

# Proactive Pipeline Management:

Gresham's Innovative Approach to Watermain Assessment  
using Non-linear Vibroacoustics

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City of Gresham, Oregon

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OREGON



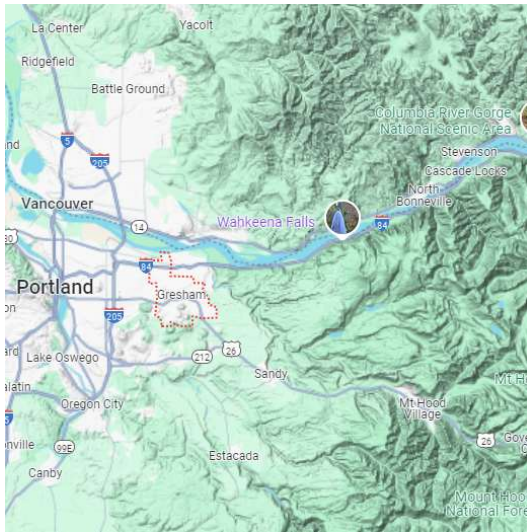
# Outline

1. Gresham Watermain Inspection Program
2. Vibroacoustic Inspection Technology
3. Fall 2023 Pilot Project with Validated Results
4. Fall 2024 Assessment Summary

