How to Economically and Accurately Assess the Condition of Small-Diameter Water Mains

Dan Ellison and Dave Spencer

August 13, 2020

Because NDE is seldom used for small mains…..

» Relatively **strong mains are discarded** because they are perceived to be weak

» **Unnecessary breaks occur** because some weak mains are left in service too long

» **Renewal methods are not always appropriate** for the condition of the host main

» We **lack confidence** in our renewal decisions

NDE is rarely used for small water mains, because…

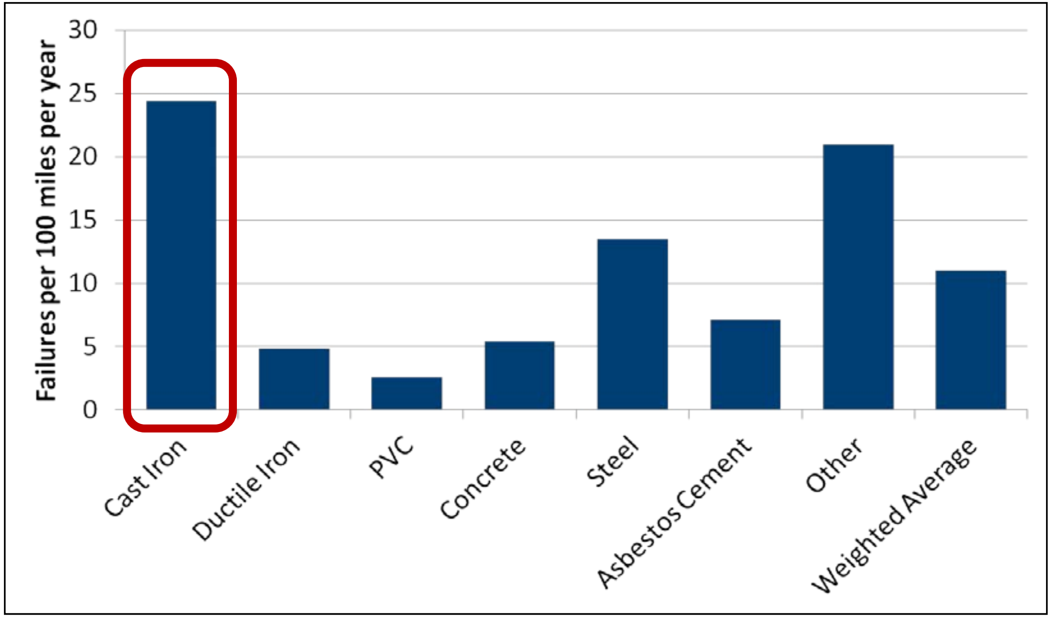
- **Cost**: “Money is better spent on renewal”
- **Risk**: “Something could go wrong”
- **Misunderstanding**: “Old mains have no value”
- **Uncertainty**: “What do the data indicate?”

THIS IS IMPORTANT!!!

» Because small mains break the most

» Because cast iron mains break the most

SMALL MAINS are our CANARIES in the coal mine



Failure rates from survey of 188 North American Utilities

Source: Utah State University (Folkman), 2012

...and even small mains can have catastrophic consequences

Photo: Al Seib, LA Times

Course Objectives

After this webinar, participants will be able to:

1. Describe **different condition assessment methods** applicable to small water mains, their advantages and disadvantages
2. Determine **how and where these methods might be applied** within their own utilities
3. Initiate **planning for a condition assessment project** involving small water mains
4. Demonstrate **the benefits that condition assessment** can provide in terms of reducing breaks or extending the service lives of pipes

Agenda

1. Using High-Resolution Condition Assessment on Small Iron Mains (WRF 4471)
2. Using High-Resolution Condition Assessment on Rehab Projects (WRF 4473)
3. Opportunistic Assessment of AC and other Water Mains (WRF 44480)
4. Questions

Audience Question #1 – Why is Water Main Assessment Difficult?

Sewer mains are commonly assessed using VIDEO equipment (CCTV).

Water mains are not as easily assessed.

Why is water main assessment difficult?

Please type your answers into the chat box.

WATER MAIN ASSESSMENT IS (A LITTLE) DIFFICULT

1. No Manholes
2. Pipes are Pressurized
3. Contamination and other Water Quality Concerns
4. Disruption of Service
5. Inspection Risks
   - Might trigger a pipe break
   - Tool could get stuck or lost
6. No Perfect Method
7. Results *Can* be Hard to Interpret
8. The Lining Hides the Pipe
9. Defects are internal, external, tiny, hidden…
10. Cost

Finding Ways to Effectively Use NDE on Small Mains

<u>Project 4471: Leveraging NDE</u>

» Use NDE to “sample”

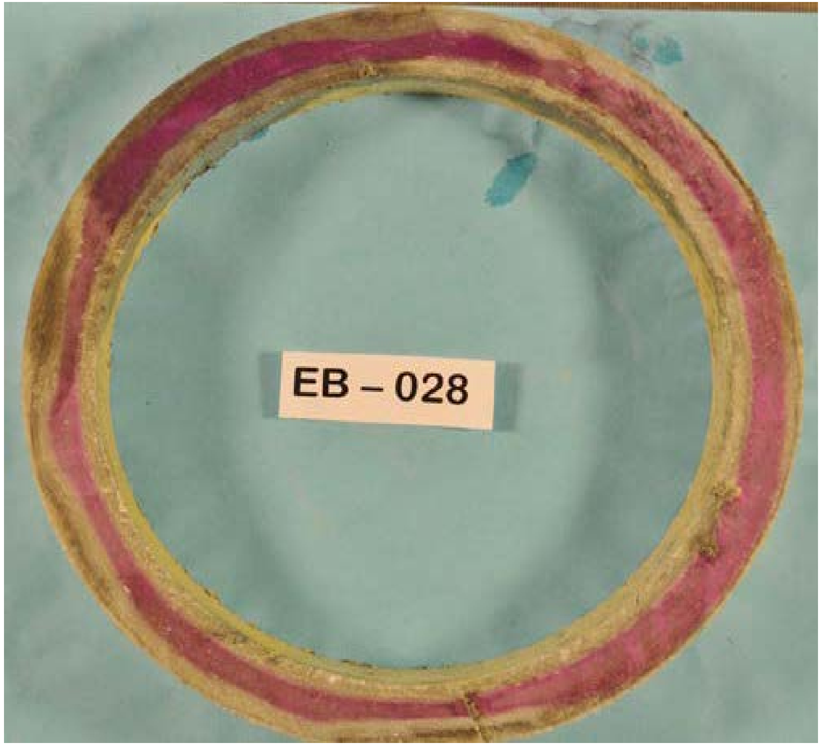
» Employ where easy

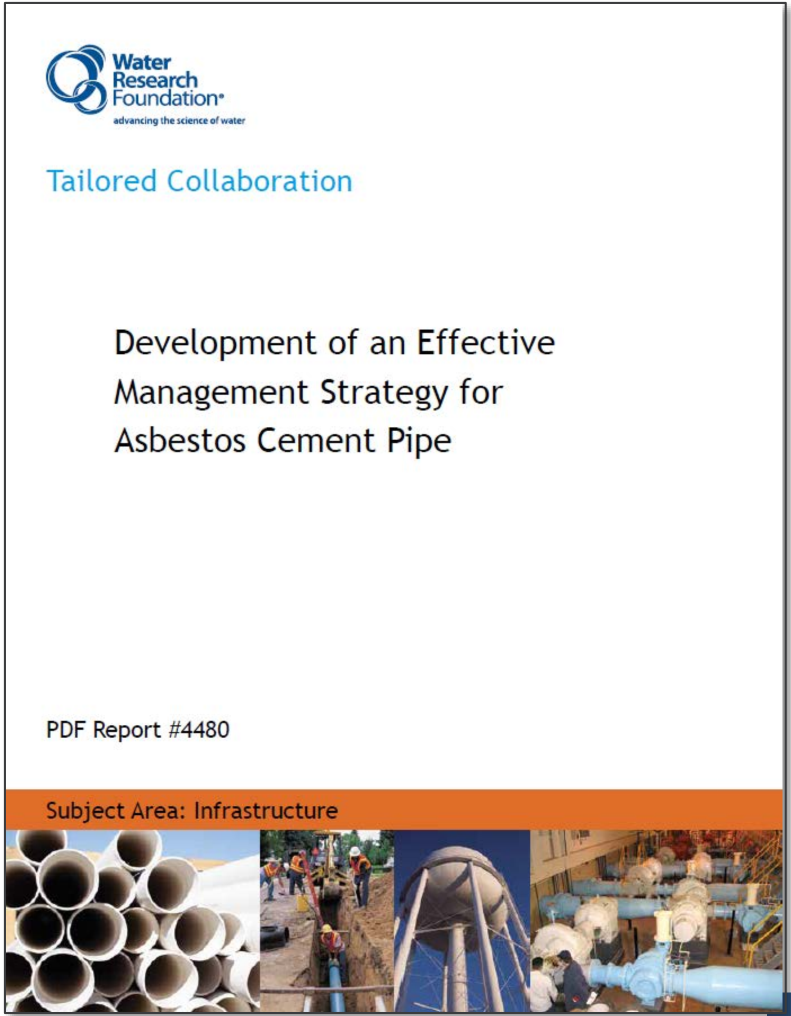
<u>Project 4473: Assess and Fix</u>

» Perform NDE with rehab

» Tailor rehab using NDE

WRF 4480 – Managing AC Pipe

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Tailored Collaboration

Development of an Effective Management Strategy for Asbestos Cement Pipe

PDF Report #4480

Subject Area: Infrastructure

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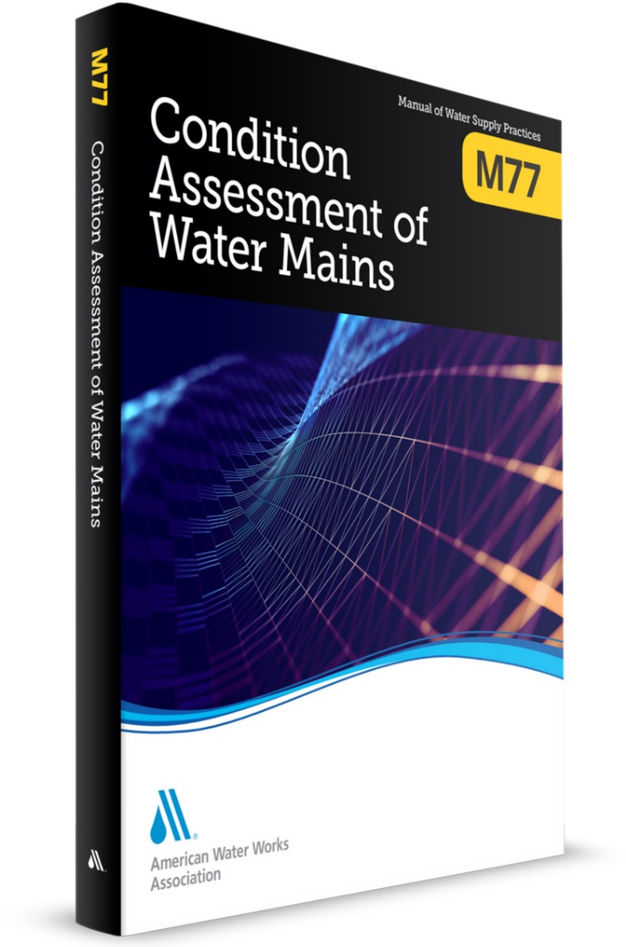

