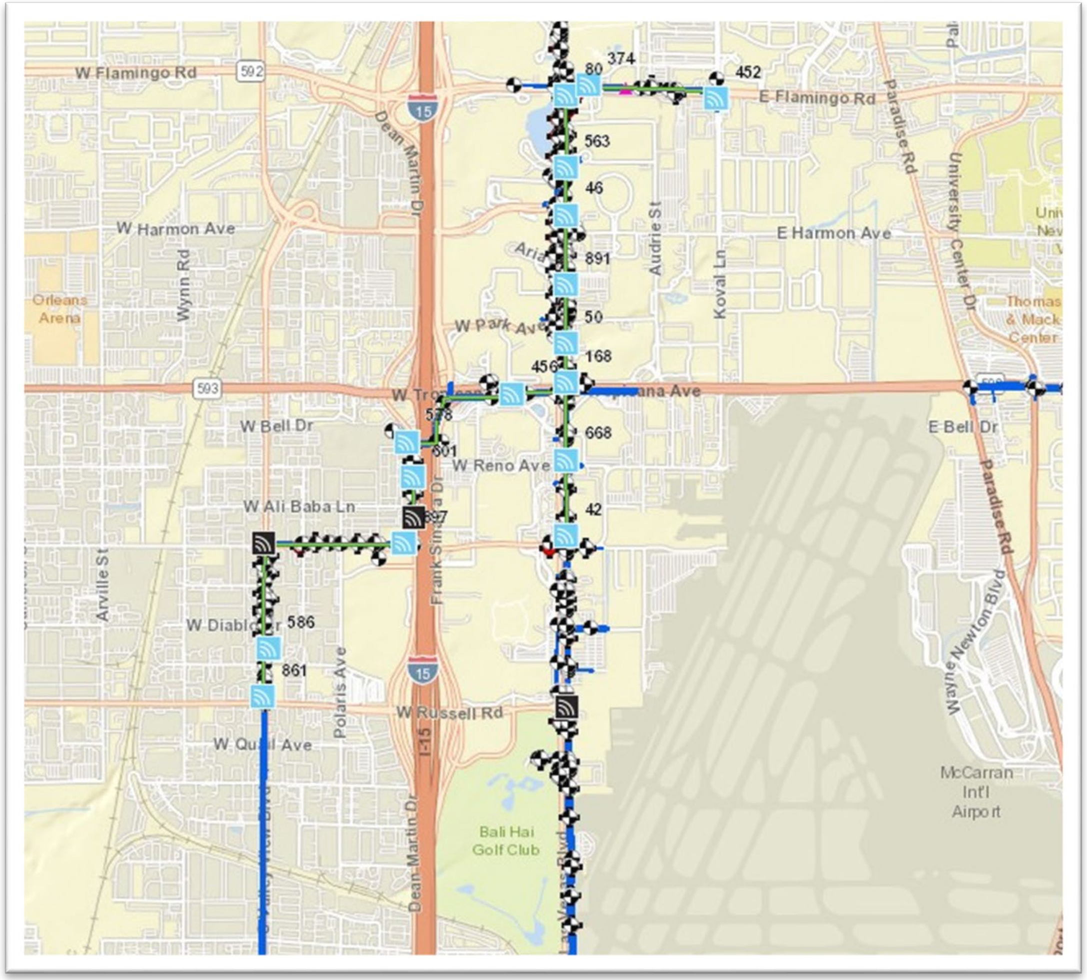
Leak Detection Monitoring





- Monitoring critical 36inch PCCP mains that service: Allegiant Stadium, Mandalay Bay, Luxor, Tropicana, MGM Grand, Aria, Planet Hollywood, Bellagio etc.
- ~4.5 miles covered by 19 nodes

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EchoShore: Technical Qualification

1.

Pipe Material	Typical Sensor Spacing for 5 gpm leak
Metal & Concrete	2,500 feet
Plastic	600 feet

2. GIS Or Hard Copy Maps
3. Pressurized Pipes
4. Cellular Service

EchoShore In Action

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Asset Management

Why Do Pipes Break/Leak?

- Water corrosivity
- Third party digging
- Ground heave & slip
- Earth/Traffic loading
- Ground support: pipe spans
- AC/DC corrosion from power lines, street cars and utilities
- Thermal changes
- Age & neglect
- Road salts
- Soil corrosivity
- Microbially induced corrosion
- Water Hammer
- Excessive Water Pressure
- Material Defects
- Faulty Installation
- Fire Department Usage

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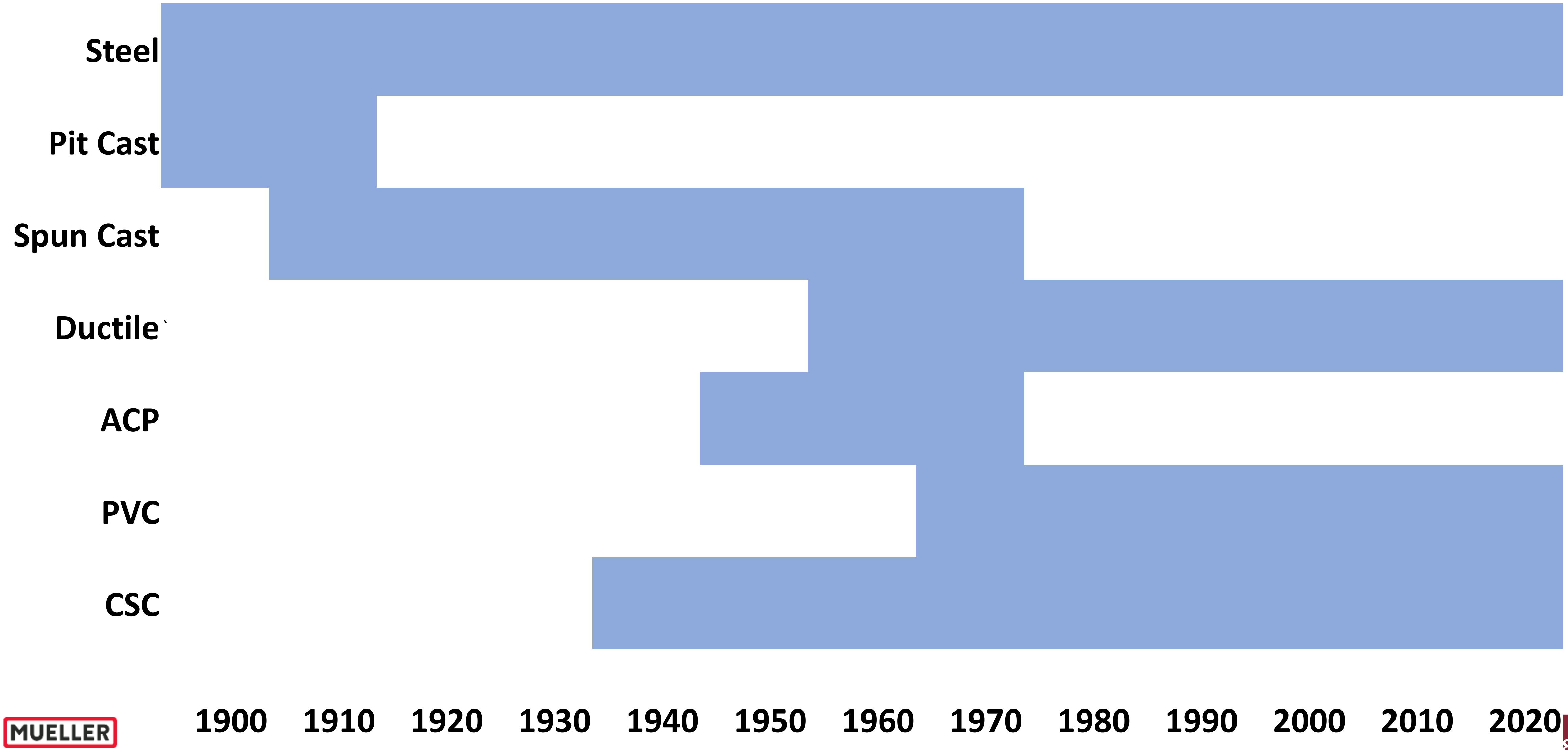
Pipe Installation Era