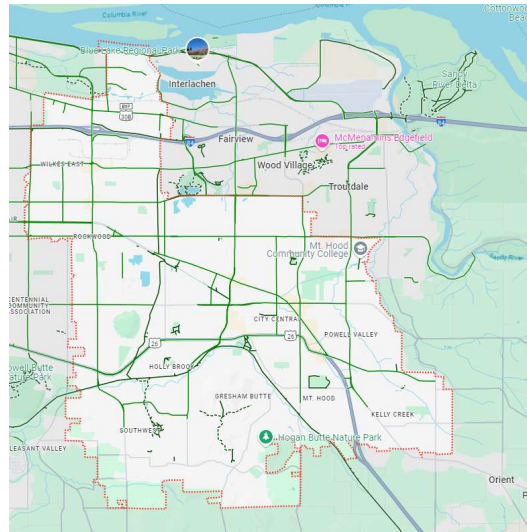




# Gresham, Oregon



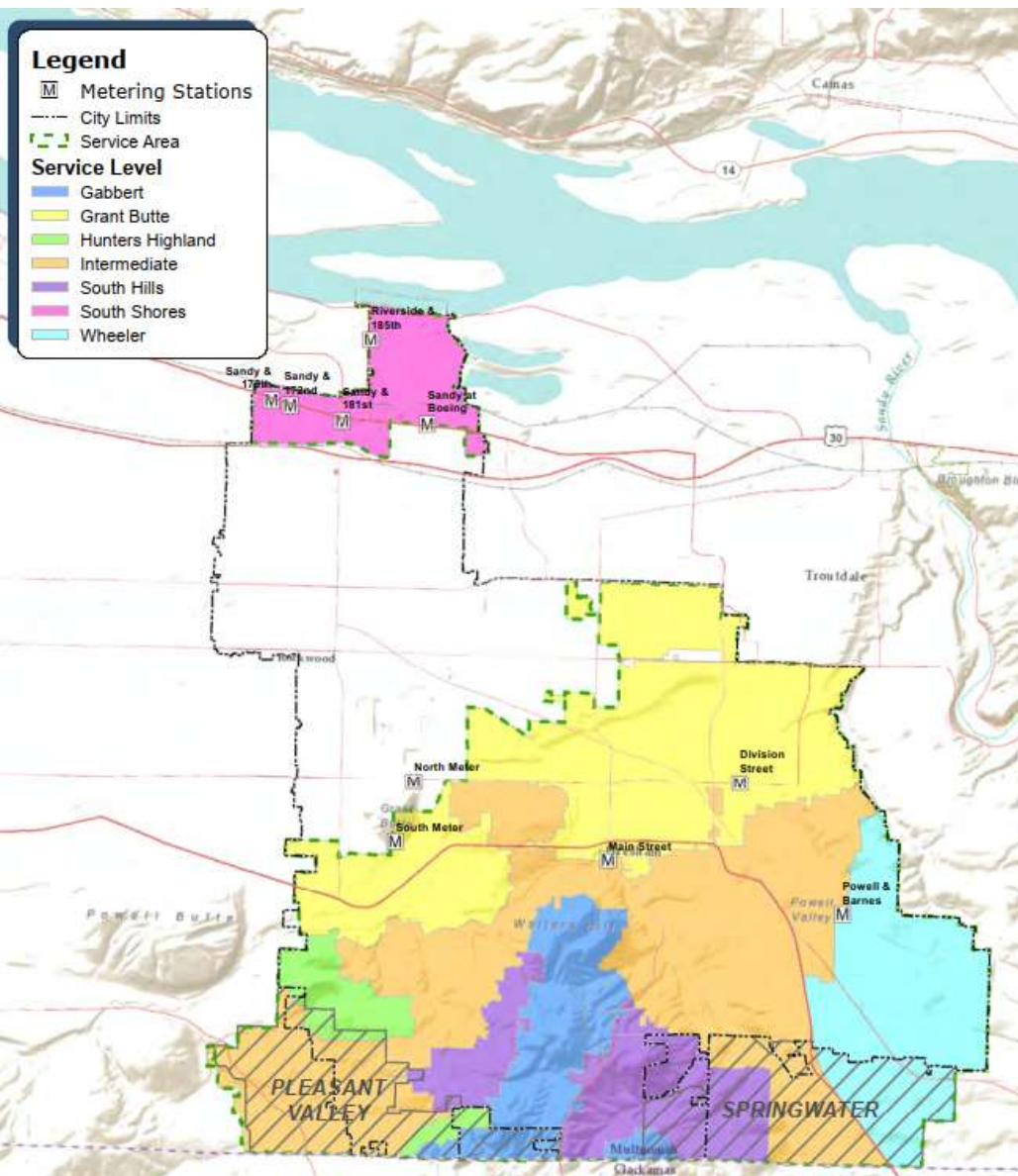
Located East of Portland, Oregon



Gresham, Oregon



Mt Hood



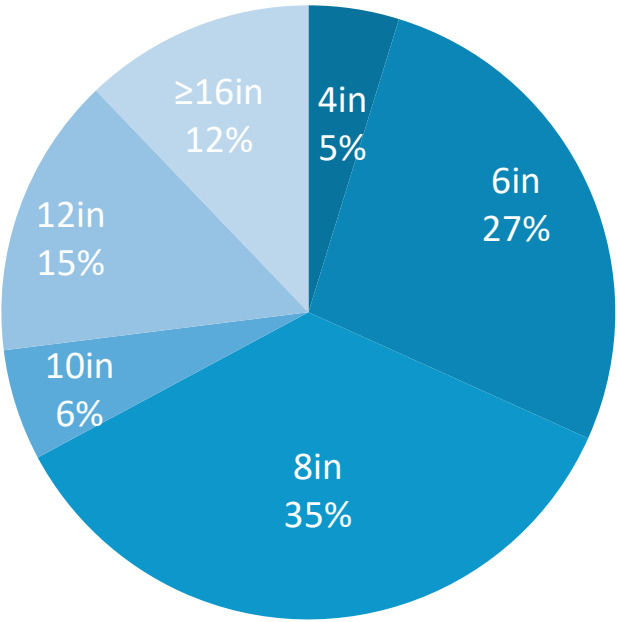
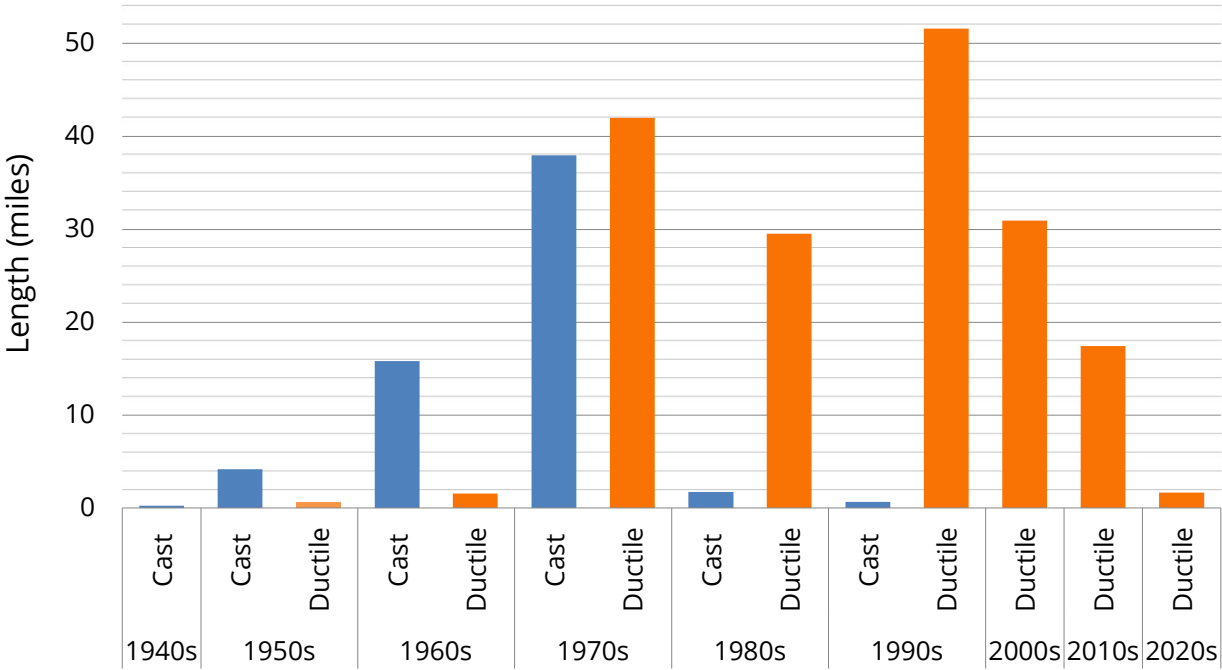
# CITY OF GRESHAM OREGON

## Water System

- Seven Service Areas
- Seven storage reservoirs
- Eight pump stations
- 280 miles (450km) of water pipelines



# Gresham - Water Pipeline Inventory



Source: Gresham Water Master Plan 2022

# Pipeline Replacement and Renewal Program

## Benefits of Program – Failure Reduction

- Impacts to customers and the environment
- Repair and replacement costs by performing work proactively rather than emergency
- Reduced water loss
- Reduction in Claims

## Suggested Pace of program

- 2.4 miles (4 km) per year
- ~1% of the system
- ~2% of the pipes installed prior to 1980





# Gresham - Risk Analysis Strategy

## AWWA M77 Manual

Likelihood of Failure X Consequence of Failure

### Likelihood of Failure

Uninspected pipes

- Age
- Material
- Leak / Break History

Inspected pipes

- Score (1 to 4) based on Remaining Useful Life (RUL) Estimate
- Bonus point for segments w break or leak

$$RISK = [LOF] \times [COF]$$

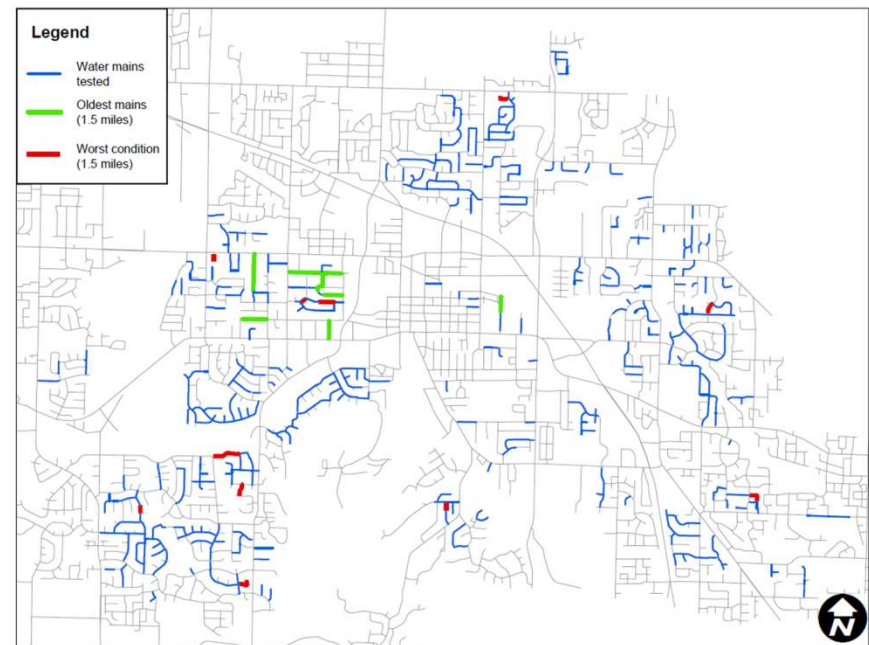
	LOF - 1	LOF - 2	LOF - 3	LOF - 4	LOF - 5
COF - 1	Lowest Priority				Medium Priority
COF - 2				Medium Priority	
COF - 3			Medium Priority		
COF - 4		Medium Priority			
COF - 5	Medium Priority				Highest Priority