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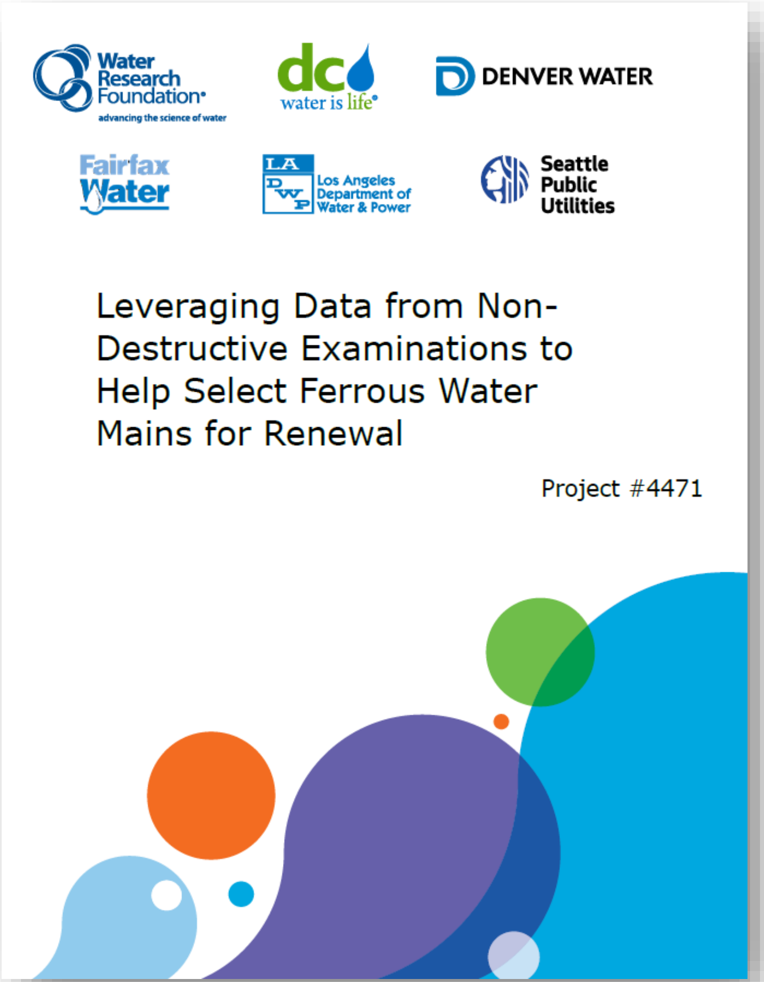
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Fairfax Water
LA DWP Los Angeles Department of Water & Power
Seattle Public Utilities

Leveraging Data from Non-Destructive Examinations to Help Select Ferrous Water Mains for Renewal

Project #4471

Premise:

(1) Use Condition Assessment Where Feasible

(2) Infer the Condition of Other Mains

Phase 1. Side-by-Side Technology Comparisons

Phase 2. Pilot Testing in LA, Denver, Seattle, Fairfax and Washington DC

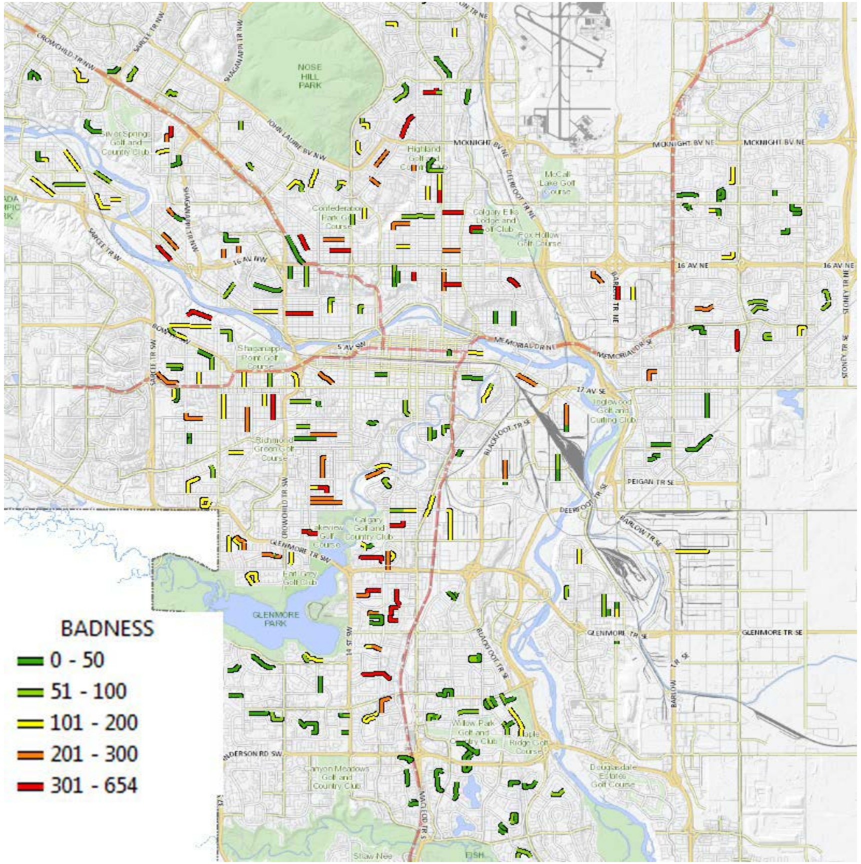
Phase 3. Analysis of NDE data

WRF 4471 Participating Utilities

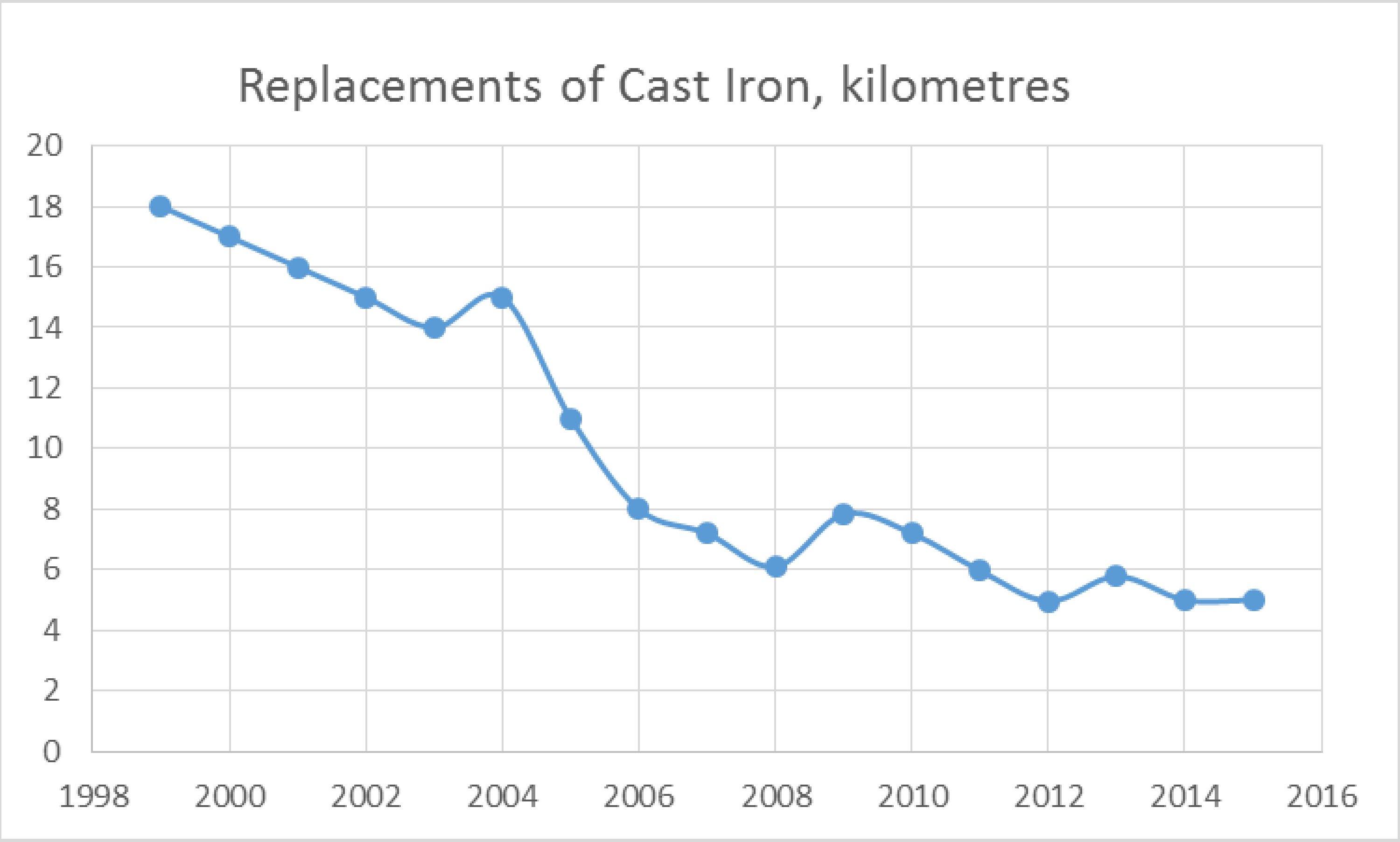
HDR

Calgary Case Study: Using NDE to optimize

- 8% of system scanned in 15 years
- “Badness” rating for prioritization
- 50% fewer breaks
- Replace program reduced by 66%
- Costs savings pay for program



Calgary Case Study: Using NDE to optimize



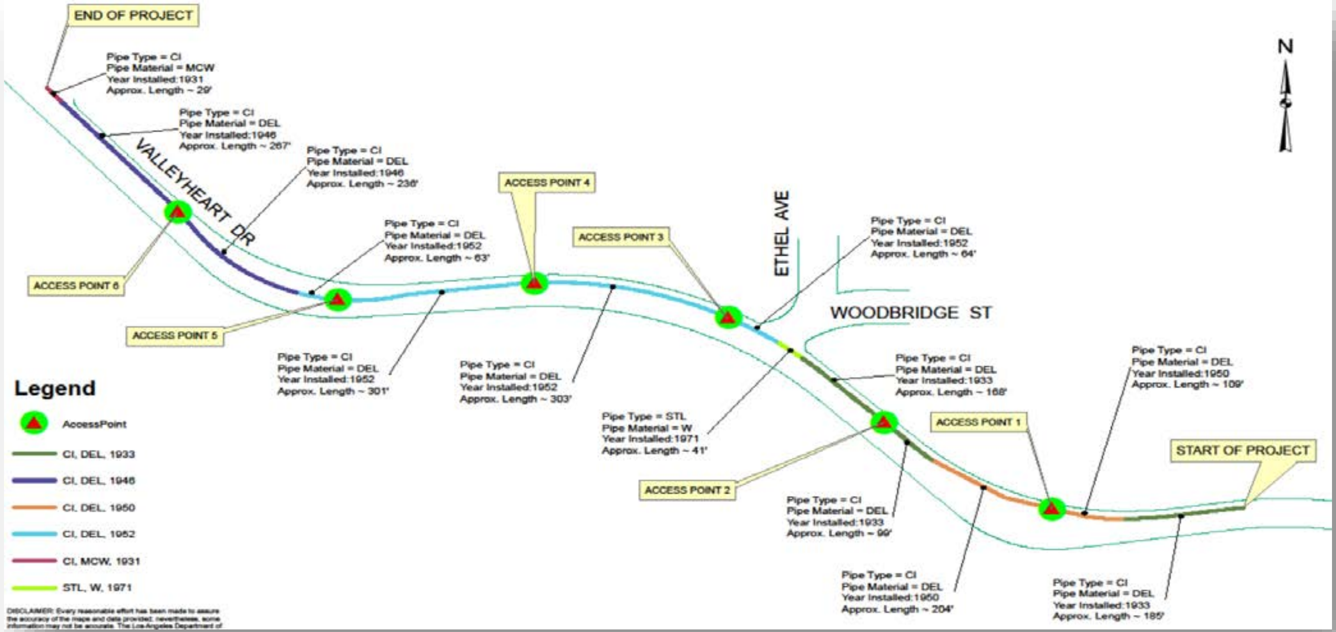
- » 8% c
- » “Bac
- » 50%
- » Repl
- » Cost