Primary Classifiers

Diameter	Age	Material	Grades
Less than 24" 94%	43% 20 – 50 yr	28% Cast Iron	Each Pipe has types and grades.
Over 24" 6%	28% 50+ yr	28% Ductile Iron	
	18% 10 – 20 yr	22% PVC	
	11% 0 – 10 yr	13% ACP	
		9% Other	

Cast Iron Types

- Pit Cast Iron
- Spun Cast

Cast Iron Grades

- Class C
- Class D

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Pipe Material Properties Drives Failure Types

Failure Type

Cracks more likely

Pinhole more likely

Brittle ⟷ **Ductile**

Young's Modulus (GPa)

PVC	Asbestos Cement	Pit Cast Iron	Spun Cast Iron	Ductile Iron	Steel
(varies)	30	90	120 - 170	170	190+





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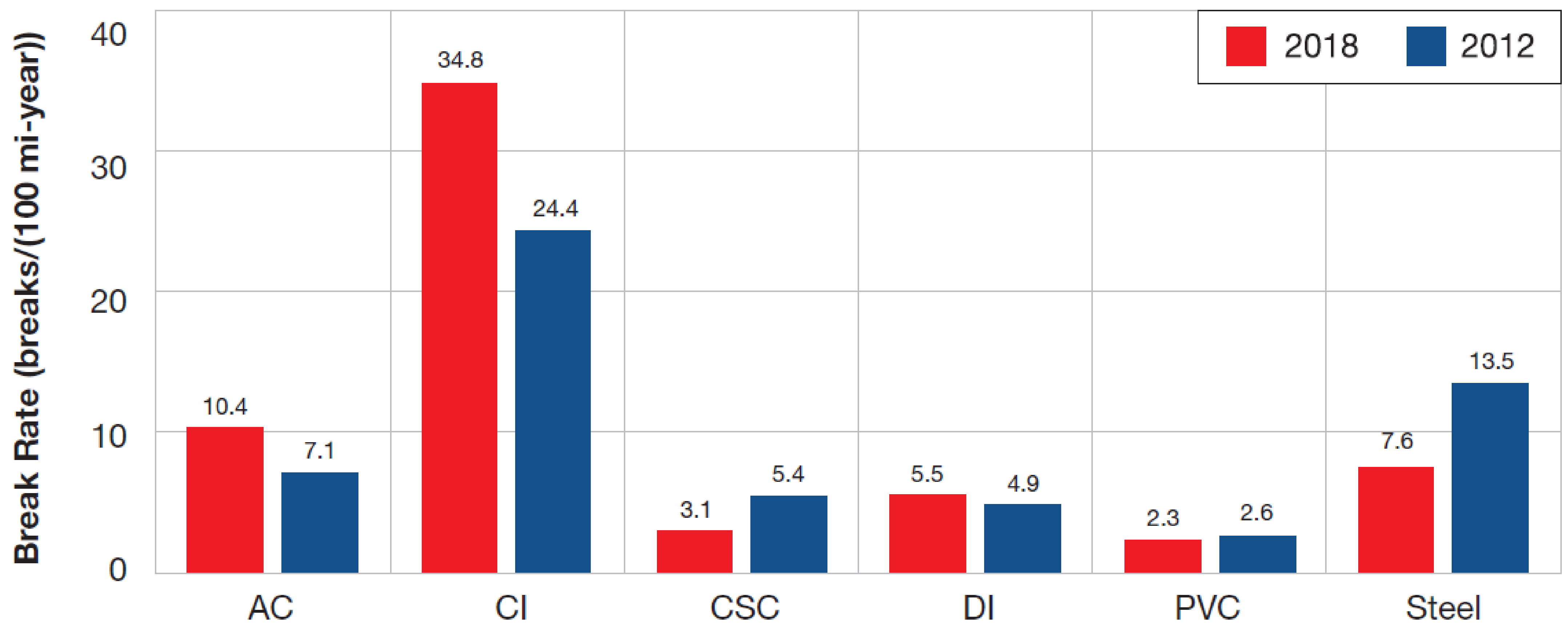
Distribution Pipe Failure Rates

FIGURE 22: COMPARISON OF BREAK RATES OF THE 2018 AND 2012 SURVEYS



How is Replacement and Rehabilitation of waterlines decided?

- Failures.
- Age.
- Pipe type.
- Capacity.
- Fiscal limits.
- Mandates.
- Guess work.

Condition Assessment

- *Continuous or periodic inspection, assessment, measurement and interpretation of the resultant data, to indicate the condition of a specific component so as to determine the need for some preventive or remedial action*

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Prioritizing Pipeline Renewal Based on Condition

Pipeline 1	Pipeline 2
Installed 1860	Installed 1860
Brown sandy soil	Brown sandy soil
Moderate soil corrosivity	Moderate soil corrosivity
6” Cast Iron Pipe	6” Cast Iron Pipe

