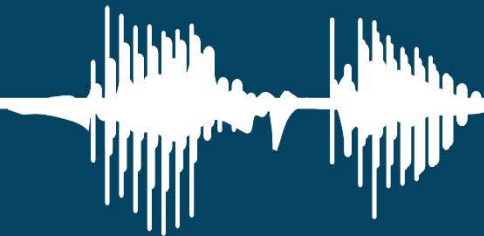


# Predictive Models Based On Force Main Condition Assessment



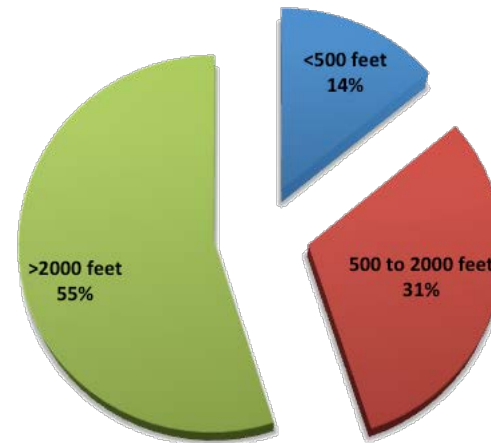
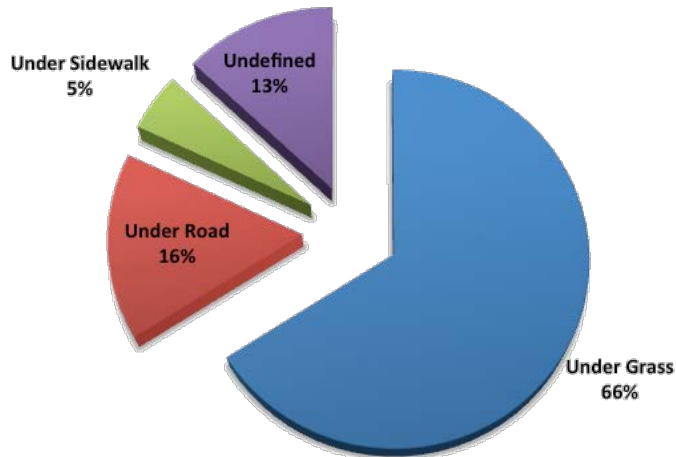
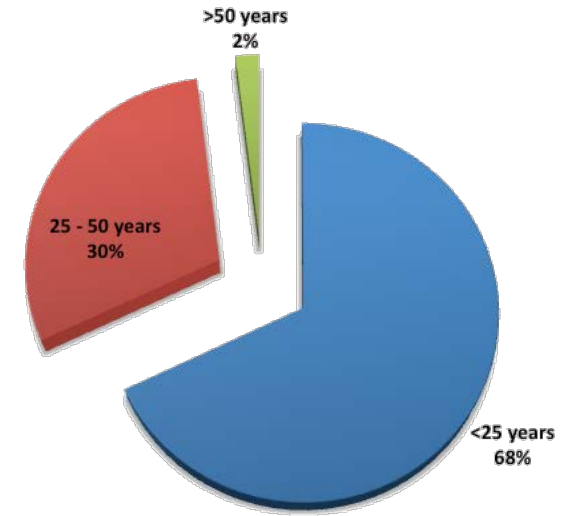
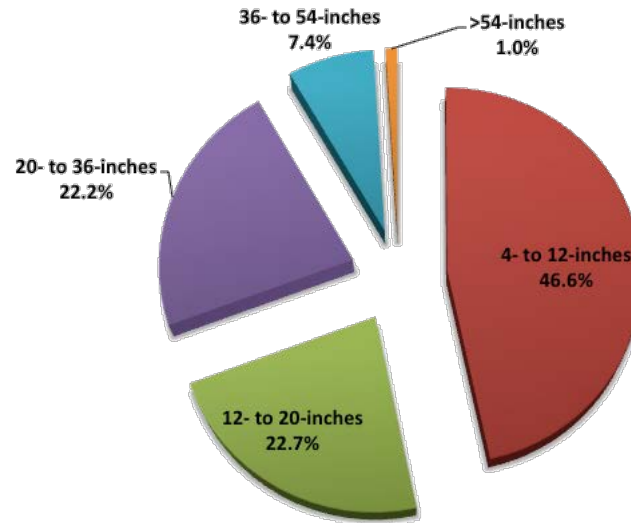
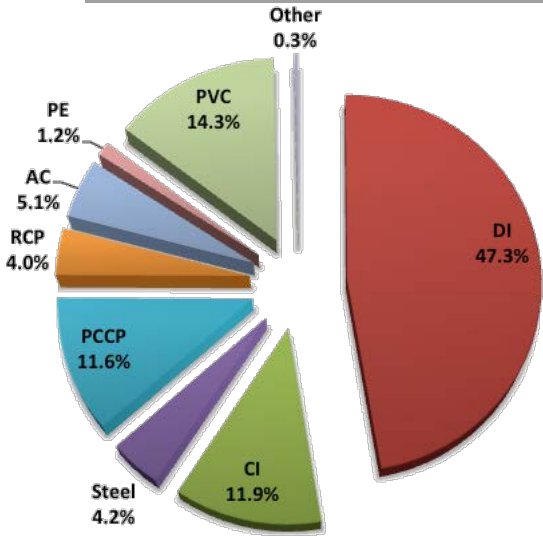
## Key Concepts