Project 4471, Phase 1: Valleyheart Tests, LADWP

<u>2000-ft, 6-inch main, discarded in 2010</u>

» 1933 (unlined spun cast)

» 1946, 1950, 1952 (factory-lined spun cast); 1971 welded steel CML



Four Technology Firms Proposed Five Methods

1. Push-in video/audio probe (JD7 / Wachs)
2. Keyhole broadband electromagnetic scanning (Rock Solid)
3. In-pipe broadband electromagnetic scanning (Rock Solid)
4. Acoustic velocity pipe wall thickness analysis (Echologics)
5. In-pipe remote-field electromagnetic scanning (PICA)

Pure (Xylem) did not have an appropriately-sized tool

Push-in probe (**Investigator**)

» Entry through 2-inch taps
» **Video / audio (Wachs Water Service / Genivar)**
» Advantage: little disruption of operation
» Limitations:
  - Can only be pushed a hundred feet, more or less
  - Time consuming; degree of inspection is limited
  - Provided no condition information

Broadband electromagnetic (Rock Solid)

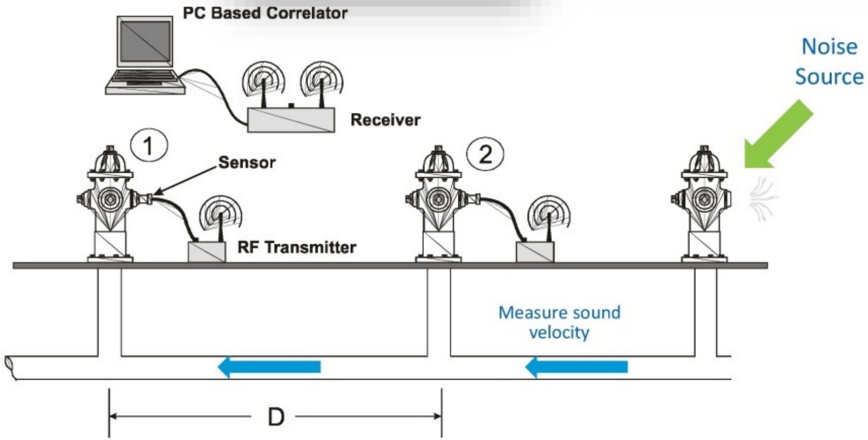
- » External scanning using vacuum-excavated keyhole
- » Internal scanning of drained pipe
- » Limitations
  - Limited coverage
  - Time consuming
  - Dry, straight pipe needed for in-pipe inspection




Acoustics velocity testing (Echologics)

- **Non-Invasive**. Pipe access using existing appurtenances or vacuum-excavated keyholes.
- Provides **average thickness** between transducers
- Limitations:
  - **Does not detect isolated pitting**
    - **Information can be lost in data noise**

$$v = v_o \times \sqrt{\frac{1}{\left[1 + \left(\frac{D_i}{t_r}\right) \times \left(\frac{K_l}{E}\right)\right]}}$$



Remote-field testing (PICA SeeSnake)

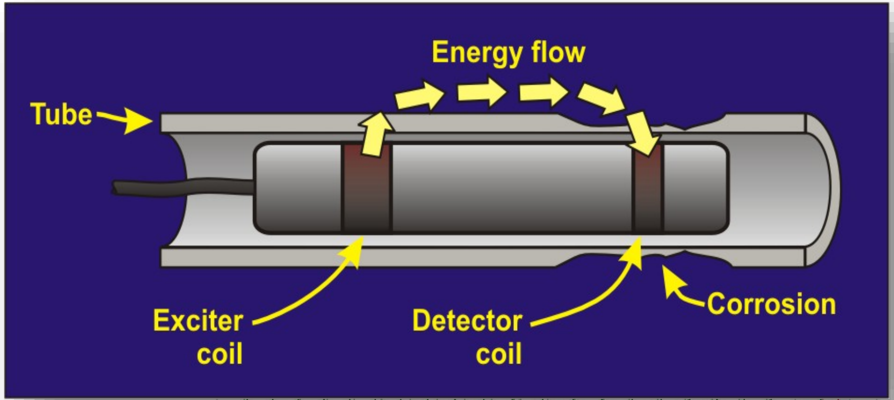
» Generates / detects electromagnetic field

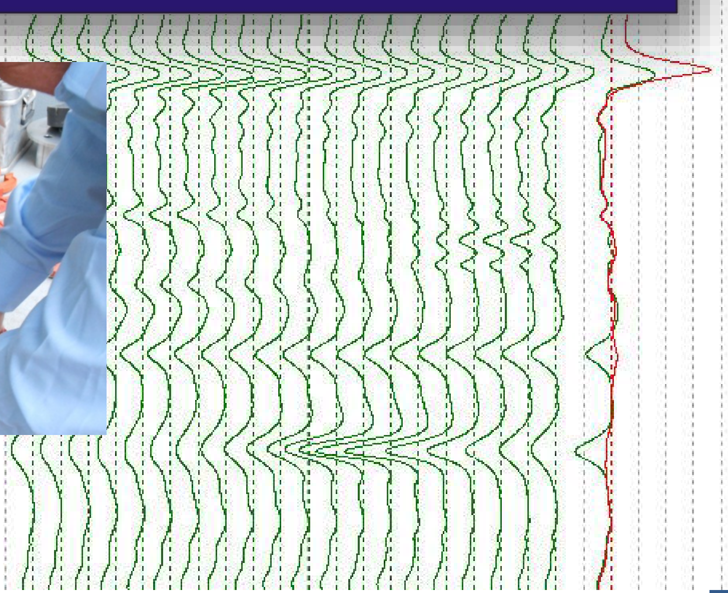
» Pros

- High resolution detection of defects
- Long runs possible
- Proven over two decades

» Cons

- Requires outage for pipe access





Using the SeeSnake on Valleyheart

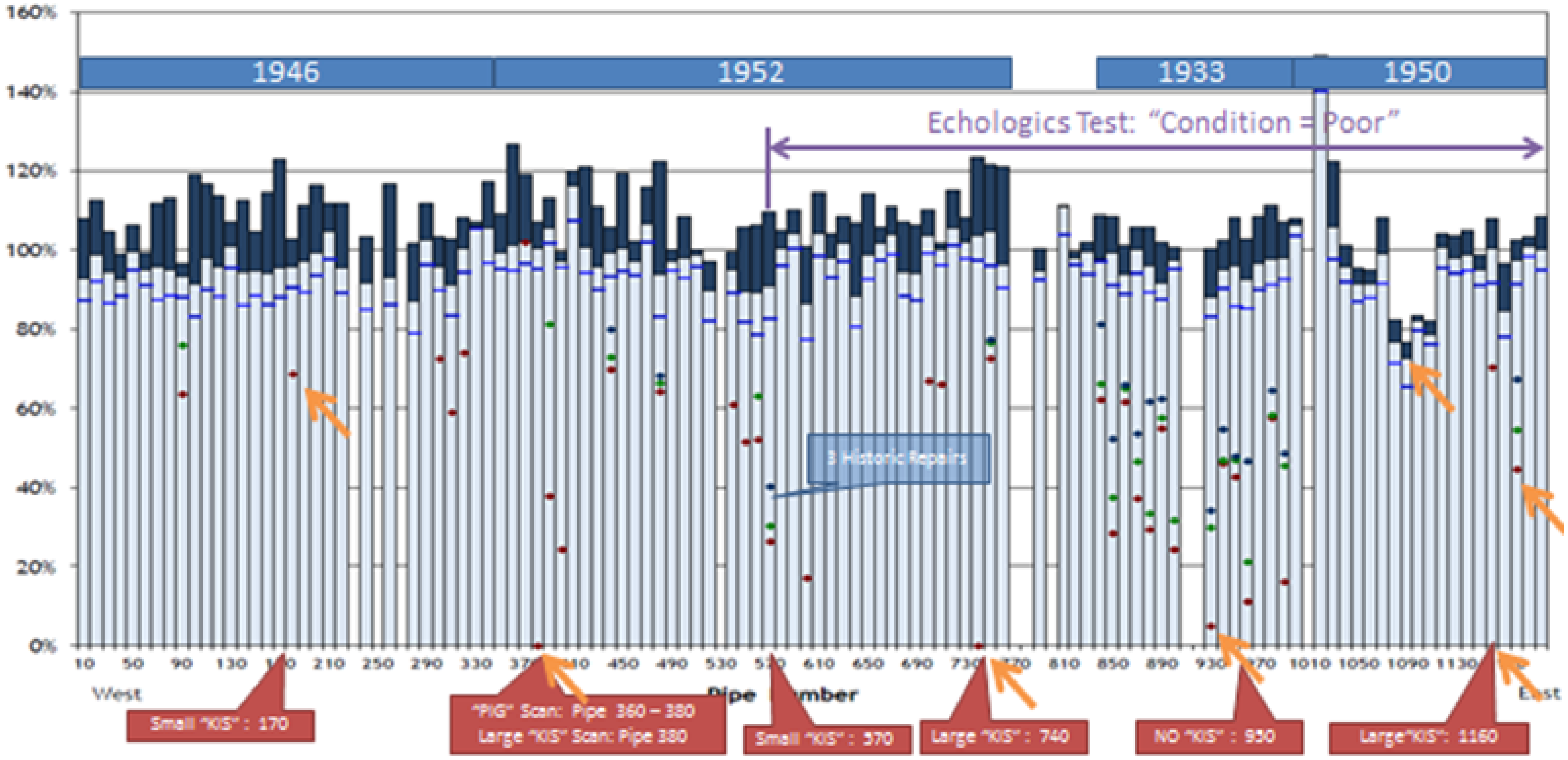
Inserting the tool into the launching port. Normally this tool is launched from a fire hydrant's vertical drop leg.

This custom hydrant guides the rope past a seal. By using clamps to hold the hydrant in place, flange patterns don't have to match.

Ready to launch. The fire hose provided water to push the tool to the far end of the main. A plastic sheet contains water that leaks from the assembly. The hydrant is braced to the trailer to counteract the winching force.

The location of the NDE tool is tracked by measuring the amount and speed of tether rope deployment. Underneath the table is the motor used to winch back the tool. All tools and equipment were powered from a small electrical generator.

Exhumation plan with a focus on 1933 pipe

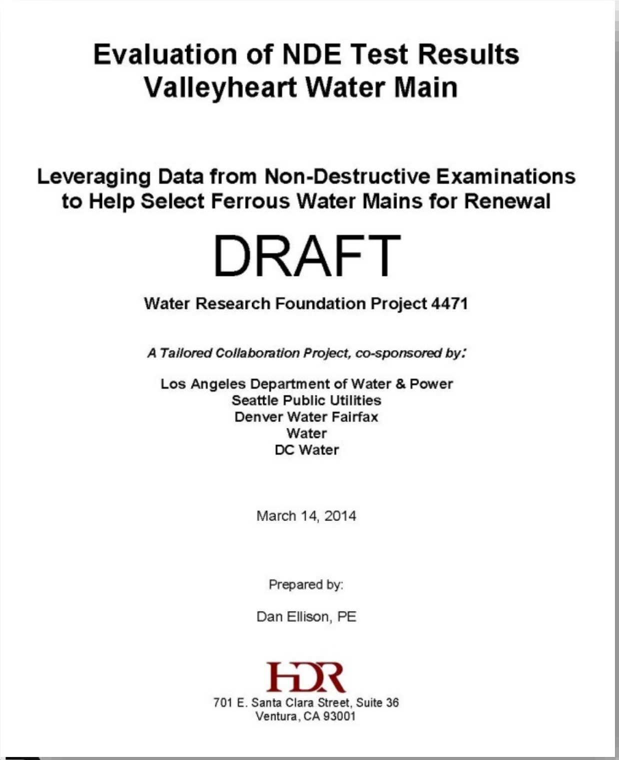


= Proposed Extraction

Seven pipe segments were split longitudinally into 14 pieces, then sandblasted.