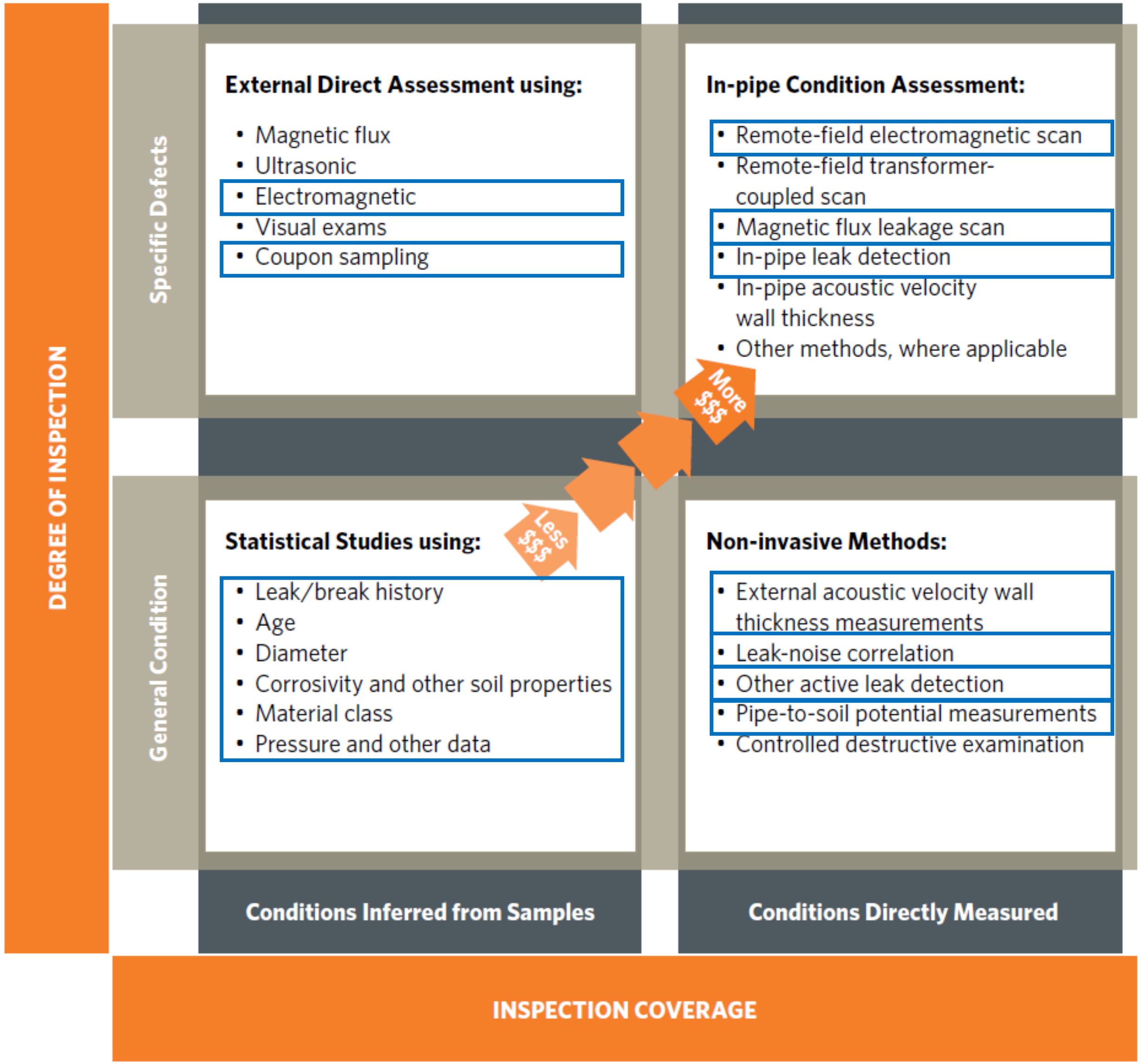
31% Thickness Loss

1% Thickness Loss

The Problem of Pipe Replacement & Failure

- All pipe will degrade and fail over time but at varying rates
  - ➢ Consequences = water loss and catastrophic breaks
- **Pipe is hidden underground**
  - ➢ No visual way to determine good versus bad pipe
- **Reliance on pipe failure history and age can be ineffective**
  - ➢ 60% to 70% of mains being replaced are still in good condition
- **Replacing and rehabilitating pipe is expensive**
  - ➢ Pipe replacement costs of $1,000,000 or more per mile
- **Because of price and selection error, wrong pipes are targeted**
  - ➢ Increasing water loss and likelihood of catastrophic breaks

Condition Assessment Methods



Assessment method fit depends on:

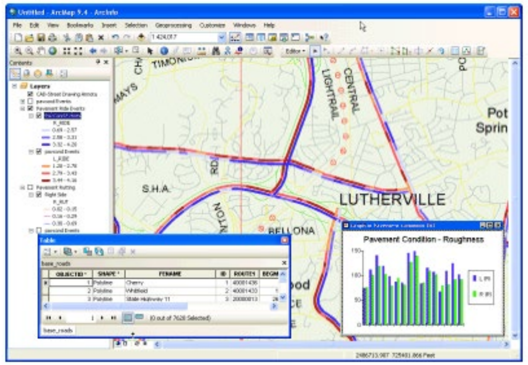
- Risk assessment
- Budget
- Coverage
- Access

Graphic from HDR

Desktop Modeling

Technology Description

- Review and statistical analysis of available existing data
- Pipe age, GIS data, break/ leak records, op data, etc.
- Inexpensive relative to collecting new data



Applicable Pipelines

- Distribution/Transmission
- All pipe materials
- All pipe diameters

Analysis Output

- Forecast break rates and service levels
- Renewal rates
- Risk assessment (LoF x CoF)

Limitations

- Relies on past to predict future performance (no new data)
- Lacks data feedback

Typical Economics

	Transmission	Distribution
Mobilization Cost	n/a	n/a
Inspection Cost	$250/mile	$250/mile
Site Preparation	n/a	n/a

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If you knew what pipes were about to break next year….

<u>what would you do about it?</u>

Case Study

Public utility with 260,000 pipe segments (~5,000 miles)

PipeRank predicted 2018:

- In top 1% of ranking, PipeRank caught 50% of all system breaks
- 86% of those pipes had no prior failure

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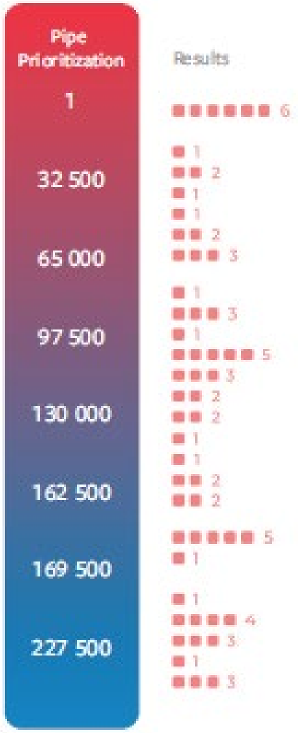
Case Study

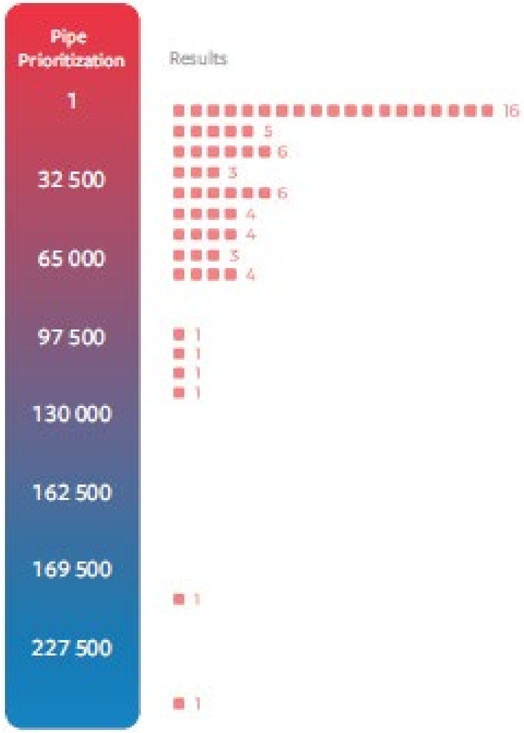
Prior Breaks

16% of failures
in top 5%



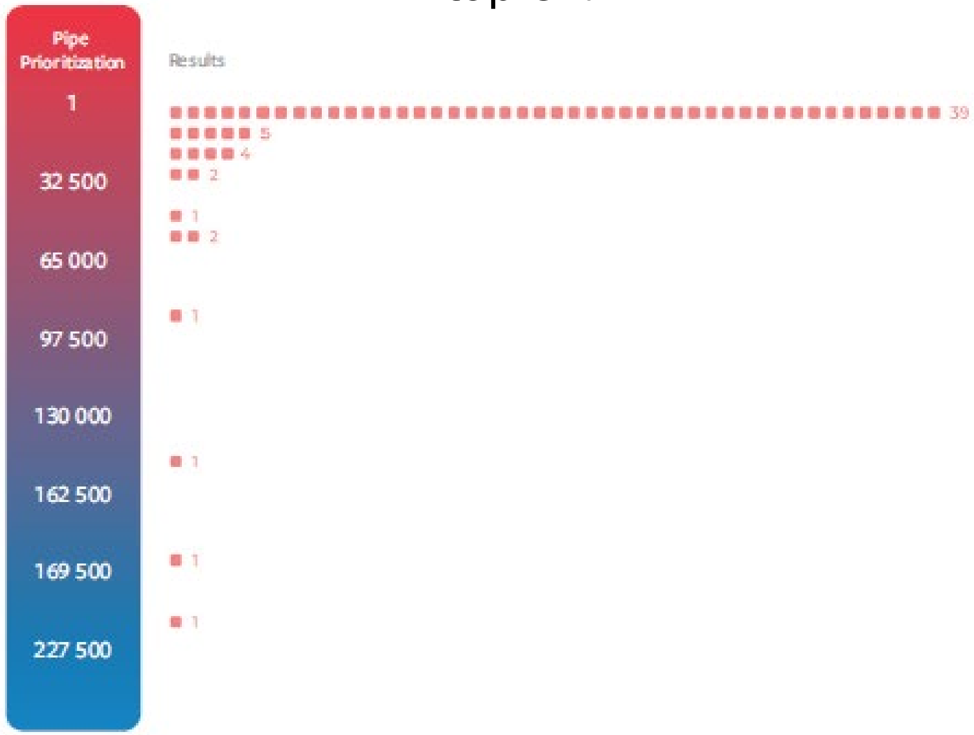
Age

44% of failures
in top 5%



PipeRank

77% of failures
in top 5%



LOF Ranking Vs Actual Failures in 2018

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Where to Start: Failure Risk Ranking