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Let's focus on some general concepts:

- **Understand** failure modes
- Use **risk** to drive correct level of **data** collection
- Collect the **right data** to make good decisions
- **Proper data** analysis is **critical**
- Allow condition, **risk**, and cost to drive **long-term decisions**
- Re-evaluate **risk** based upon data findings

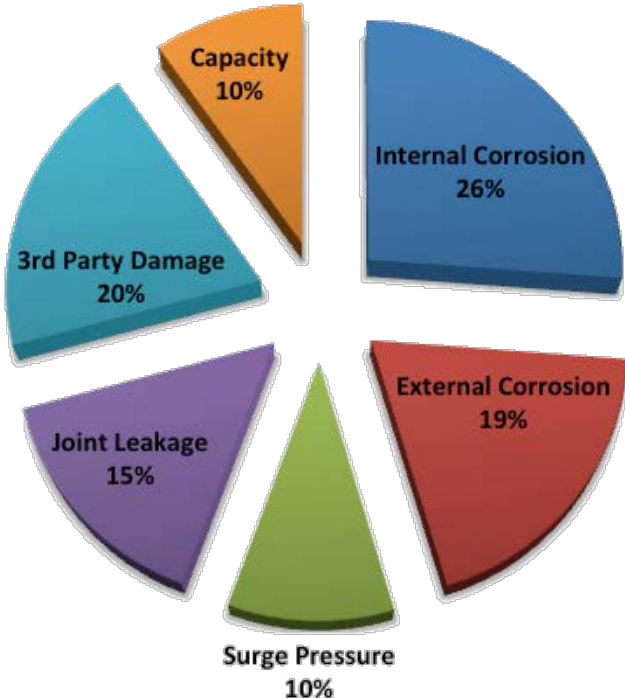
# Understanding Force Mains



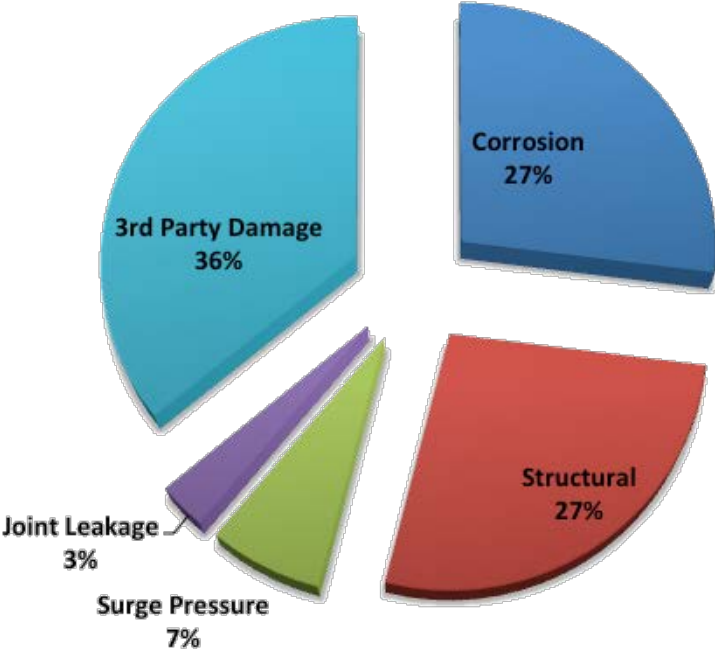
Data source: Water Environment Research Foundation –  
*Guidelines for the Inspection of Force Mains* (2010)

# Understanding Force Mains

### Ferrous Force Main Failures



### Non-Ferrous Force Main Failures



Data source: Water Environment Research Foundation – Guidelines for the Inspection of Force Mains (2010)