Uncorroded pipe measurements were generally 7/16-inch thickness (0.43 inch).

Phase 1: Side-by-side technology comparisons



Evaluation of NDE Test Results
Valleyheart Water Main

Leveraging Data from Non-Destructive Examinations to Help Select Ferrous Water Mains for Renewal

DRAFT

Water Research Foundation Project 4471

A Tailored Collaboration Project, co-sponsored by:

Los Angeles Department of Water & Power
Seattle Public Utilities
Denver Water Fairfax
Water
DC Water

March 14, 2014

Prepared by:

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- **Water Research Foundation Project 4471**
- 5 technologies applied to 2000 feet of CI pipe

Phase 1: Findings and Conclusions

- No perfect method; interpretation is art and science
- **In-pipe remote field technology provided depth and breath**
- 80 percent of Valleyheart main was “Good” to “Excellent”
- A cost-effective strategy for Valleyheart main might have been:
  - Line the unlined 1933 pipe
  - Install a few anodes near repair areas

How to Use NDE Effectively on Water Mains

» **Access**: Scan 6"/8" mains thru hydrants

» **Target**: Mains likely to be most corroded

» **Sample**: Various vintages in various areas

» **Leverage**: Extrapolate information to mains of similar vintage and area (siblings)

PHASE 2: EACH UTILITY CHOSE RFT TO TRY IN THEIR SYSTEM


DWP

HOW TO DO CONDITION ASSESSMENT?

- Please don't dig
- Please don't put something in the pipe
- Please don't interrupt operations
- Please don't disrupt community activities
- Make it very, very, very cheap
- …and also please tell us about every defect

Photo by Bettmann/Corbis

Audience Question #2 – What Needs to be Considered ?

There are multiple methods of assessing water mains.

To select the best methods, you must consider many factors.

You don’t simply drop a camera in a manhole.

What are factors to be considered in selecting an assessment method?

Please type your answers in the chat box.

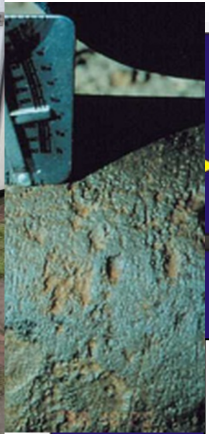
FACTORS TO CONSIDER

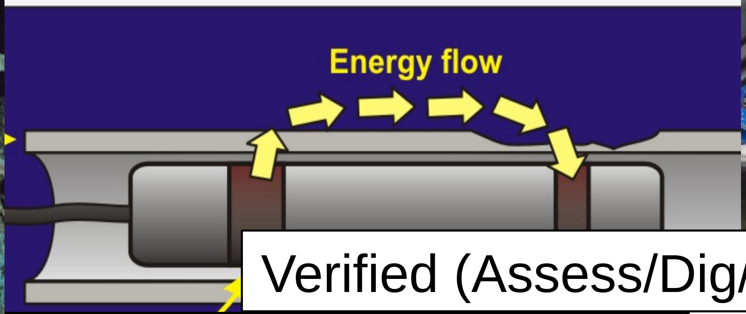
SAFETY = #1

- Type of Pipe
- Types of Defects
- Pipe Access
- Size of Pipe
- System Operations
- Value of Pipe
- Consequences of Failure
- Cost of Assessment
- Protection of Health
- Potential Water Discoloration
- Risk Tolerance
- Available Data
- Available Technologies
- Permits / Traffic

Phase 2 of 3: Each Utility Choose Technology to Use in their System

Everyone choose SeeSnake (PICA)





Verified (Assess/Dig/Measure)

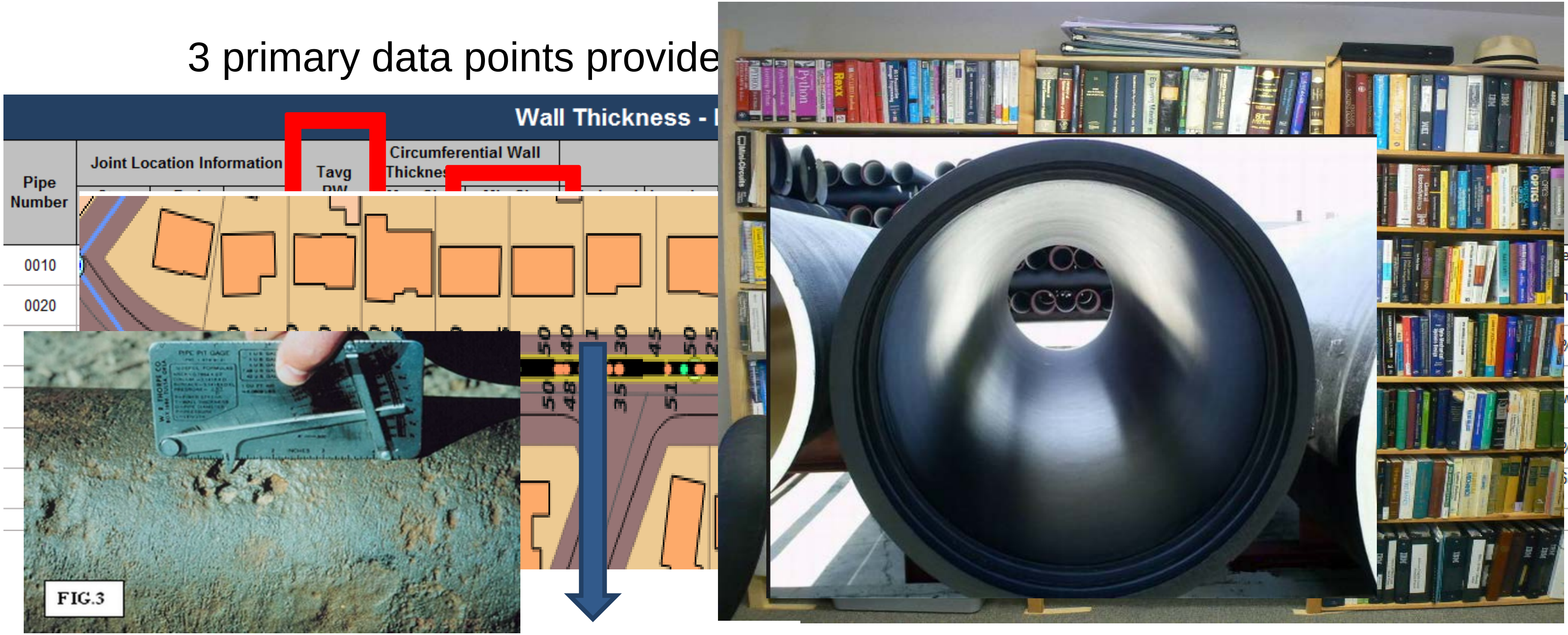
Crew Size: 4 Productivity: 50-75 mi/yr	Calgary Otay

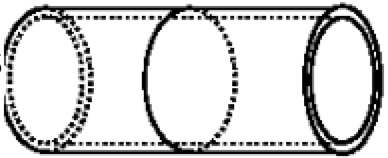
Because…

1. Reliably measure the location and depth of pitting
2. High productivity
3. No construction needed
4. Limited service interruption

Phase 3 of 3: Use data to optimize decisions?

3 primary data points provide

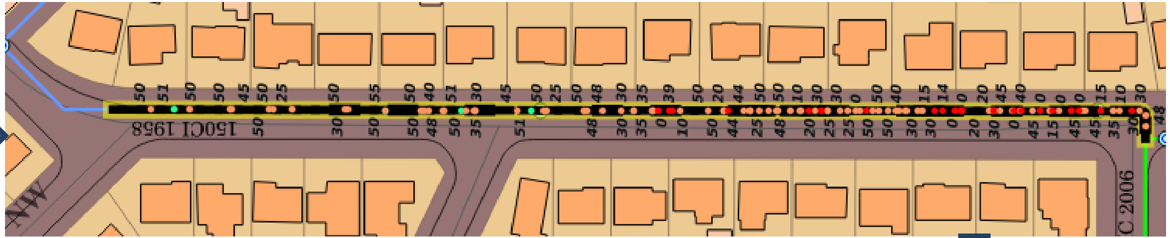


Utility reaction: It's  but how do I use this to make a decision?

Leveraging Lessons Learned from Calgary

Calgary
(~100 mi since 1999)

Stored Data in GIS

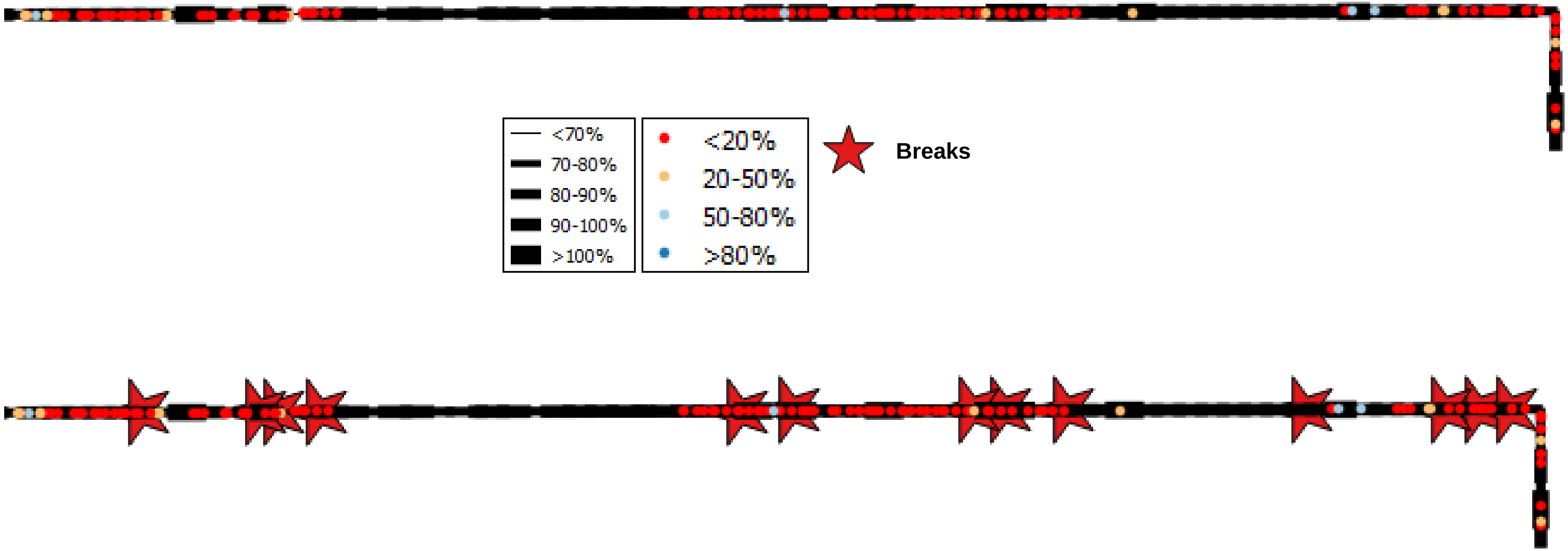


Institutional Knowledge:

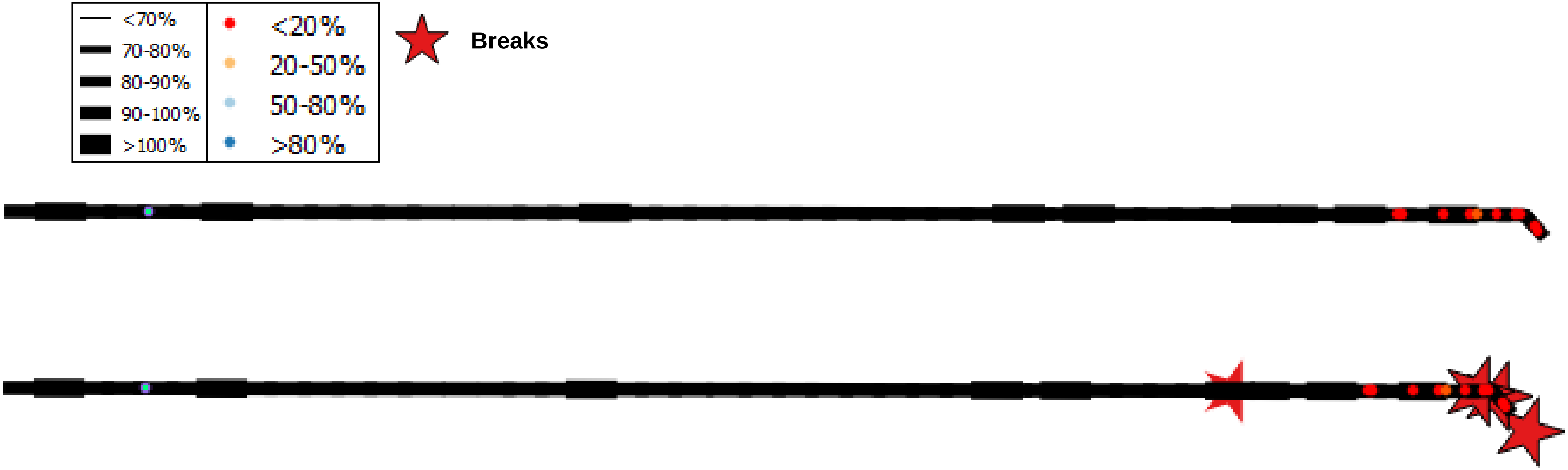
- SeeSnake is effective
- Pits drive breaks

WRF Step 1: Examples to Validate Institutional Knowledge

Validating Institutional Knowledge
Example 1 (~1,300’)



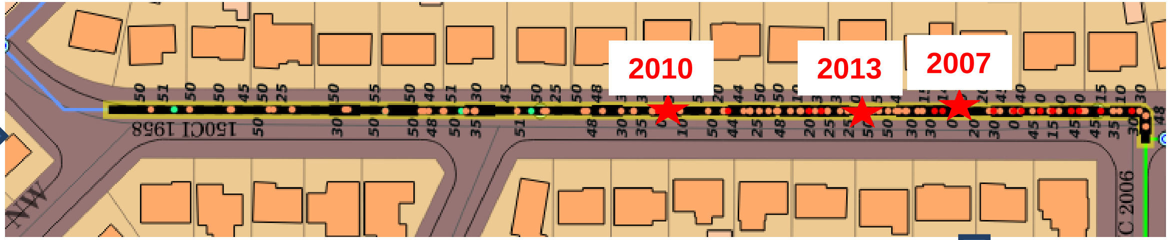
Calgary SeeSnake Results – Example 2



Lessons Learned from Calgary

Calgary
(~100mi since 1999)

Overlay breaks after inspection (e.g. inspected 2002)



143 Condition Related break after Inspection

Institutional Knowledge:
- SeeSnake is effective
- Pits drive breaks

WRF Step 1:
Examples to Validate Institutional Knowledge

WRF Step 2:
Verify data could forecast breaks

HDR

Analysis: Why did these break occur?

» **Primary Predictor - Pit depth and density**

» Data supports theory that **multiple deep pits more likely to result in catastrophic failure** (3 breaks)

		Worst Pit			
		Thru Pit (0% RW)	Deep Pit (1-30% RW)	Modest Pit (31-50% RW)	Shallow Pit (Greater than 50% RW)
Pit Count	No Pits	5			
	Isolated Pit	130	68	23	20
	Multiple Pits	208	79	66	17

Figure 7-5. Annual Break Rate (per 100 miles) by Pit Depth and Density. *This shows a strong correlation between pit data and the likilihood of future breaks*

Decision Optimization (Opportunity Example)

Calgary - Centre Street Bridge
Historic Landmark & Transport Corridor

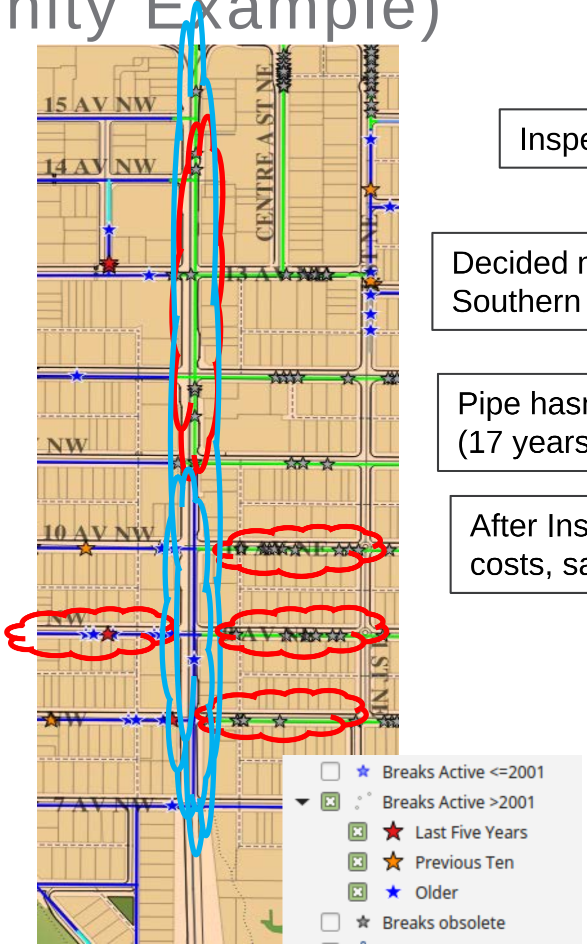
Planned Shut Downs Once Every 20 Years (2000)

Decision: Replace 1946 CI Pipe?

Easy Decision: Replace

Hard Decision: Replace?

Break Clusters on Adjacent Street



Inspected Pipe

Decided not to replace Southern section

Pipe hasn't broken yet (17 years)

After Inspection costs, saved ~$200k

Benefits of NDE

1. Extending the life of some mains
2. Preventing unnecessary breaks on other mains
3. Identifying the most cost effective renewal technology and project extents
4. Increasing confidence in decision making
5. Saving money

Poll Question

- Would you consider this technology on your small metallic pipes?
- We have already used it
- Yes
- Maybe, need more info
- No, small metal pipes aren’t a concern
- No, because of concerns

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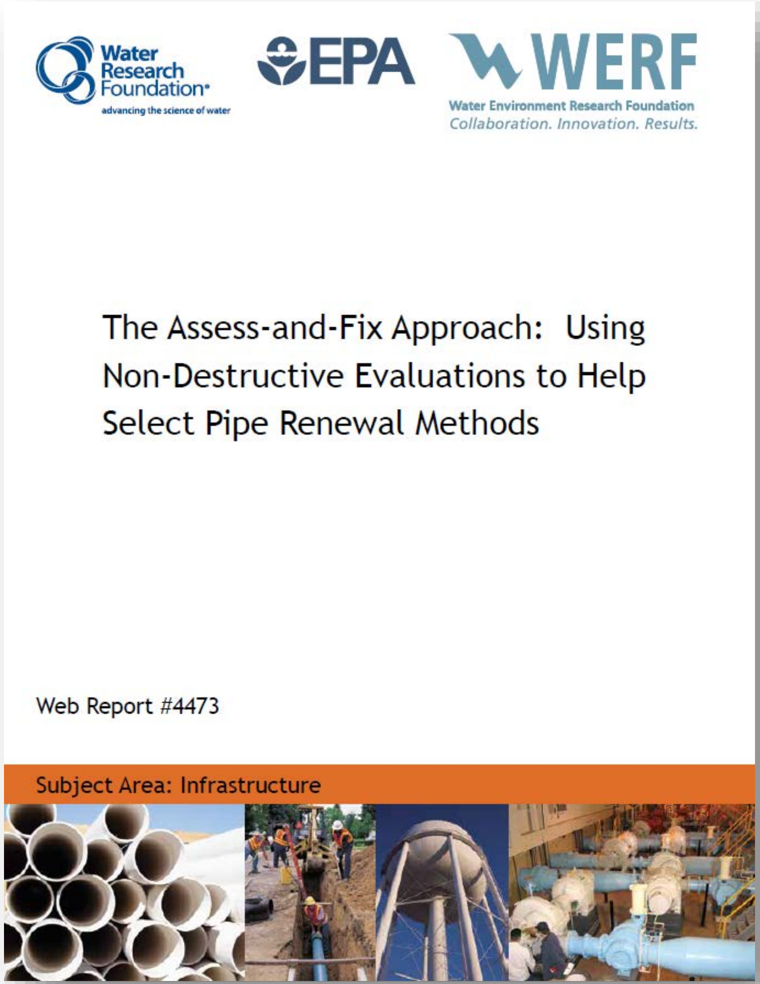
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The Assess-and-Fix Approach: Using Non-Destructive Evaluations to Help Select Pipe Renewal Methods

Web Report #4473

Subject Area: Infrastructure

Premise:

(1) Scan Mains After Cleaning

(2) Design the Lining for the Pipe Condition

» How to Employ Condition Assessment on Rehab Projects

» How to Design Rehab using Condition Assessment Data

» Pilot Test in Phoenix

Water Main Rehabilitation is Infrequently Used because…..

- **Cost**: Money is better spend on a new main
- **Misunderstanding**: Old mains have no value
- **Uncertainty**: How long will the product last?

These objections disappear, if the Assess-and-Fix method is used on a large scale

Photo: Hydrotech

"Time to Think Outside the Trench
For run-of-the-mill water infrastructure renewal, there is arguably little that is accomplished through open-trench construction that cannot be accomplished with rehabilitation and other trenchless methods…."

The Assess-and-Fix Approach
WaterRF Project 4473

» Based on….