Source: Gresham Water Master Plan 2022

# Gresham - Acoustic Velocity Testing Program

## Acoustic Velocity Testing (2018 to 2023)

- Age was not a good predictor of condition
- Physical condition correlated with
  - Soil corrosivity
  - Poor installation
  - Starting thickness
- 1970s Class 50 Ductile Iron worse than older Cast Iron
- 1980s switched to Class 52 (thicker)



**Source:** ASCE Pipelines 2021: Pipe Condition; Gresham's Approach to Asset Management



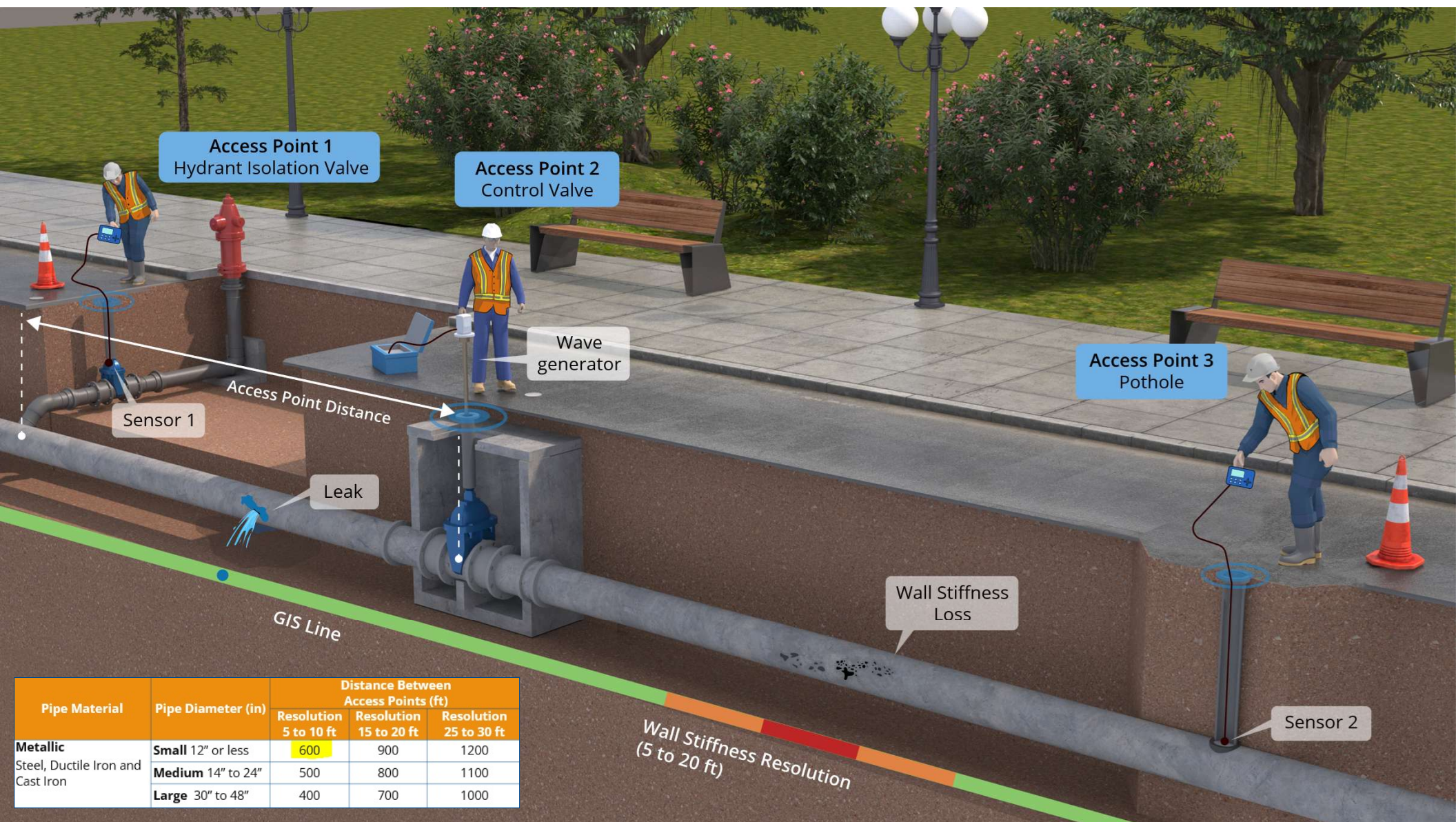
# Dynamic Response Imaging™

Vibroacoustic based Non-Invasive Pipeline Inspection

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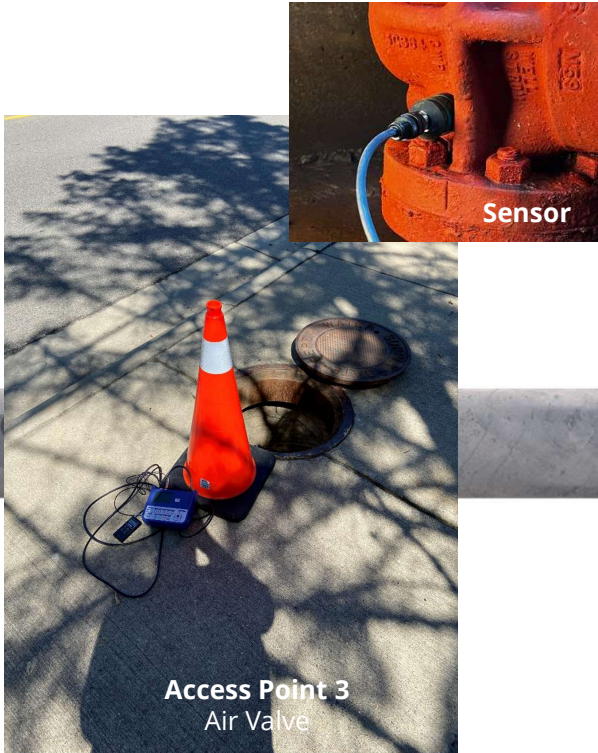
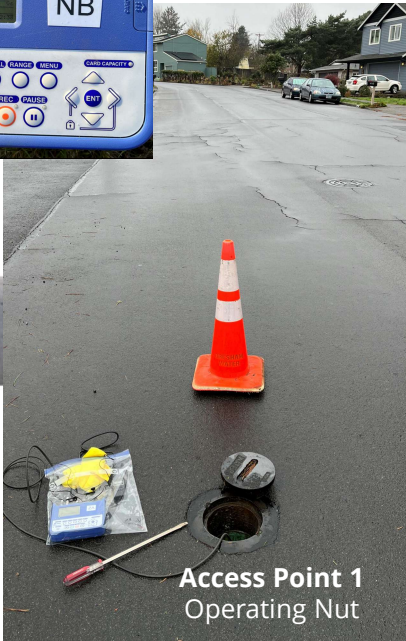