# Confident Decision Making

*Priority of Pipeline*



*Assessment Techniques*

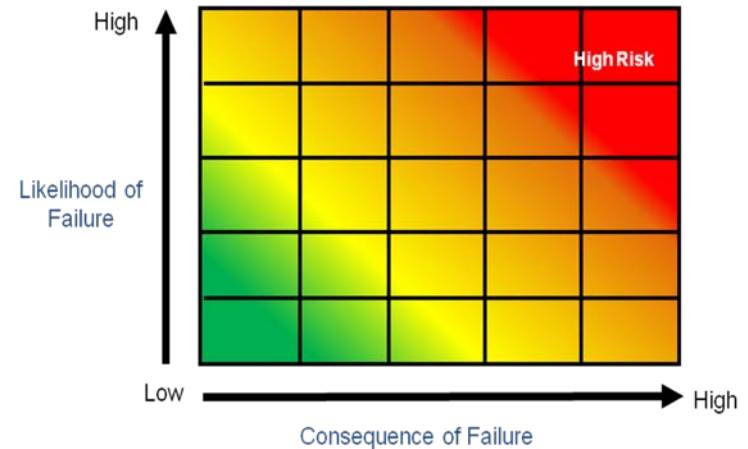


*Analysis*



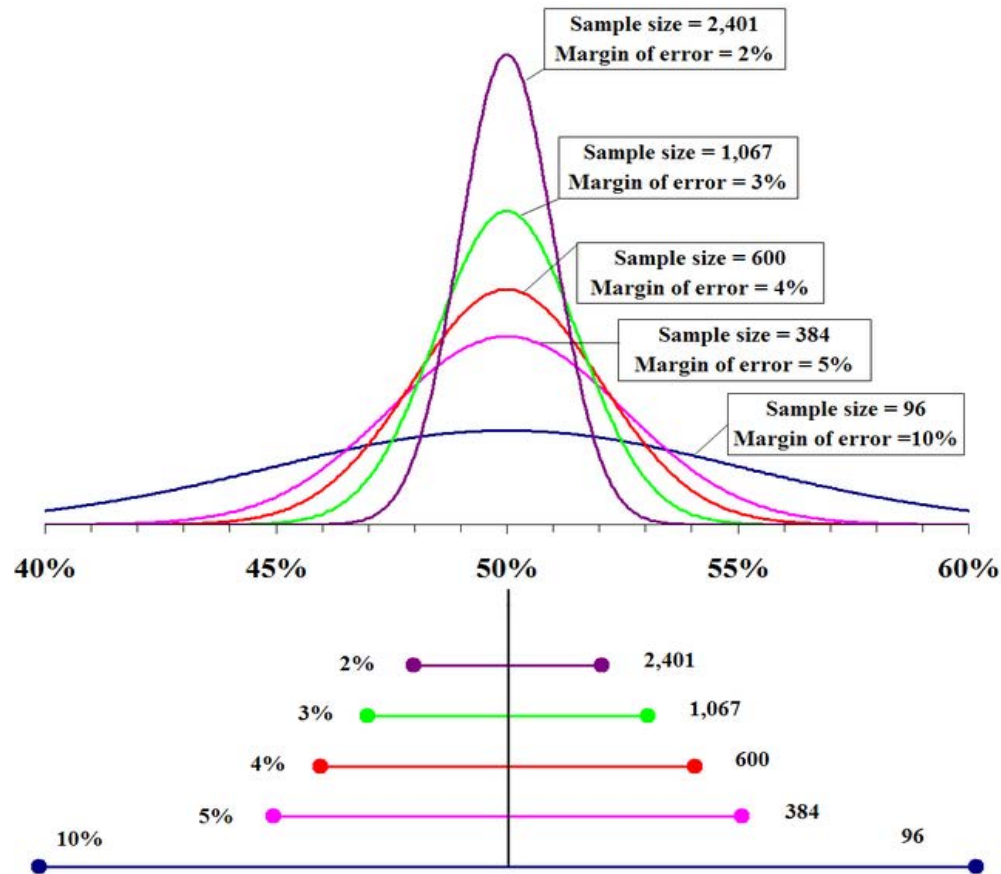
# Condition Assessment Tool Selection

- There is no silver bullet technology, it is a combination of tools and sound engineering that provides reliable assessment
- Use risk to select condition assessment tools
- High risk pipe → High resolution tools
- Least expensive tools may not be the best value



# Statistical Evaluation: What is a Distribution?

- Sample size matters



## Ferrous Force Mains

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Statistical analysis