- There's value in old pipes
- NDE is easily performed as part of a typical pipe rehab project
- By knowing the condition, rehab can be optimized

» Challenge 1

- Guideline matching pipe condition to rehab method

» Challenge 2

- Demonstration project



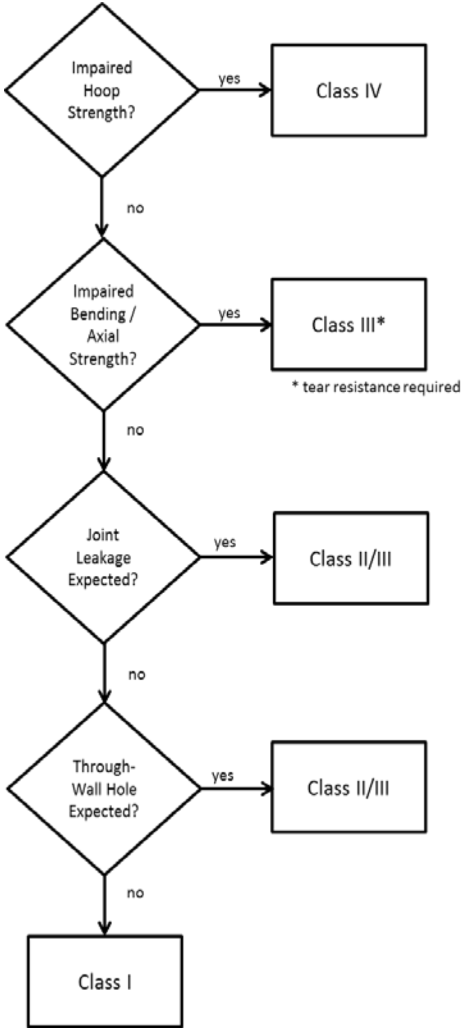
Photos: WaterRF and LADWP

Steps Involved in Assess-and-Fix Evaluation

1. Select a main for rehabilitation / renewal
2. Establish a contract suitable for the method
3. Set up a bypass piping system
4. Excavate for pipe access
5. Clean the main
6. Assess the main
7. Select and design the lining
8. Apply the lining
9. Service reinstatements
10. Return to service
11. Complete the project

With perfect knowledge, selecting a lining is simple

- Which pipes have **impaired bending strength**?
  - There's **no standard** for minimum bending resistance
  - Bending moments are generally **unknowable**
  - **Chaotic pit patterns** are very difficult to analyze



Three methods are suggested for evaluating pipe integrity

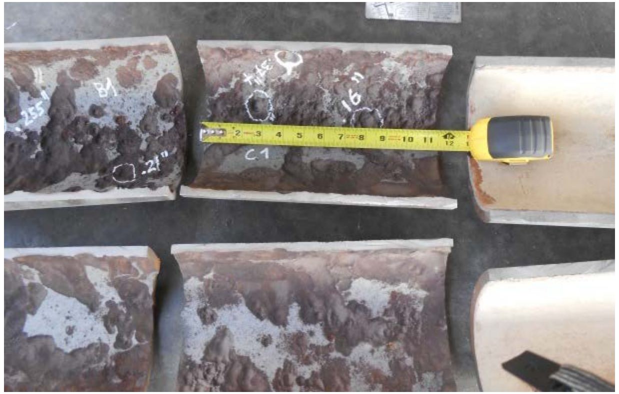
» **Deterministic Analysis** – Calculate stresses and associated safety factors

- Forecast future condition
- Determine loading conditions
- Calculate stresses
- Compare to material strengths

- Requires knowledge about many variables
- Requires complex calculations

» **Statistical Analysis** – compare pipe characteristics to historic break data

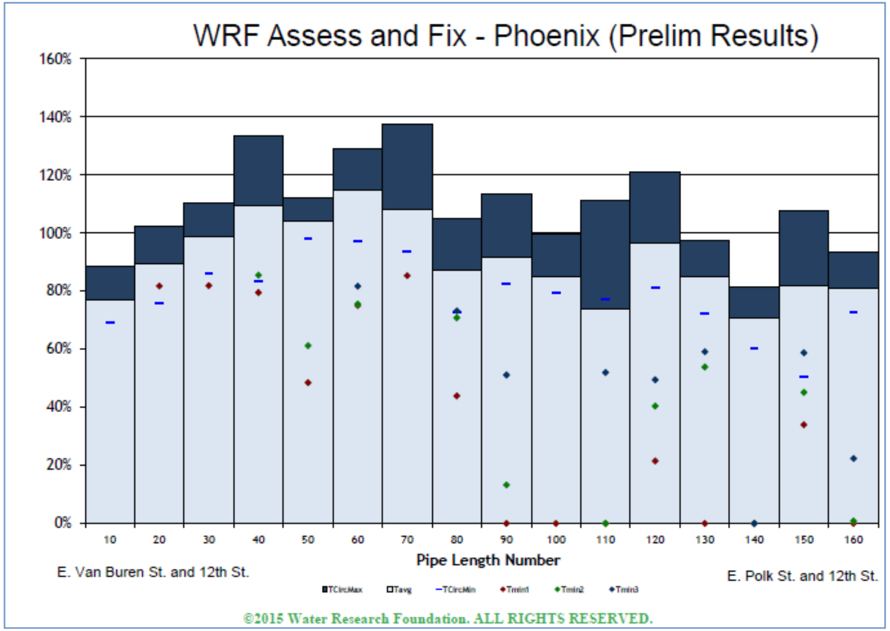
» **Risk Analysis** – assess risk based on weighted matrix analysis of relevant variables

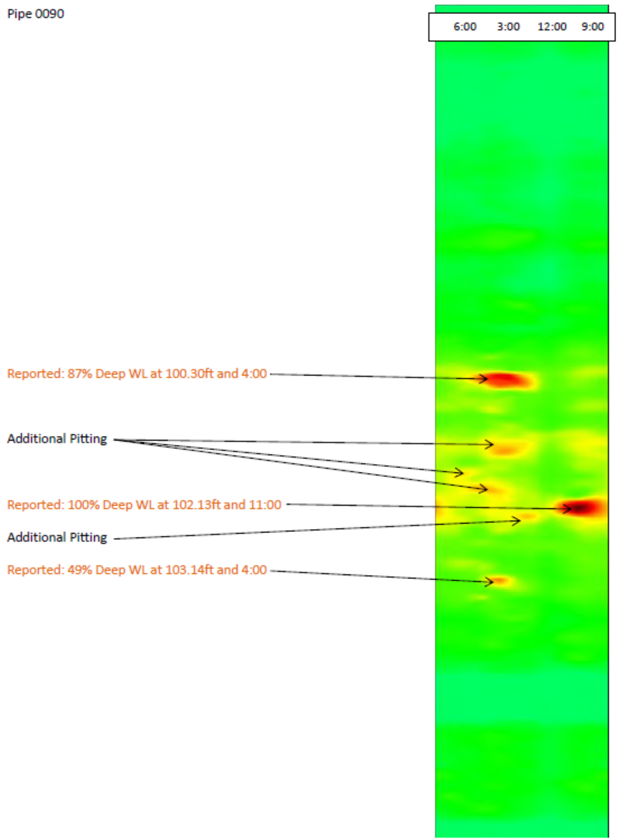


Field demonstration in Phoenix

Phoenix Results Showed the Potential Benefits of the Method

- Several deep pits
- Widely scattered pits
- Minimal overall metal loss





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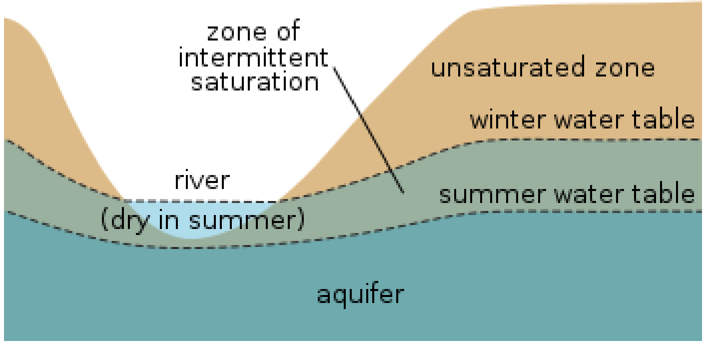
Prominent Mechanisms for AC Pipe Deterioration

1. Sulfate Attack
2. Salt Cracking
3. Calcium Leaching

Sulfates in Soil react with free lime → Expansive Ettringite → Cracking → Loss of Strength

Reaction accelerated if exposed to wet/dry cycles



Sulfate attack is LEAST COMMON

If Soft/Mushy pipe encountered

→

Soil sample

Pipe sample

→ Verify Sulfate Attack

Prominent Mechanisms for AC Pipe Deterioration

1. Sulfate Attack
2. <u>Salt Cracking</u>
3. Calcium Leaching

Salts migrate into crack or pore spaces → Hydrate/ Expand/ Crystalize → Cracking → Loss of Strength

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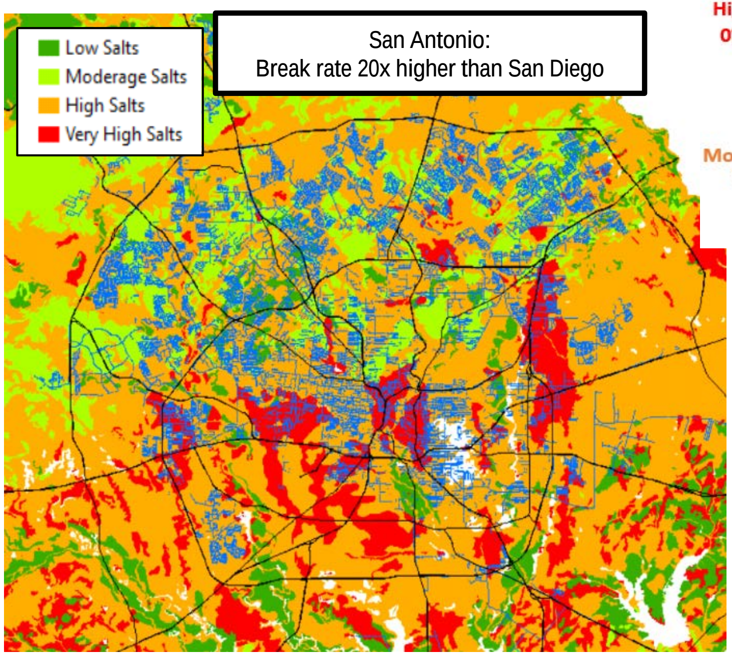
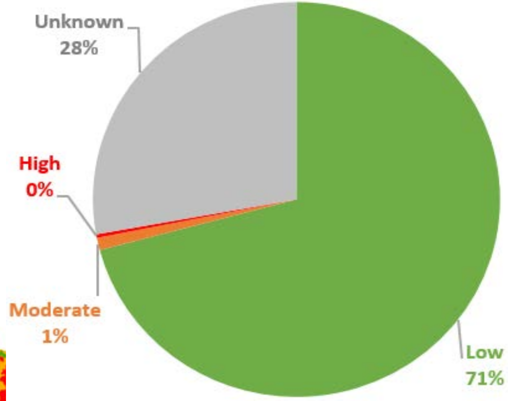
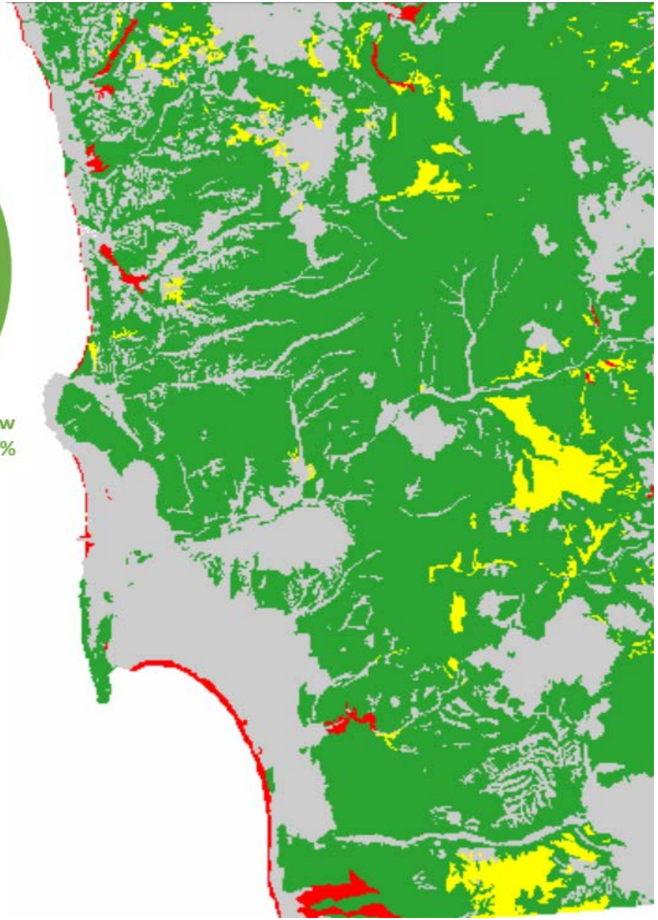


USGS Salt Mapping





Prominent Mechanisms for AC Pipe Deterioration

1. Sulfate Attack
2. <u>Salt Cracking</u>
3. Calcium Leaching

Salts migrate into crack or pore spaces → Hydrate/ Expand/ Crystalize → Cracking → Loss of Strength