# Dynamic Response Imaging



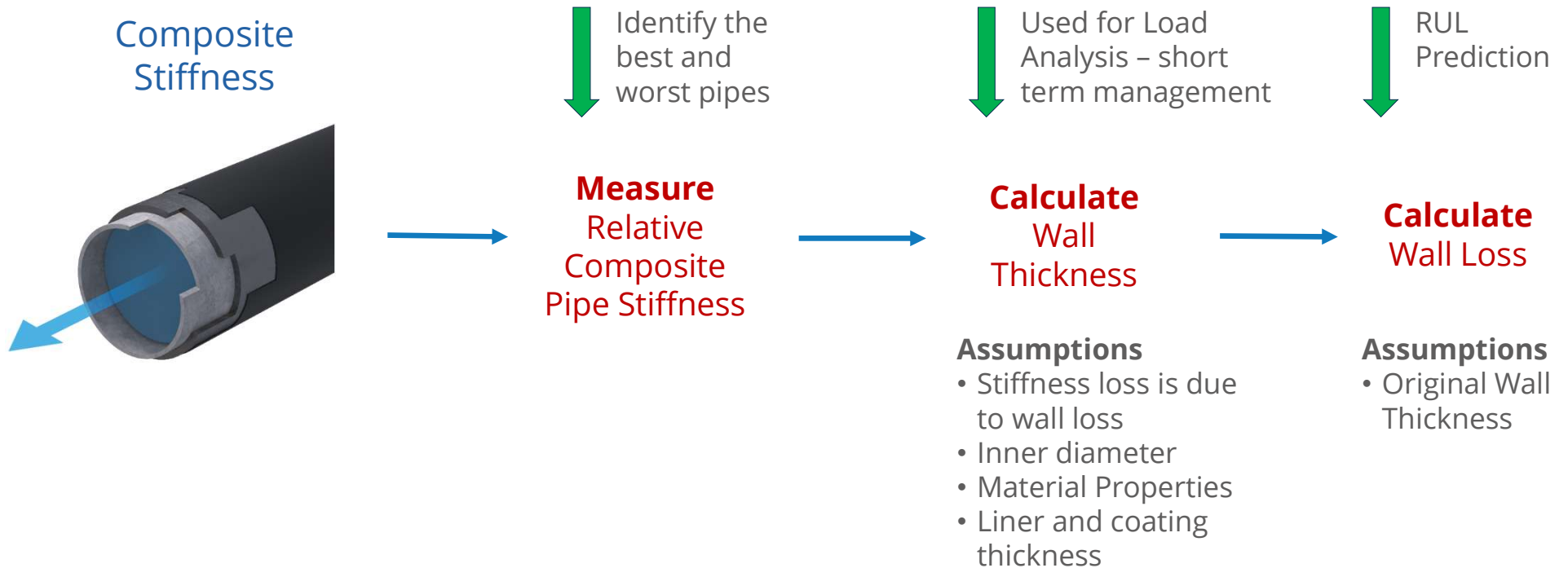


# DRI in the Field



# DRI Analysis

## Metallic Pipe



# Gresham 2023 - Pilot Project

Dynamic Response Imaging

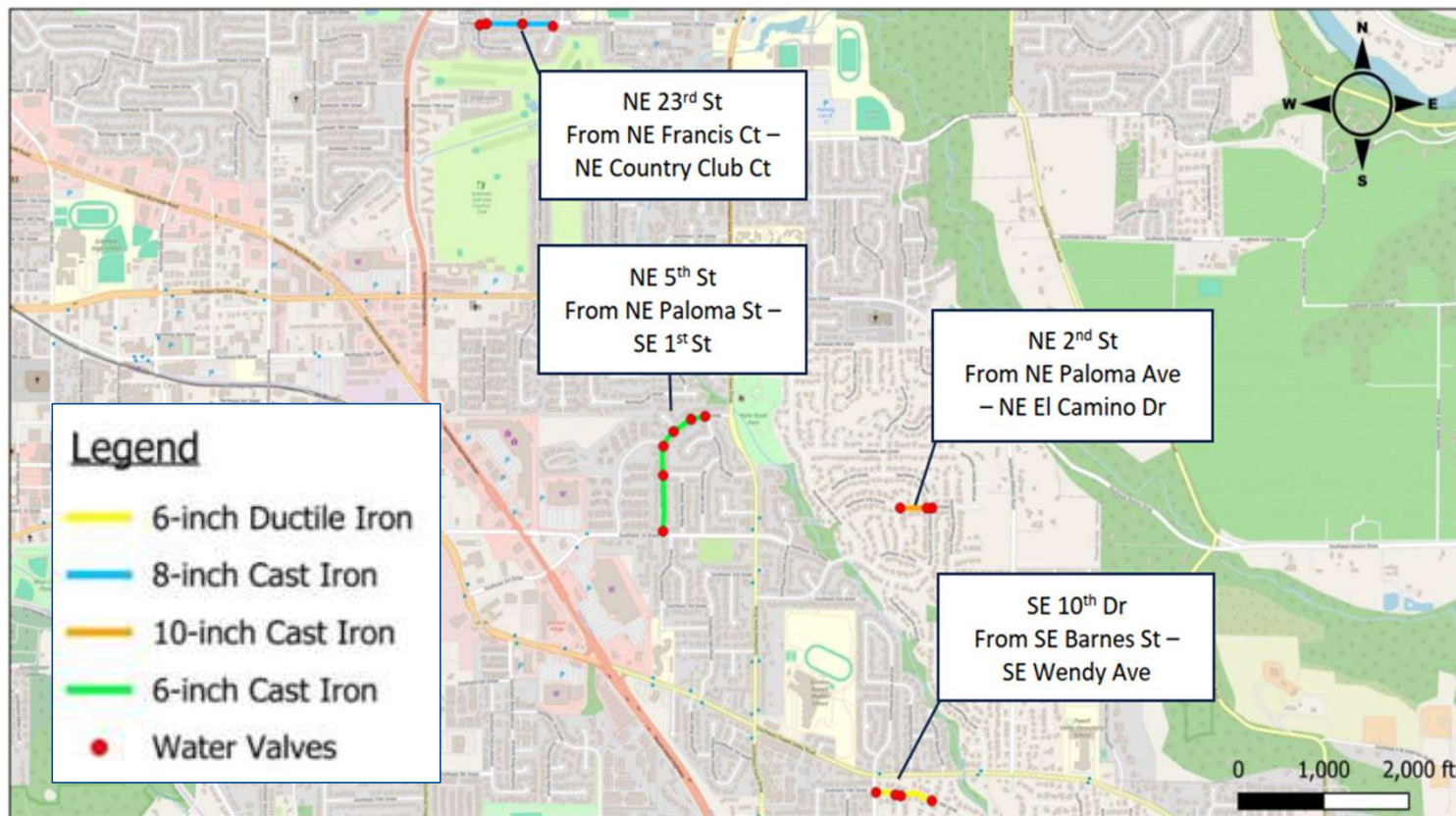
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# Pilot Project – Nov 21<sup>st</sup> and 22<sup>nd</sup>, 2023