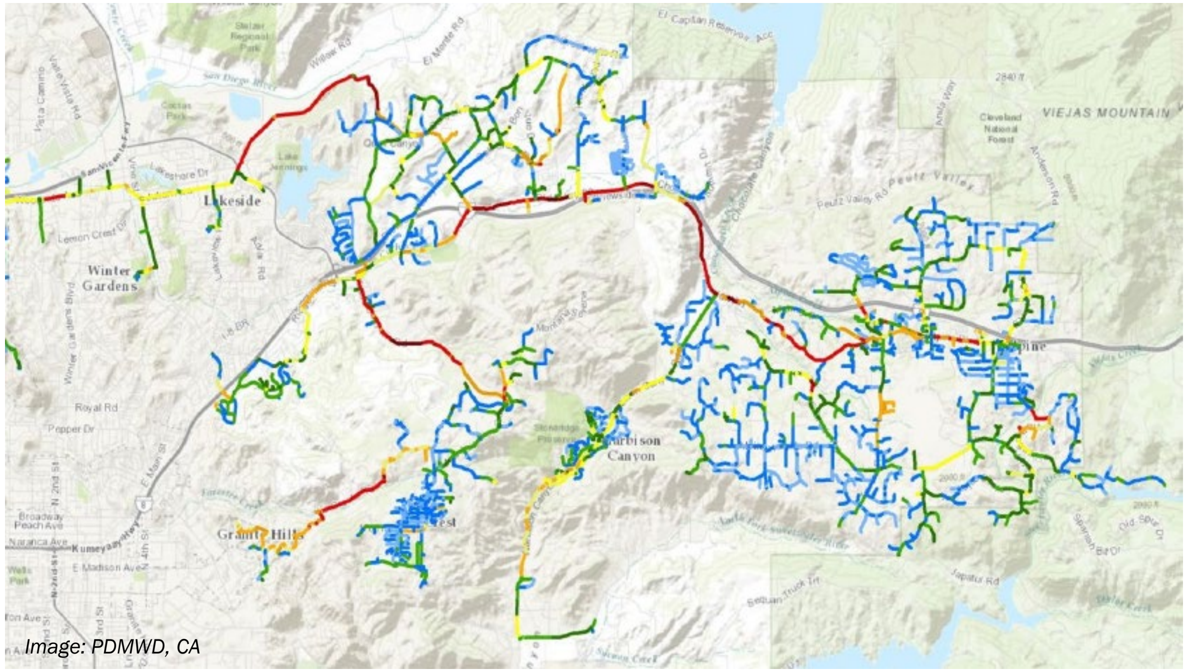

Image: PDMWD, CA

- Life Safety
- Property Damage
- Service Interruption
- Political Costs
- Loss of Public Trust
- System Constraints

- Pipeline Age, Design
- Manufacture, Installation
- Environment (Corrosivity)
- Performance History
- Operation
- Failure Margin

Risk of Failure Pipeline Criticality		Consequence of Failure			
		None	Low	Medium	High
Likelihood of Failure	Low	Low Risk			
	Medium				
	High				High Risk

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Electromagnetic Inspection Technology (EM)

Technology Description

- Free swimming, robotic, walker
- Electromagnetic field travels between an exciter and a receiver
- Passes through pipe wall and carries info about the pipe at the point it travels

Applicable Pipelines

- Distribution/Transmission
- Ductile Iron, Steel
- Concrete (C301, C303)
- 6” - 144”+

Data Collected

- Broken wires for PCCP
- Local areas of corrosion
- Relative wall thickness

Limitations

- Calibration
- Fittings/joints (up to 15% of a pipeline)
- Pigging
- bends, elbows, valves
- Tool disinfection
- Analyst interpretation

Typical Economics

	Transmission	Distribution
Mobilization Cost	$100,000	$25,000
Inspection Cost	$70,000/mile	$42,000/mile
Site Preparation	$200,000 per chamber	$15,000/mile PIG run

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Broadband Electromagnetic (BEM)

Technology Description

- In-pipe or external
- Spot measurements statistically interpolated over a length
- Magnetic field induced in the pipe wall to produce eddy currents. The induced voltage provides info about the wall.

Applicable Pipelines

- Distribution/Transmission
- Cast Iron, Ductile Iron
- 4” - 96”+

Data Collected

- Internal and external corrosion
- Relative wall thickness
- Pipe condition interpolation between scans

Limitations

- Spot measurements only
- Access to pipeline
- Tool disinfection

Typical Economics

	Transmission	Distribution
Mobilization Cost	$25,000	$15,000
Inspection Cost	$7,500/spot	$5,000/spot
Site Preparation	$7,500/spot	$3,000/spot

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Pressure Wave Analysis

<u>Technology Description</u>

- Free swimming or tethered
- Transient wave induced in the pipeline. Partial reflections are measured.
- Reflections caused by discontinuity: pitting, change in thickness, fittings, bends, etc.

<u>Applicable Pipelines</u>

- Distribution/Transmission
- Cast Iron, Ductile Iron
- Concrete
- Asbestos Cement
- 12” - 40”

<u>Data Collected</u>

- Localized faults
- Material changes
- Thickness changes

<u>Limitations</u>

- Scans are 30’ at a time
- Reflections from joints, bends, elbows, tees, laterals

<u>Typical Economics</u>

	Transmission	Distribution
Mobilization Cost	$20,000	$20,000
Inspection Cost	$15,000/mile	$12,000/mile
Site Preparation	~$2,500/mile	~$4,000/mile

Distribution Pipe Coupon Sampling

Technology Description

- Pipe samples are extracted for evaluation
- Hot tap removes a small section
- Full ring is removed with a shutdown/repair

Applicable Pipelines

- Distribution
- Cast Iron, Ductile Iron, Steel, asbestos Cement

Data Collected

- Pipe wall thickness
- Corrosion
- Metallurgy/chemical composition

Limitations

- Not representative of the pipe as a whole ring section (for hot tap)
- Spot test

Typical Economics

	Distribution
Mobilization Cost	$8,000
Inspection Cost	$3,000/coupon
Site Preparation	$5,000/coupon

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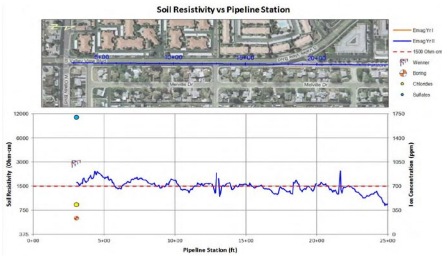
Soil Sampling

Technology Description
- Soil sample collection at the pipeline (emag test) or at 5 depths (4-Pin testing)
- Moisture, chemistry, electrical properties
- 'Aggressive' soils that are a determining factor of corrosion



Applicable Pipelines
- Distribution/Transmission
- Cast Iron, Ductile Iron
- Steel
- All pipe diameters

Data Collected
- Moisture content
- Chemistry
- Electrical properties
- Pipe-to-soil potential

Limitations
- Indirect test
- Spot test

Typical Economics

	Transmission	Distribution
Mobilization Cost	$6,000	$6,000
Inspection Cost	$4,500/mile	$4,500/mile
Site Preparation	$3,000/pothole	$2,500/pothole

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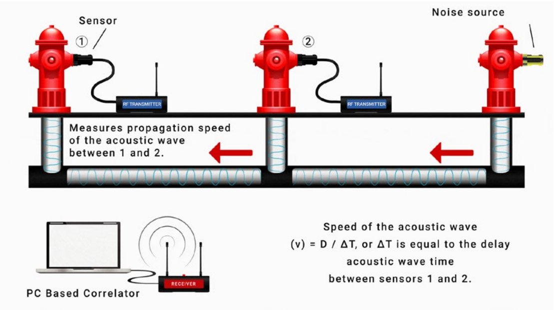
Acoustic Velocity Analysis

Technology Description

- External, correlation-based
- Acoustic waves traveling along a pipe are affected by pipe stiffness
- Acoustic velocity slows where pipe is less stiff, indicating degradation