Extend of salt cracking is likely High Variable, in the US

Soil sample

Pipe sample

→ Verify Salt Cracking

Prominent Mechanisms for AC Pipe Deterioration

1. Sulfate Attack
2. Salt Cracking
3. Calcium Leaching

Cement leaching is the most common deterioration mechanism, in the US

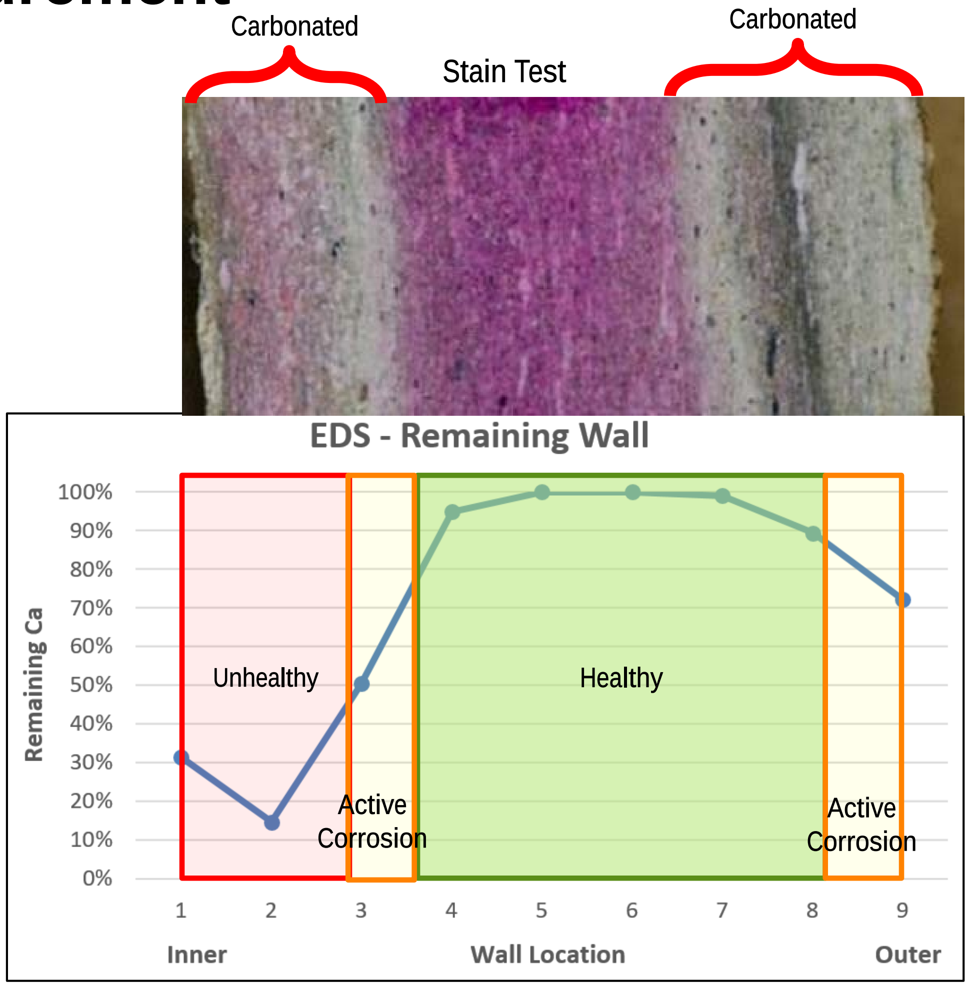
Calcium Leaching & Measurement

Step 1: Carbonation (Fine for AC)

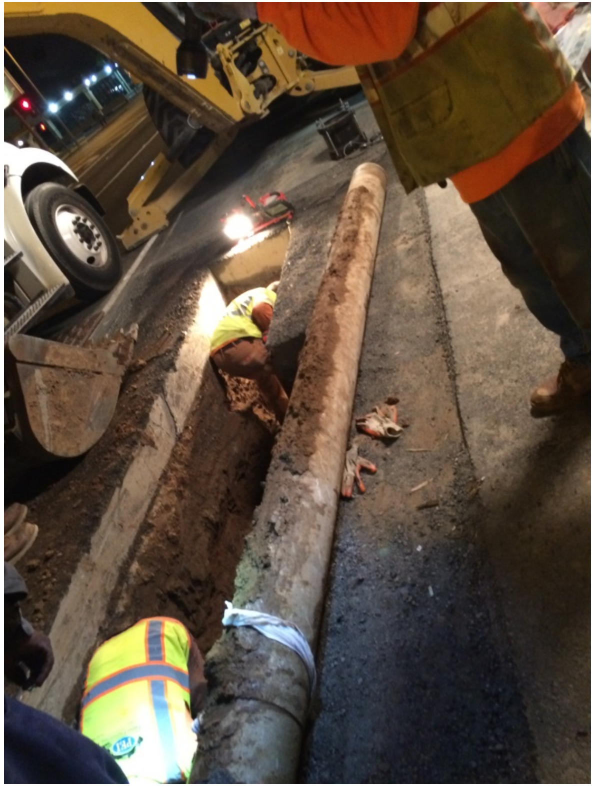
- Precursor to deterioration

Step 2: Dissolve & Carry Away Ca (Bad)

- Loss of strength



Cost-effect AC Condition Assessment (Opportunistic)



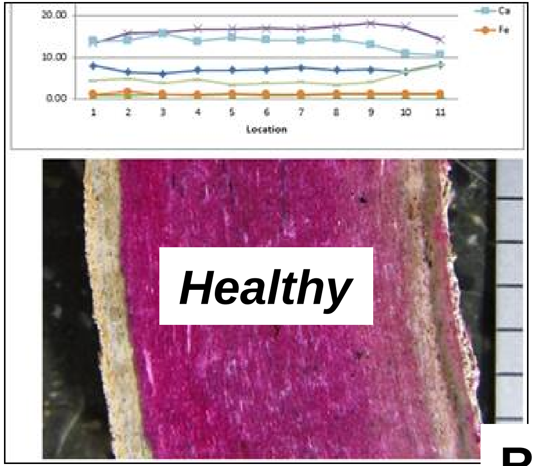
Proactive Assessment

- *$$$*
- *Disrupts Customers & Community*
- *Only cost effective on high consequence pipes*

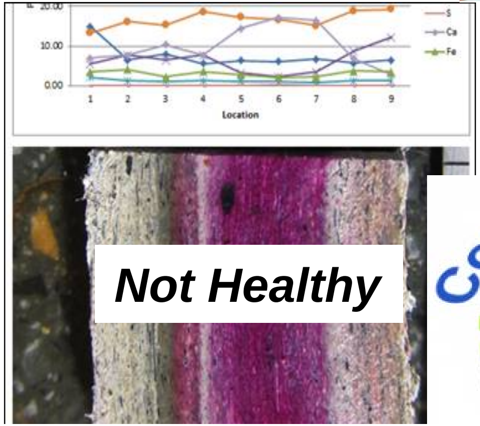
Cost-effect AC Condition Assessment (Opportunistic)

Pipe Exposed

Reduce cost ~90%



Healthy



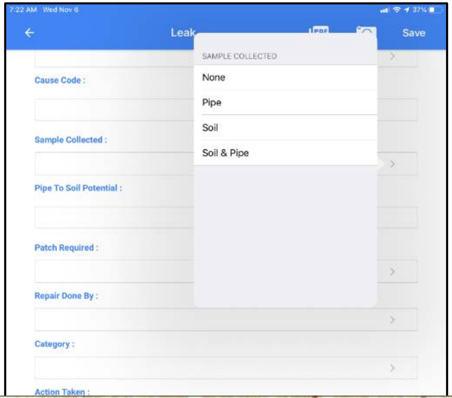
Not Healthy

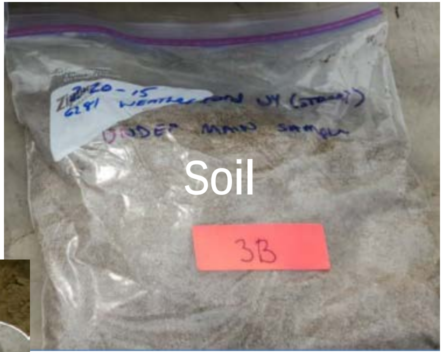
Replace the right pipe at the right time

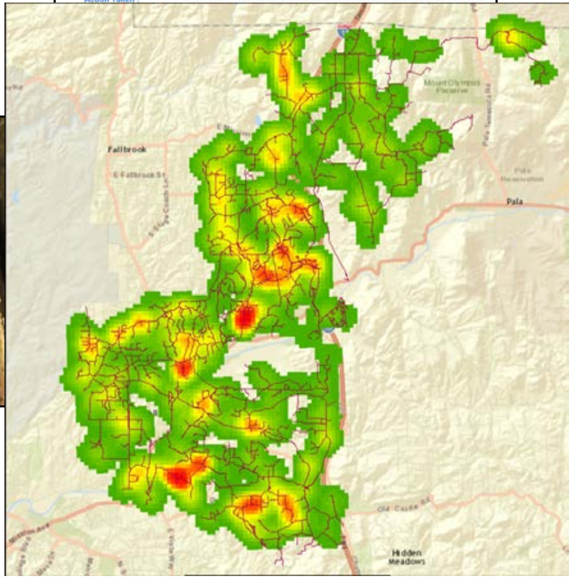
AC Samples Can be Small (1” or more, full wall thickness)

Opportunistic Testing Varies by Material

Pipe Exposed: Cost Effective CA







Cathodic Protection (Metallic Pipe)

Pipe Exposed: Cost Effective CA

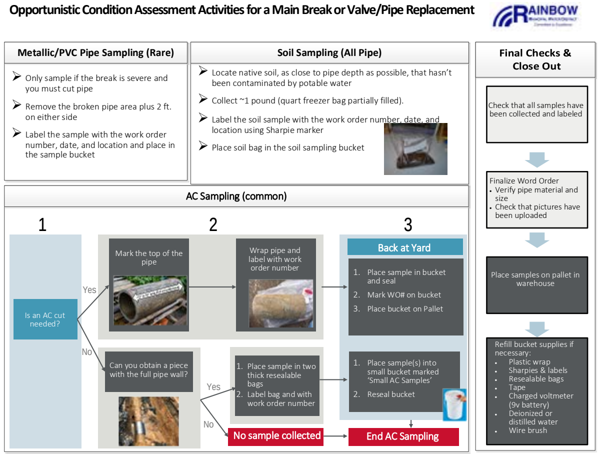
Larger, Electrically Continuous Pipes

Anode

(~90% less expensive)

Successful Opportunistic CP & Condition Assessment Program

Crew SOPs, Tools, & Training

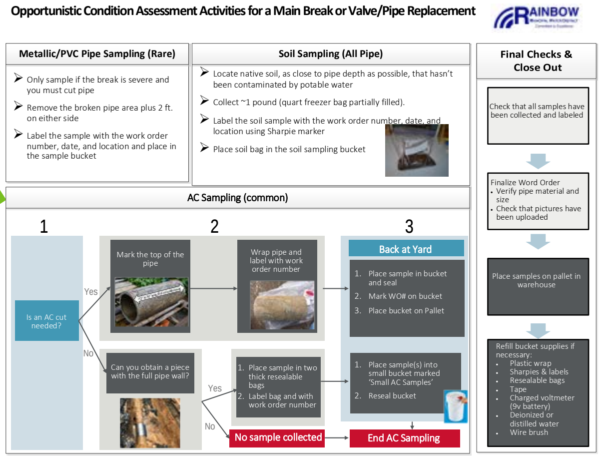


How data will be used to make decisions

SOPs, Tools, & Training

Transforming Challenges…

into Opportunities



Opportunistic Condition Assessment Activities for a Main Break or Valve/Pipe Replacement

Metallic/PVC Pipe Sampling (Rare)

- Only sample if the break is severe and you must cut pipe
- Remove the broken pipe area plus 2 ft. on either side
- Label the sample with the work order number, date, and location and place in the sample bucket

Soil Sampling (All Pipe)

- Locate native soil, as close to pipe depth as possible, that hasn't been contaminated by potable water
- Collect ~1 pound (quart freezer bag partially filled).
- Label the soil sample with the work order number, date, and location using Sharpie marker
- Place soil bag in the soil sampling bucket

AC Sampling (common)

1

Is an AC cut needed?