3,528 feet inspected over 2 days



# Pilot Project




## Field Work




# Pilot Project

## Result Summary

Pipeline	Pipe Type	Diameter (in)	Install Year	Length (ft)	Nominal Wall Thickness (in)	Avg Wall Loss (%)	Max Wall Loss (%)	Min Wall Loss (%)	
NE 5 <sup>th</sup> Street	CIP	6	1969	1581	0.38	24.0	37.2	5.8	← Previous Leak
NE 2 <sup>nd</sup> Street	CIP	10	1974	377	0.44	2.8	-3.3	11.9	←
NE 23rd	CIP	8	1965	887	0.41	-0.1	5.8	-6.5	←
SE 10 <sup>th</sup> Drive	DIP	6	1977	748	0.25	14.3	23.9	0	← Previous Leak

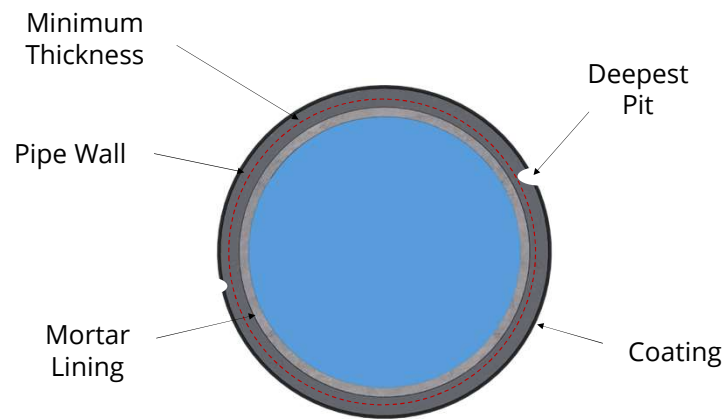




 Nominal Thickness Assumption

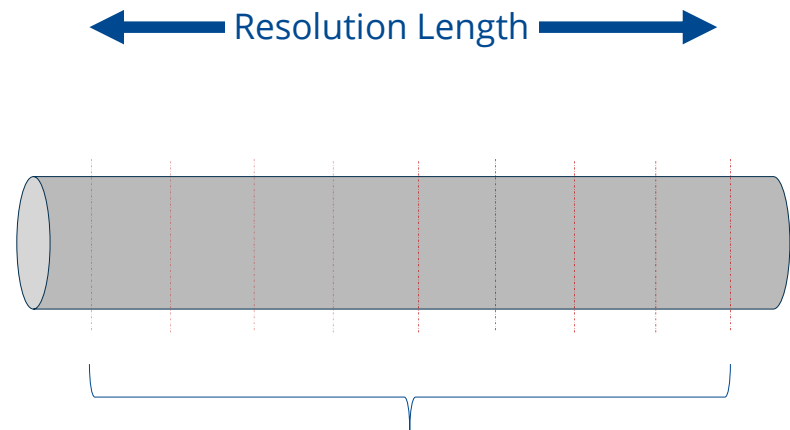


# Pilot Project

## Validation Process



The stiffness of a 'hoop' is driven by the lowest circumferential thickness.