Applicable Pipelines

- Distribution/Transmission
- Cast Iron, Ductile Iron
- Asbestos Cement
- Steel
- PCCP (with failure risk curves)
- 4” - 72”

Data Collected

- Remaining structural wall thickness
- leaks

Limitations

- Access to the pipeline
- General pipe condition (averaged over the inspection section)

Typical Economics

	Transmission	Distribution
Mobilization Cost	$12,500	$12,500
Inspection Cost	$28,000/mile	$18,000/mile
Site Preparation	$3,000/pothole	$2,500/pothole

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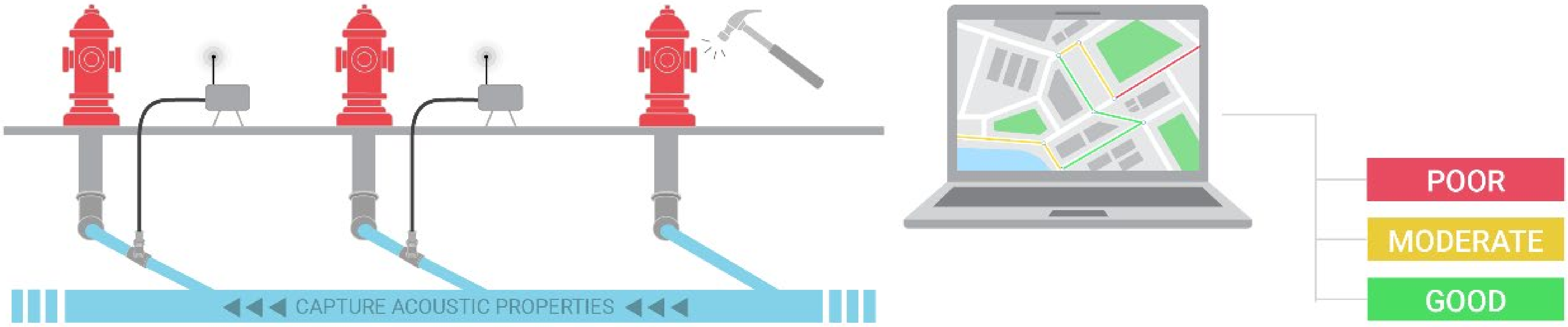
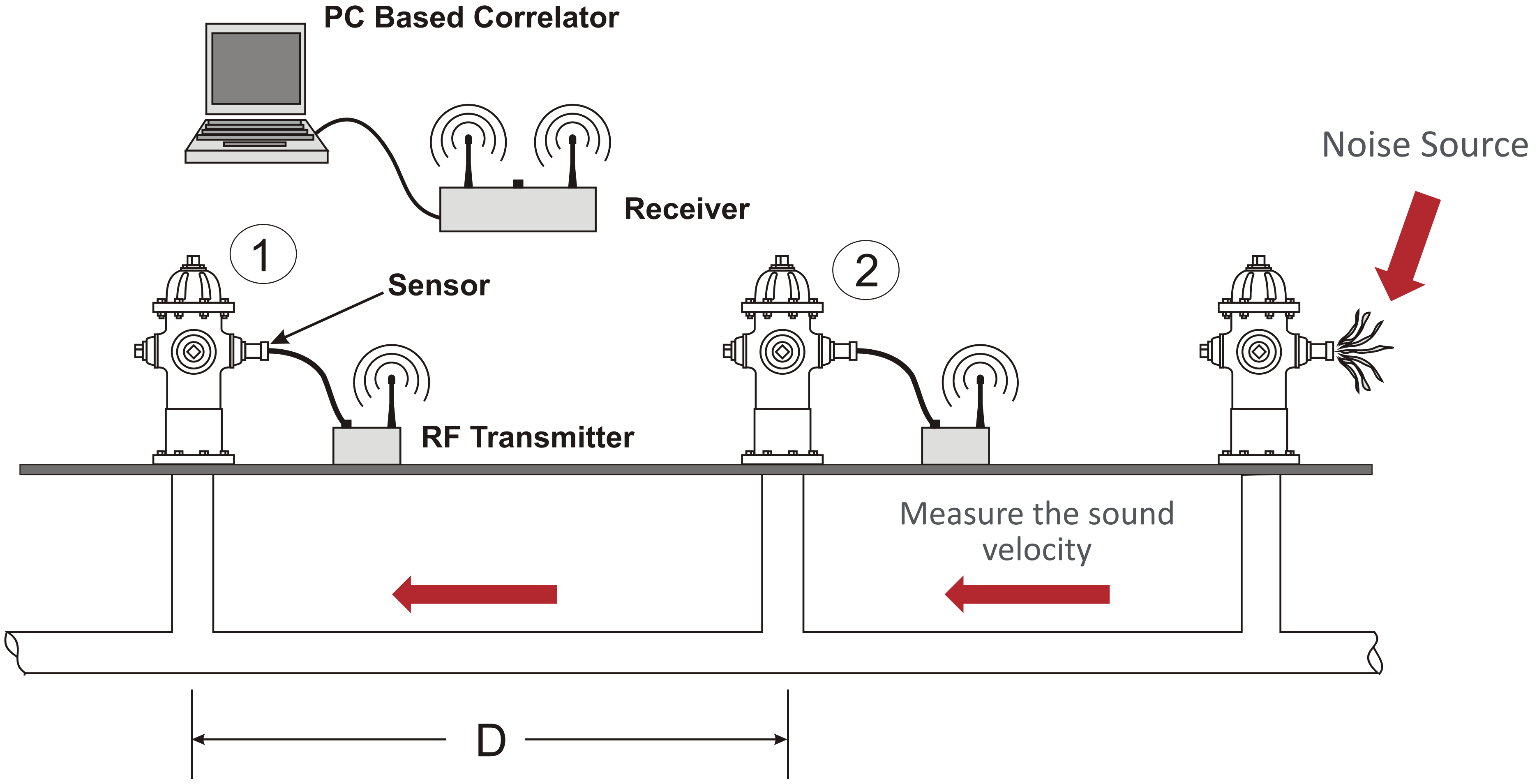
ePulse Discovery



ePulse – How it works (for distribution mains)….



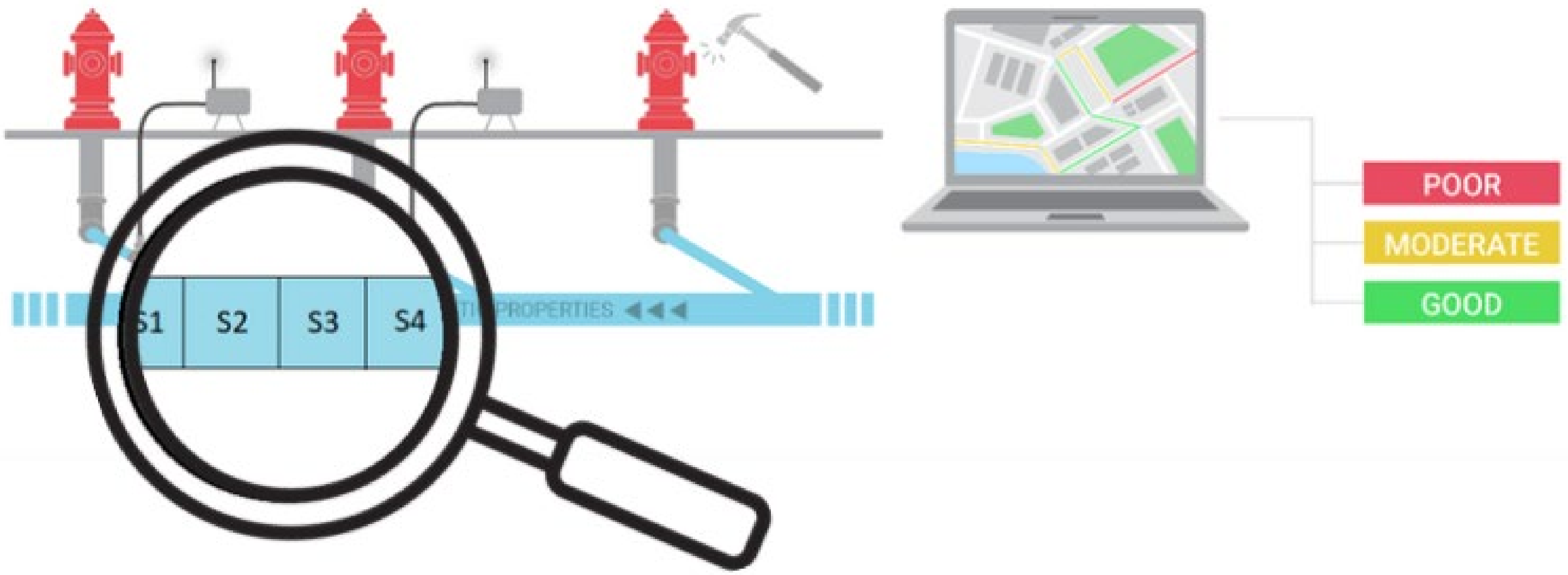
Wave propagation velocity (v) = D/ΔT, where ΔT is time delay between signals 1 and 2