Yes

2

Mark the top of the pipe

Wrap pipe and label with work order number

3

Back at Yard

1. Place sample in bucket and seal
2. Mark WO# on bucket
3. Place bucket on Pallet

No

Can you obtain a piece with the full pipe wall?

Yes

1. Place sample in two thick resealable bags
2. Label bag and with work order number

1. Place sample(s) into small bucket marked 'Small AC Samples'
2. Reseal bucket

No

No sample collected

End AC Sampling

Final Checks & Close Out

Check that all samples have been collected and labeled

Finalize Word Order
- Verify pipe material and size
- Check that pictures have been uploaded

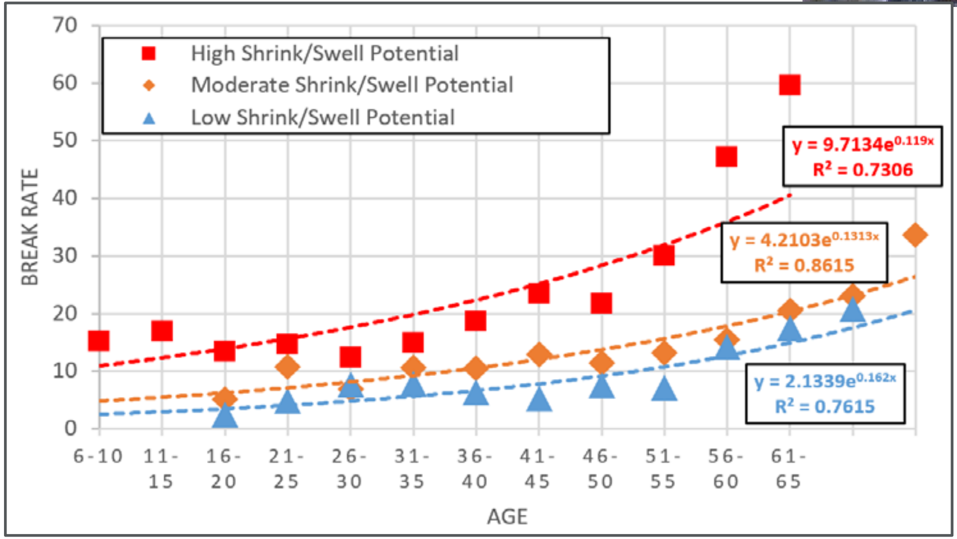
Place samples on pallet in warehouse

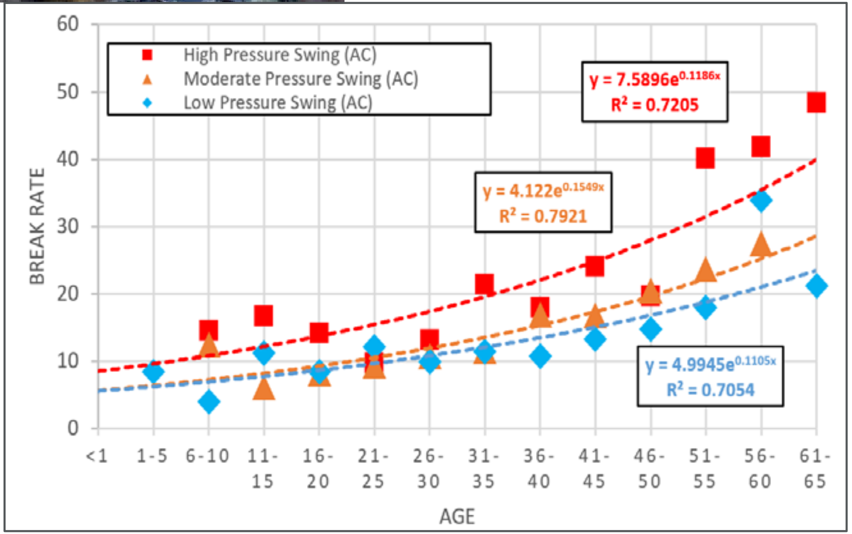
Refill bucket supplies if necessary:
- Plastic wrap
- Sharpies & labels
- Resealable bags
- Tape
- Charged voltmeter (9v battery)
- Deionized or distilled water
- Wire brush

For brittle AC pipe, Condition & STRESS → Breaks

Ground Movement

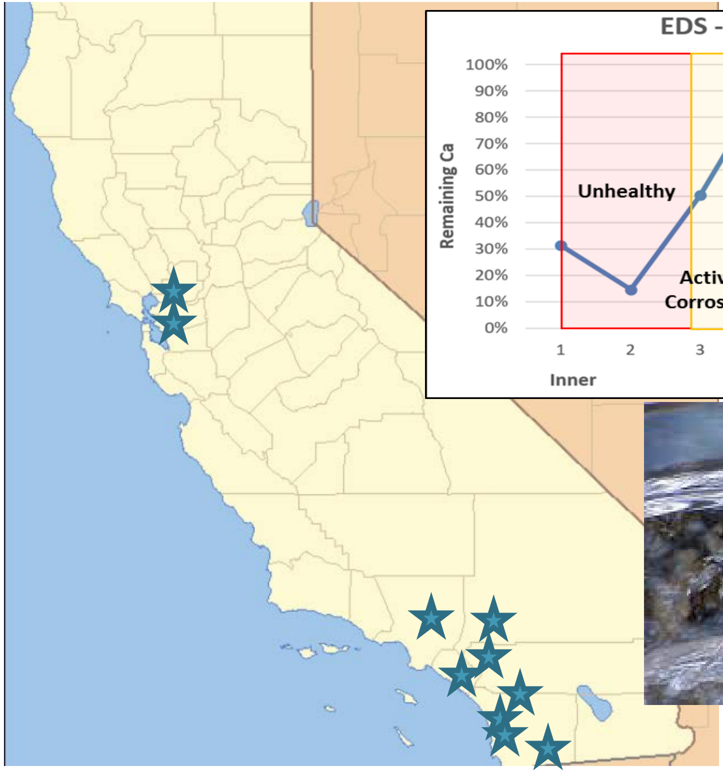
Pressure

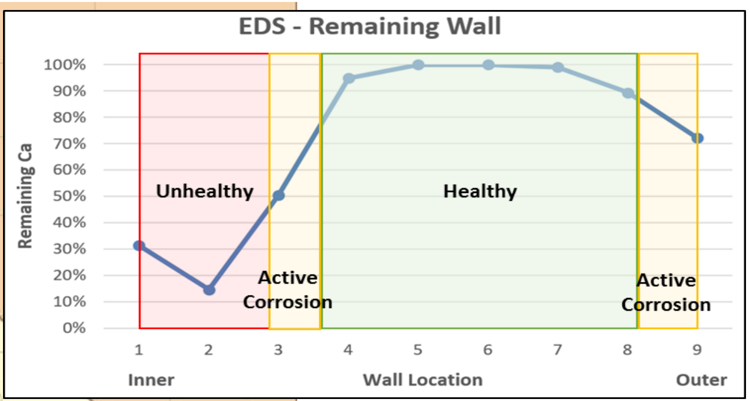




Quantify Relationship: Stress, Condition, Breaks

Consolidated 163 data points from 10 CA utilities

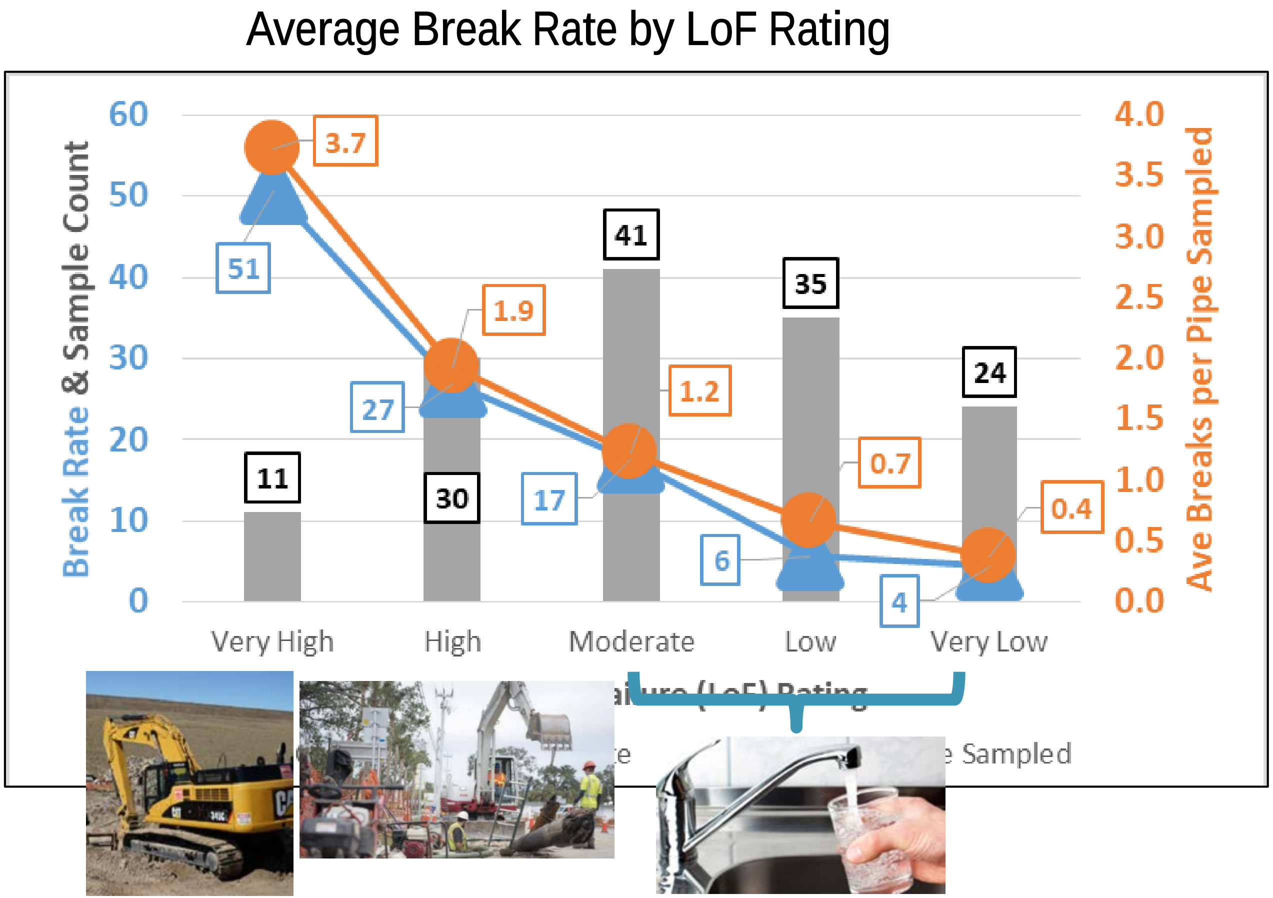




LoF Rating

Percent Remaining Wall	Stress	
	Low	High
Less than 50%	Very High	Very High
50% to 57%	High	Very High
57% to 62%	High	High
62% to 67%	Moderate	High
67% to 72%	Moderate	Moderate
72% to 77%	Low	Moderate
77% to 82%	Very Low	Low
More than 82%	Very Low	Very Low

Quantify Relationship: Stress, Condition, Breaks



Poll Question

- **Would you consider an opportunistic assessment program?**
- We have already implemented it
- Yes, we would consider implementing it
- Maybe
- No

Questions?

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