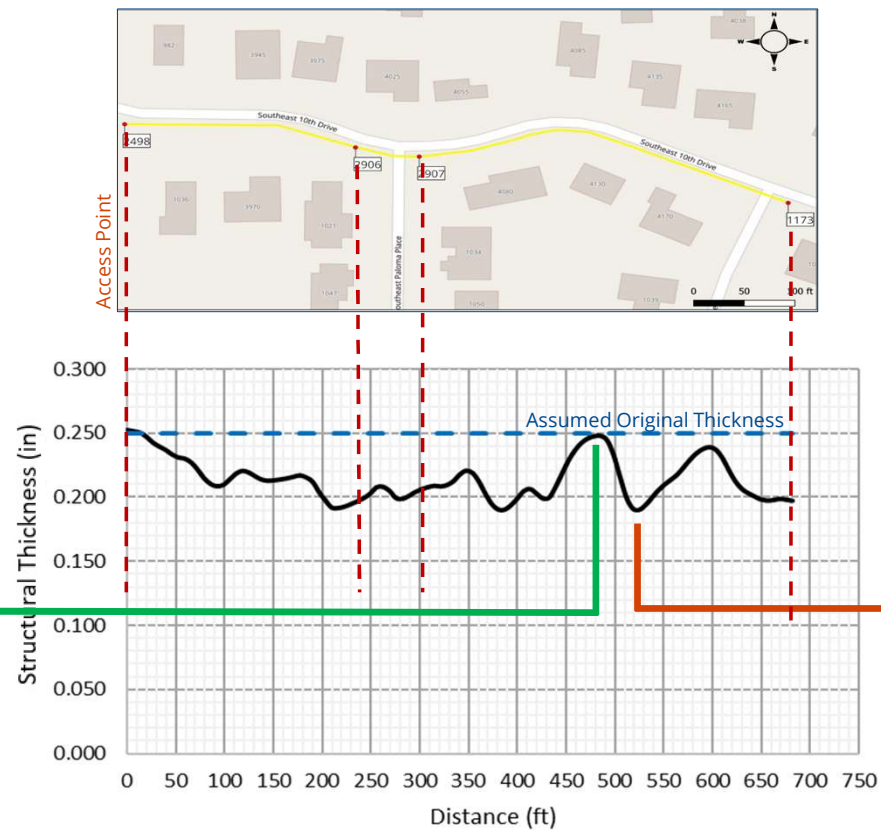
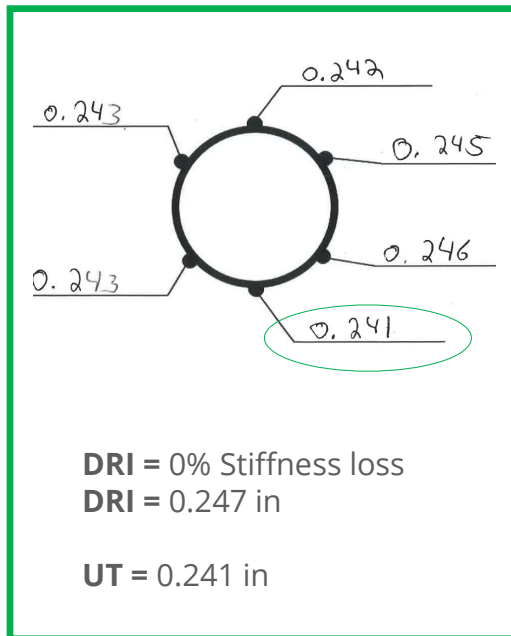


DRI Thickness  $\approx$  Minimum circumferential thickness averaged over the resolution length

# Pilot Project

## Validation Results: SE 10<sup>th</sup> Dr, 6-inch Ductile Iron

### Daylight - Slice



### Pipe Stick Removed



**DRI = 24% Stiffness Loss**  
**DRI = 0.189 in**  
**UT = 0.187 in**

# Pilot Project

Validation – SE 10<sup>th</sup> Drive 6in Ductile Iron

↓ “Slice” every 6 in



— Minimum Circumferential Wall thickness

Distance	Top	Upper Right	Lower Right	Bottom	Lower Left	Upper Left
0.5	0.461	0.223	0.245	0.232	0.332	0.219
1	0.235	0.224	0.229	0.228	0.228	0.248
1.5	0.196	0.237	0.255	0.255	0.23	0.291
2	0.23	0.180	0.256	0.209	0.225	0.228
2.5	0.26	0.255	0.259	0.209	0.222	0.225
3	0.209	0.24	0.24	0.251	0.246	0.239
3.5	0.259	0.220	0.277	0.238	0.228	0.259
4	0.26	0.288	0.263	0.238	0	0.224
4.5	0.293	0.24	0.234	0.245	0.246	0.232
5	0.261	0.275	0.221	0.248	0.26	0.199
5.5	0.248	0.251	0.177	0.269	0.264	0.247
6	0.180	0.273	0.251	0.284	0.26	0.275