ePulse® Optimize

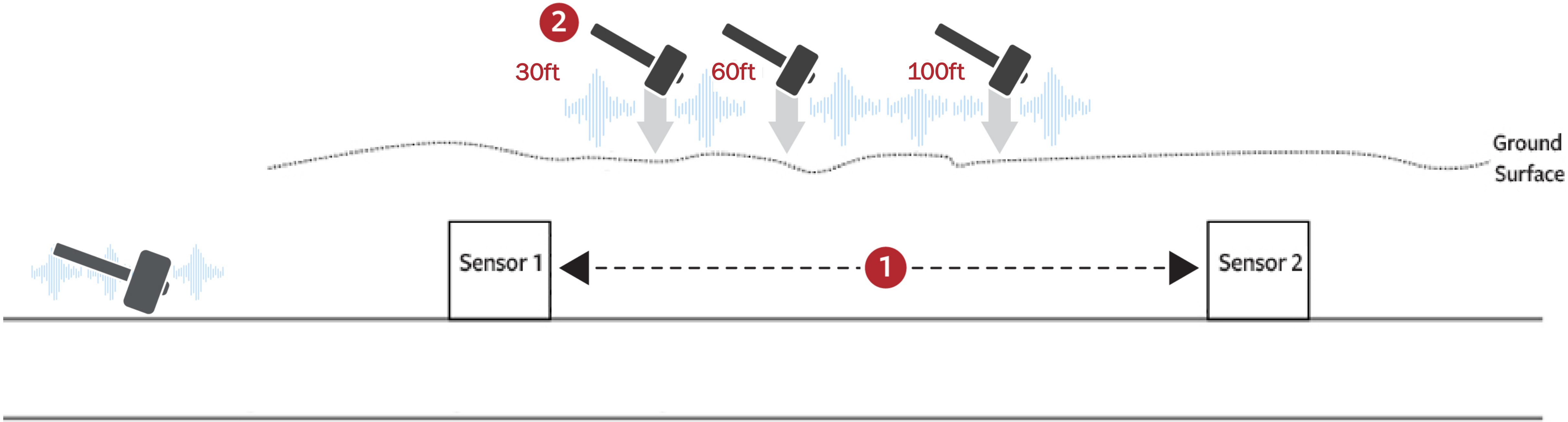
- Provides pipe ranking of poor, moderate, or good

- Analyzes sections of pipe as low as 30ft

- Provides simultaneous leak detection



How it Works?



1. Carry out standard ePulse including distance measurement between sensors and "out of bracket" excitation recordings.
2. Divide and measure out desired sections within the segment and generate "in-bracket" excitation recordings for each section.
3. Recordings are sent to Echologics data science team for analysis. A report is provided with pipe condition and location of any leak(s) identified during survey.

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ePulse: Technical Qualification

1. The Right Pipes

Pipe Material	Pipe Diameter
Ductile & AC	Up to 24”
Cast Iron & Concrete	Up to 108”

2. Maps
3. Access to outside of pipe (every 700’)
   NOTE: May require potholing
4. Known Pipe Material & Diameter
5. Pressurized, Buried Pipes

Often GIS maps is all you need to develop an ePulse proposal

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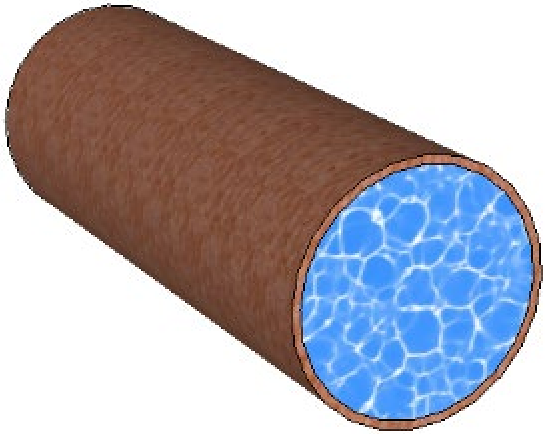
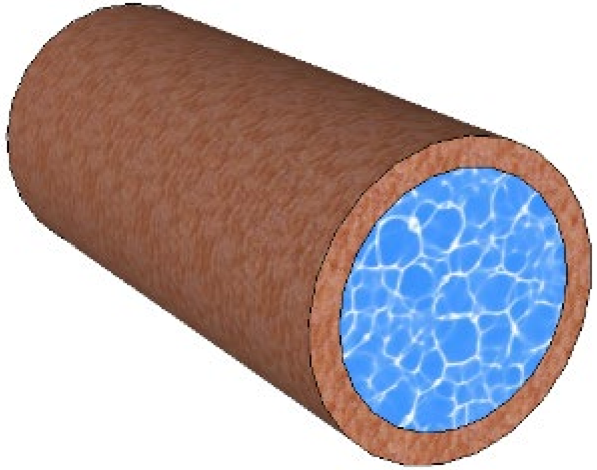
ePulse – Acoustic Wave Speed Principle



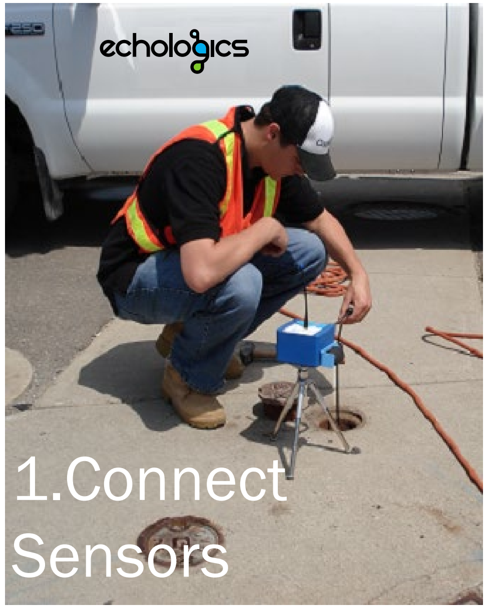
Slower



Faster

- This pressure wave causes pipe wall to “flex” on a microscopic level
- Thicker (“stiffer”) pipe walls more resistant to “breathing”, causing this wave to travel faster
- Measuring this phenomenon allows calculation of remaining average wall thickness