Avg minimum (Red) = 0.187 in



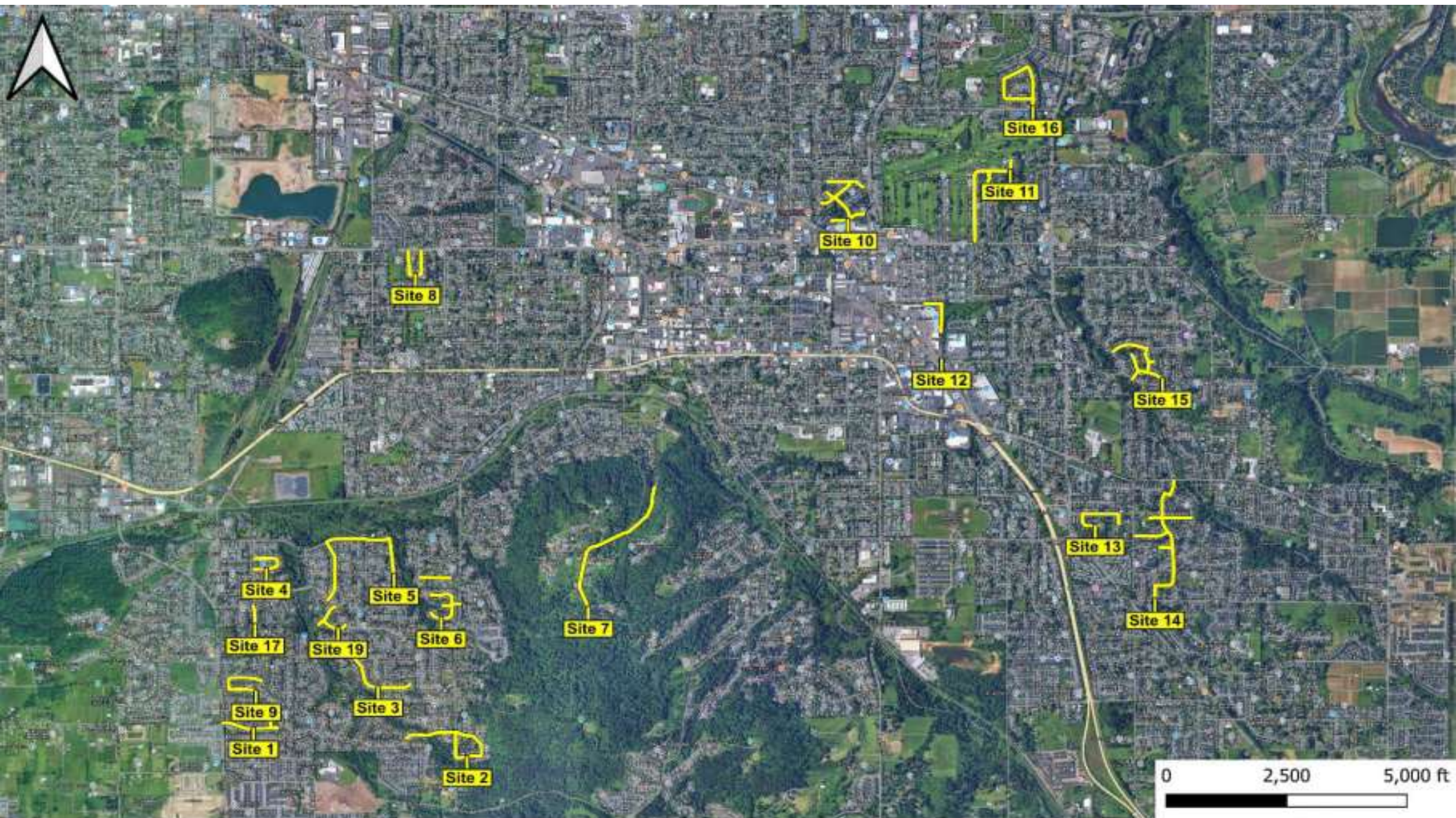
# Pilot Project

## Validation Summary (7 locations)

Pipeline	Pipe Type	Pipe Size (In)	Nominal Stiffness Lost (%)	DRI Residual Wall Thickness (in)	Validation Method	Measured Minimum Avg Hoop Thickness (in)
NE 5 <sup>th</sup> St	Cast	6	19%	0.30	Daylight / Slice	0.32
NE 5 <sup>th</sup> St	Cast	6	33%	0.25	Pipe Stick	0.27
NE 5 <sup>th</sup> St	Cast	6	3%	0.34	Daylight / Slice	0.36
SE 10 <sup>th</sup> Drive	Ductile	6	0%	0.25	Daylight / Slice	0.24
SE 10 <sup>th</sup> Drive	Ductile	6	24%	0.19	Pipe Stick	0.19
NE 23 <sup>rd</sup> St	Cast	8	10%	0.40	Daylight / Slice	0.40
NE 23 <sup>rd</sup> St	Cast	8	3%	0.42	Daylight / Slice	0.41

# Fall 2024 Assessment

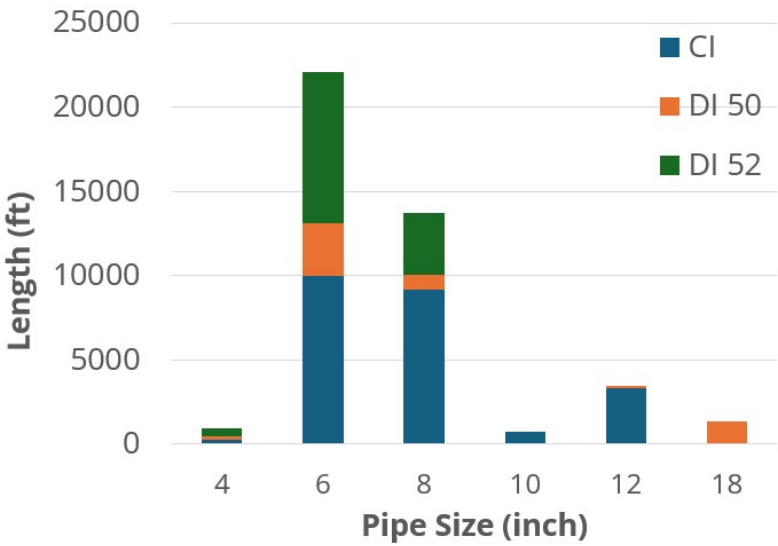
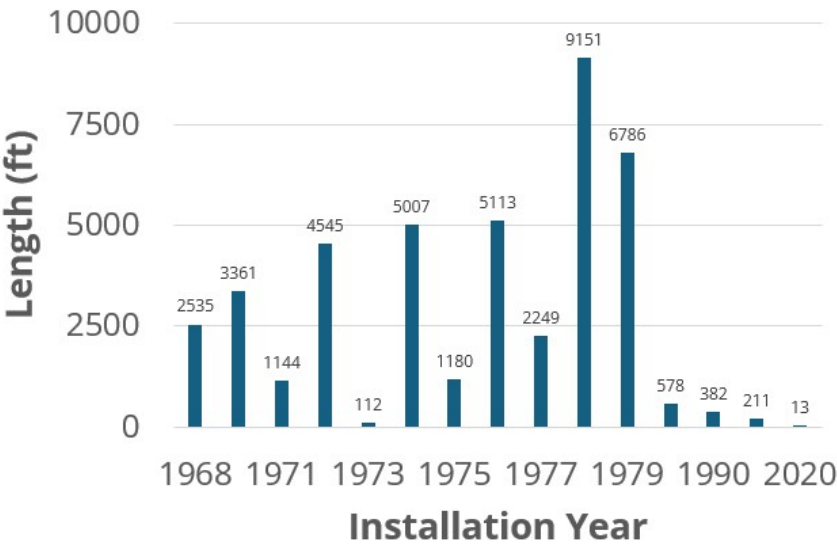
Turning Data Into Actionable Information – Preliminary Results





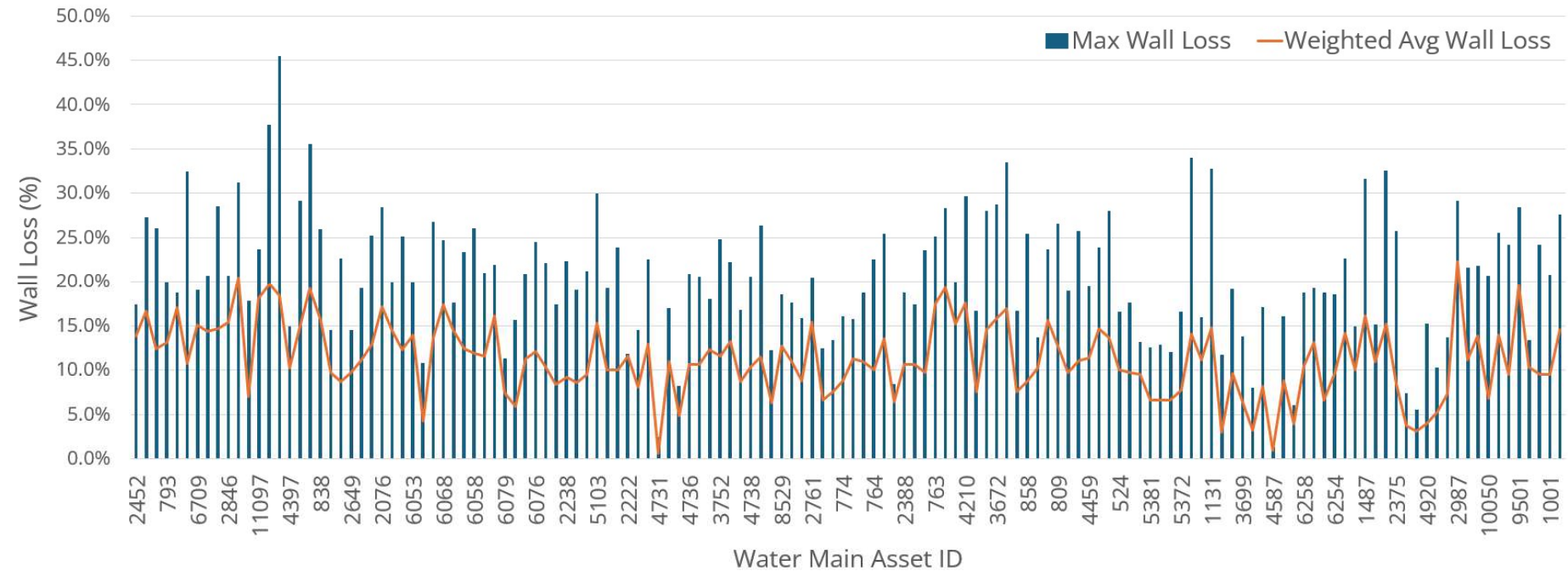
# Fall 2024 Assessment

7.7 miles collected over 6 field days (2 crews)



# Fall 2024 Assessment

## Wall Loss by Asset ID



# Fall 2024 Assessment

## Factor of Safety and Current Probability of Failure

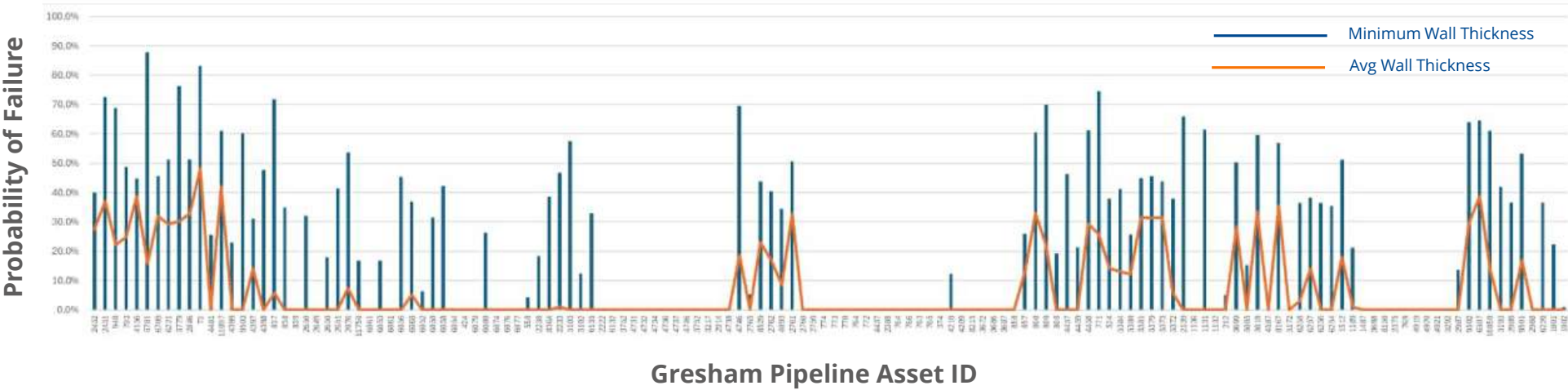
Factor of Safety (FOS)

$$FOS = \frac{\sigma_{Yield}}{\sigma_{Total Hoop Stresses}}$$

Probability of Failure (POF)

FOS ≤ 1 = 100% (pipe is at or below yield limit)

FOS ≥ 2 = 0%



# Fall 2024 Assessment

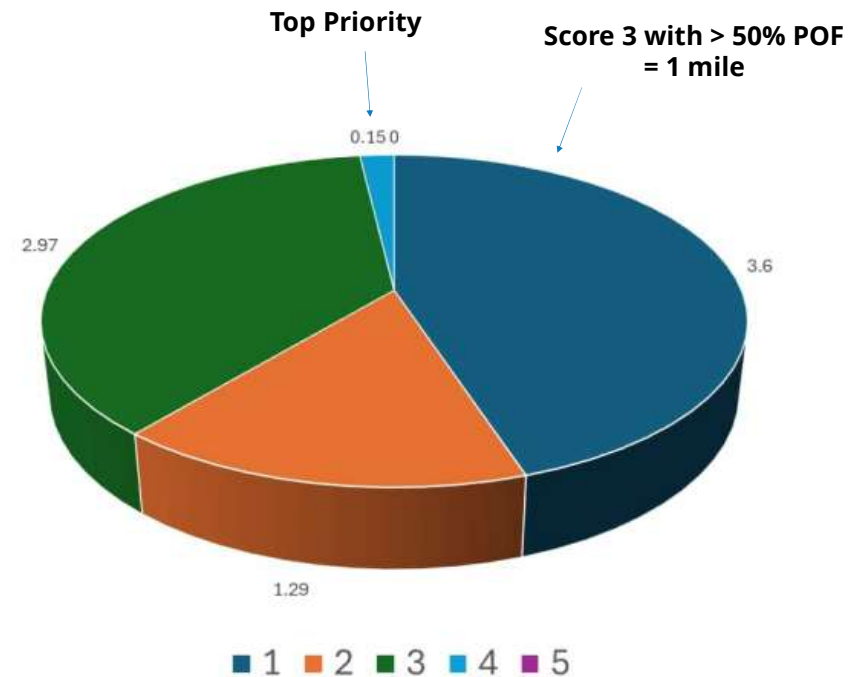
## Likelihood of Failure (LOF) 1 to 5

Inspected pipes

- Score (1 to 4) based on Remaining Useful Life (RUL) Estimate
  - RUL = time to reach  $FOS \leq 1$
  - RUL assumes straight line deterioration
- Bonus point for segments w break or leak

RUL (Years)	Likelihood of Failure <sup>1</sup>
50-100	1
40-49	2
1-39	3
0	4
0 (with history of main break)	5

(1) Add 1 if there is a history of main breaks





# Acknowledgements



# Contact Information

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