How Does ePulse Work? In The Field



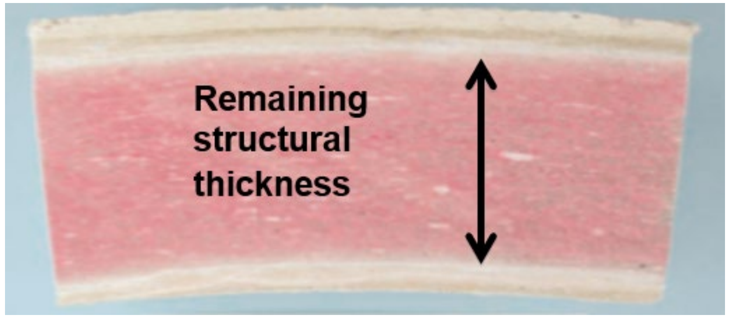
ePulse Survey Results

ePulse Data

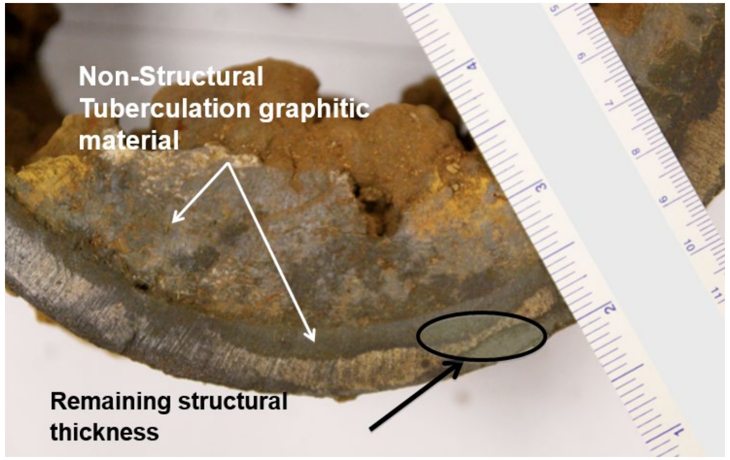
- → Remaining Structural Wall Thickness
- → % Loss from Original Thickness
- → Qualitative Pipe Grade
- → Presence and Location of Any Leaks

Section	Diameter (In)	Length (Ft)	Material	Pressure Class	Nominal Thickness	Measured Thickness	Loss
Unit	In	Ft	-	-	In	In	%
1	16	546	DI	350	0.38	0.31	20%
2	16	251	DI	350	0.38	0.23	40%
3	16	252	DI	350	0.38	0.34	11%
4	16	428	DI	350	0.38	0.35	7%
5	16	427	DI	350	0.38	0.37	4%
6	16	516	DI	350	0.38	0.41	0%
[illegible]	[illegible]	513	DI	350	0.38	0.32	17%
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Pipe Samples

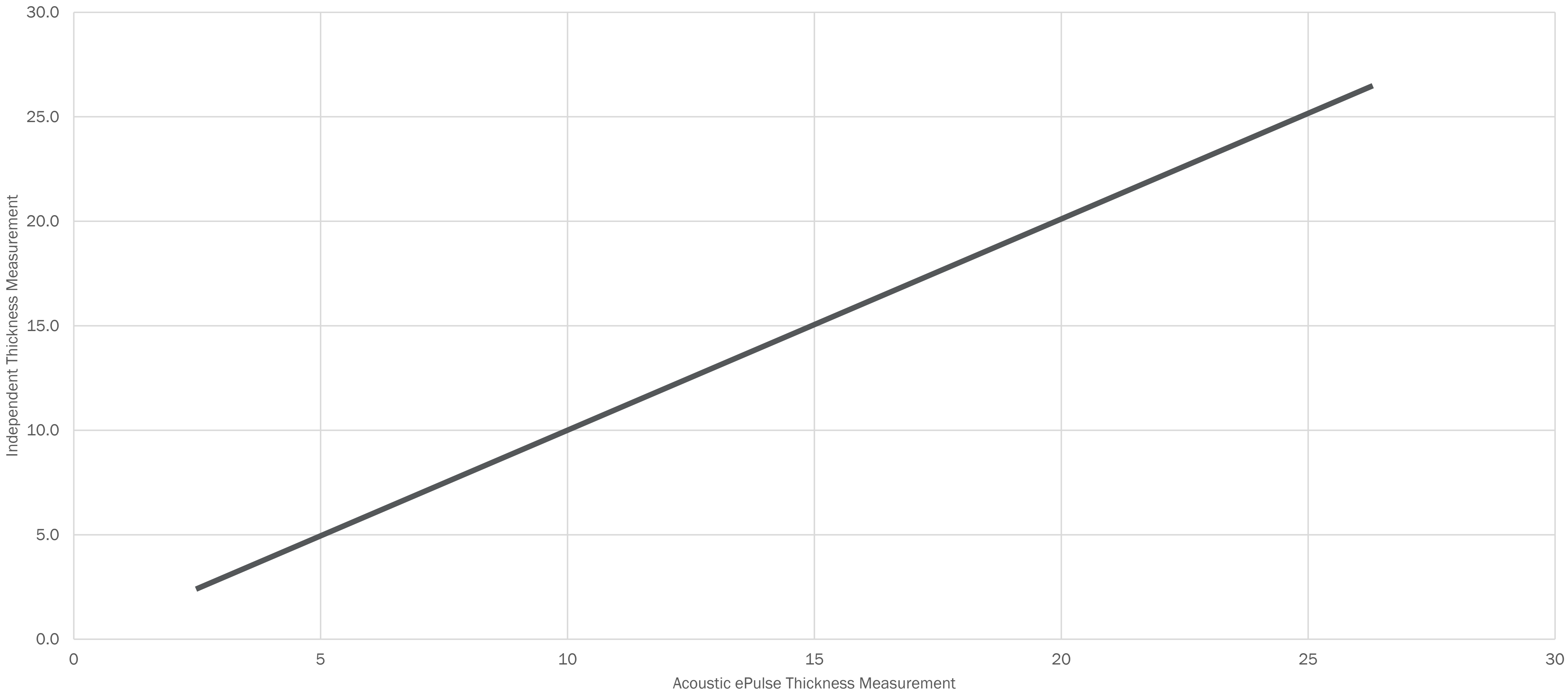


Asbestos Cement



Ferrous

124 Validated Measurements



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ePulse – Typical Results

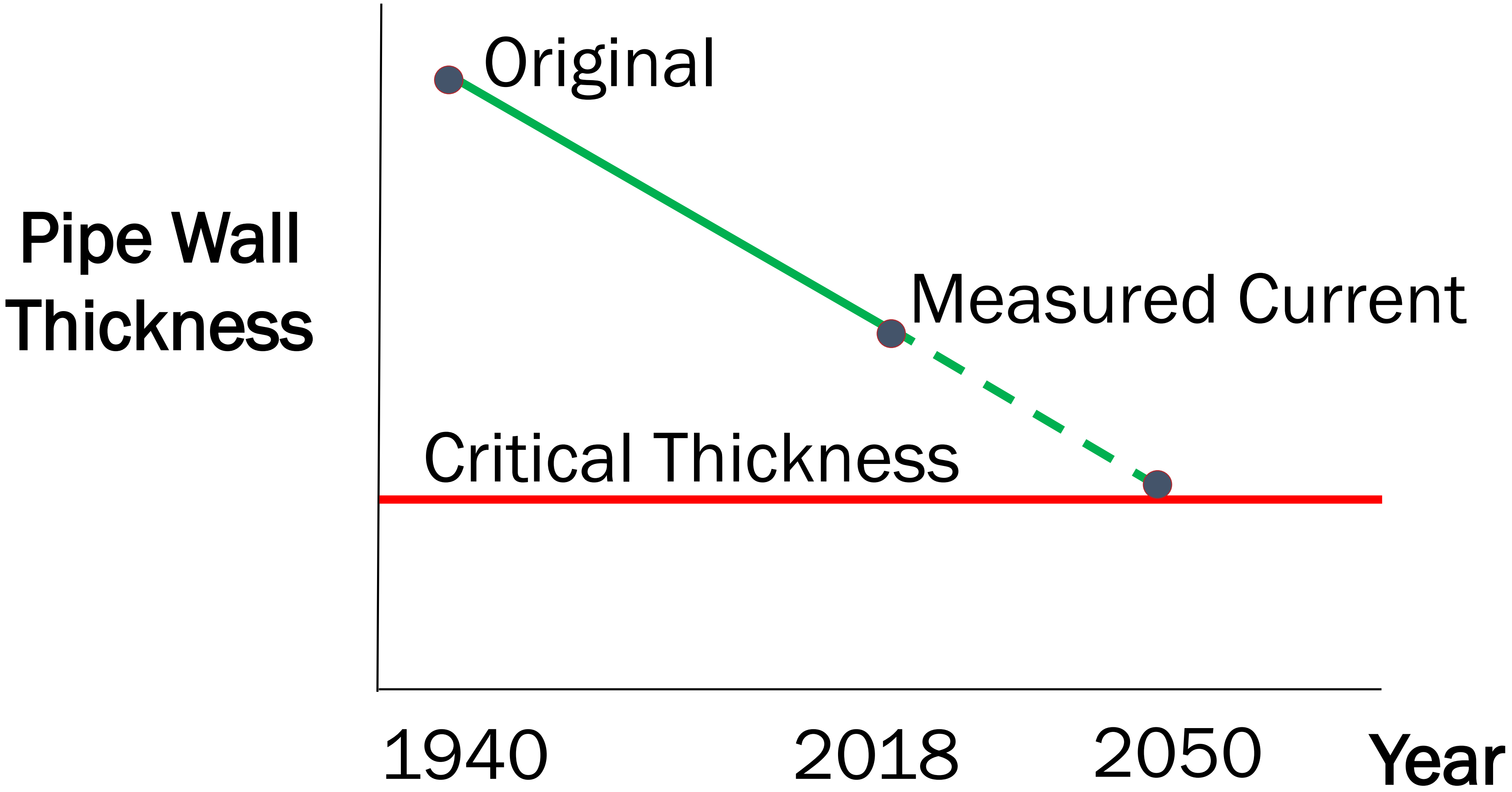
Leak

Applications

- Pipe Types: CI, DI, AC, BWP
- Segment Distances:
  - Minimum = 150 lf
  - Maximum =750 lf
  - Preferred = 500 lf

Segment	Street	Distance (ft)	Pipe Material	Internal Diameter (in)	Nominal Thickness (in)	Remaining Thickness (in)	Change from Nominal %
1	West Vine St.	413	Asbestos Cement	6	0.66	0.31	53%
2	West Vine St.	338	Asbestos Cement	6	0.66	0.43	35%
3	West Vine St.	323	Asbestos Cement	6	0.66	0.41	38%
4	Cottage St.	381	Ductile Iron	8	0.33	0.28	15%
5	Cottage St.	425	Ductile Iron	8	0.33	0.30	9%

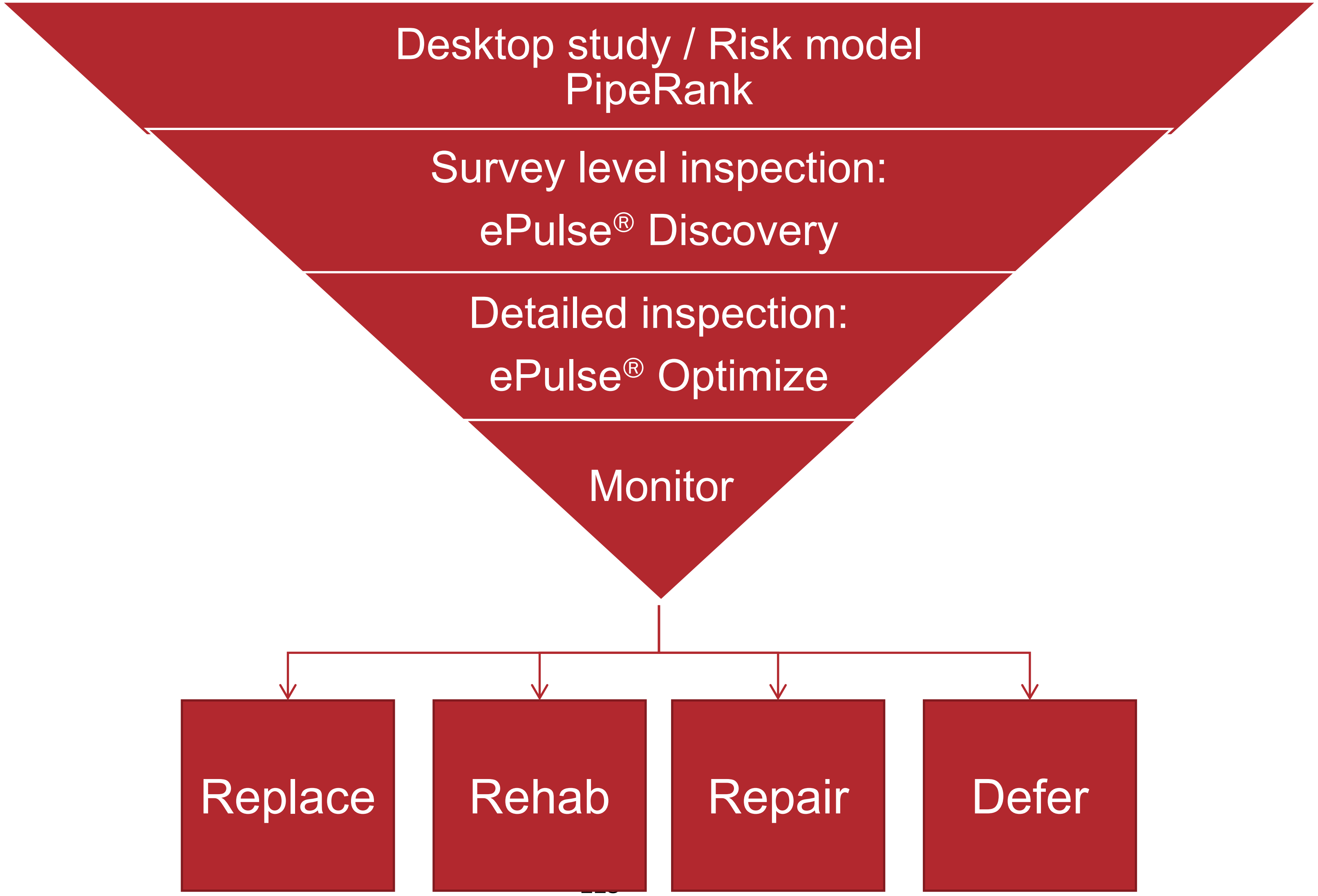
Remaining Service Life Calculation



Remaining Service Life Calculation with ePulse

Pipe Segment	Street Name	Length	Nominal Thickness[1]	ePulse® Measured Thickness	Pressure	Temp	Installation Year	% Change from Nominal	Remaining Service Life (years)	Predicted Breakage Rate	Probability of Failure Per Segment Length
#		(m)	(mm)	(mm)	(PSI)	(°C)				(brks/km/yr)	(this year)
1	Hennebury Pl	185.9	10.9	9.1	85	11	1940	-17%	50+	0.01	<1%
2	McNeil St	152.4	10.9	4.4	70	11.3	1940	-60%	Exceeded RSL	1.02	3%
3	Howley Ave	175.9	11.7	10.2	70	11.3	1940	-13%	50+	0.00	<1%
4	Summer St	132.6	10.9	3.1	70	11.3	1940	-72%	Exceeded RSL	1.71	4%
5	Merrymeeting Rd	168.2	14.7	9.9	85	11.6	1940	-33%	Exceeded RSL	0.16	1%
6	Merrymeeting Rd	133.8	14.7	11.0	85	11.6	1940	-25%	20 to 29	0.05	<1%
7	Merrymeeting Rd	149.7	14.7	10.9	85	11.6	1940	-26%	20 to 29	0.05	<1%
8	Winchester St	114.3	10.9	8.2	85	11.6	1940	-25%	30 to 39	0.04	<1%
9	Monchy St	152.7	10.9	7.8	75	11.6	1940	-28%	10 to 19	0.07	<1%
10	Monchy St	99.4	10.9	8.5	75	11.3	1940	-22%	40 to 49	0.02	<1%
11	Hamel St	147.8	10.9	3.4	95	11.3	1940	-69%	Exceeded RSL	4.21	39%

Asset Management Inverted Pyramid



Questions?