incorporating inspection data and engineering analysis can be used to predict remaining useful life of ferrous force mains.

### Minimum Data Required

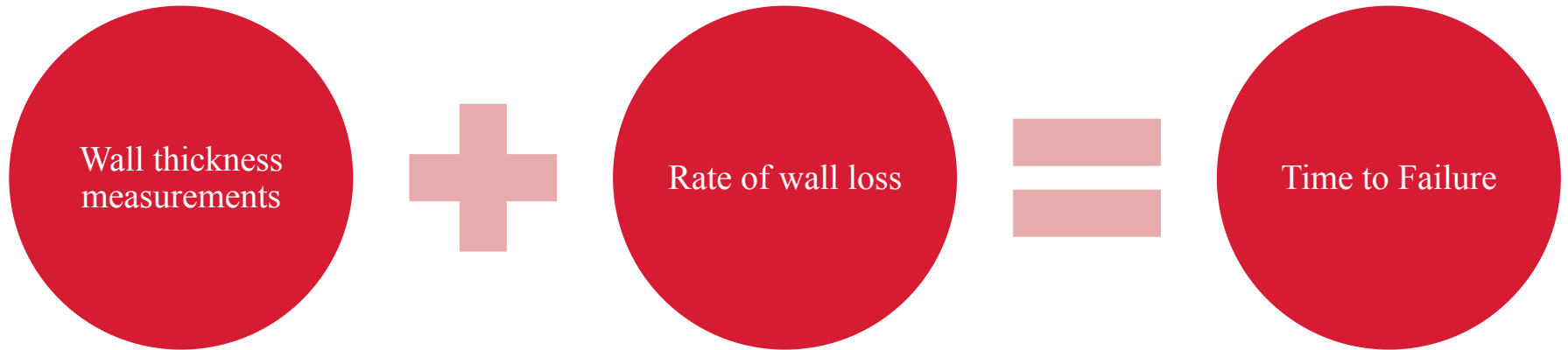
- number of integrity measurements to achieve desired confidence level
- adequate data collection methodology to ensure representative sampling
- structural analysis based on design standards, current loading and operational conditions



# Statistical Evaluation: Remaining Useful Life

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Based on corrosion wall loss.



## Prestressed Concrete Cylinder Pipe Force Mains

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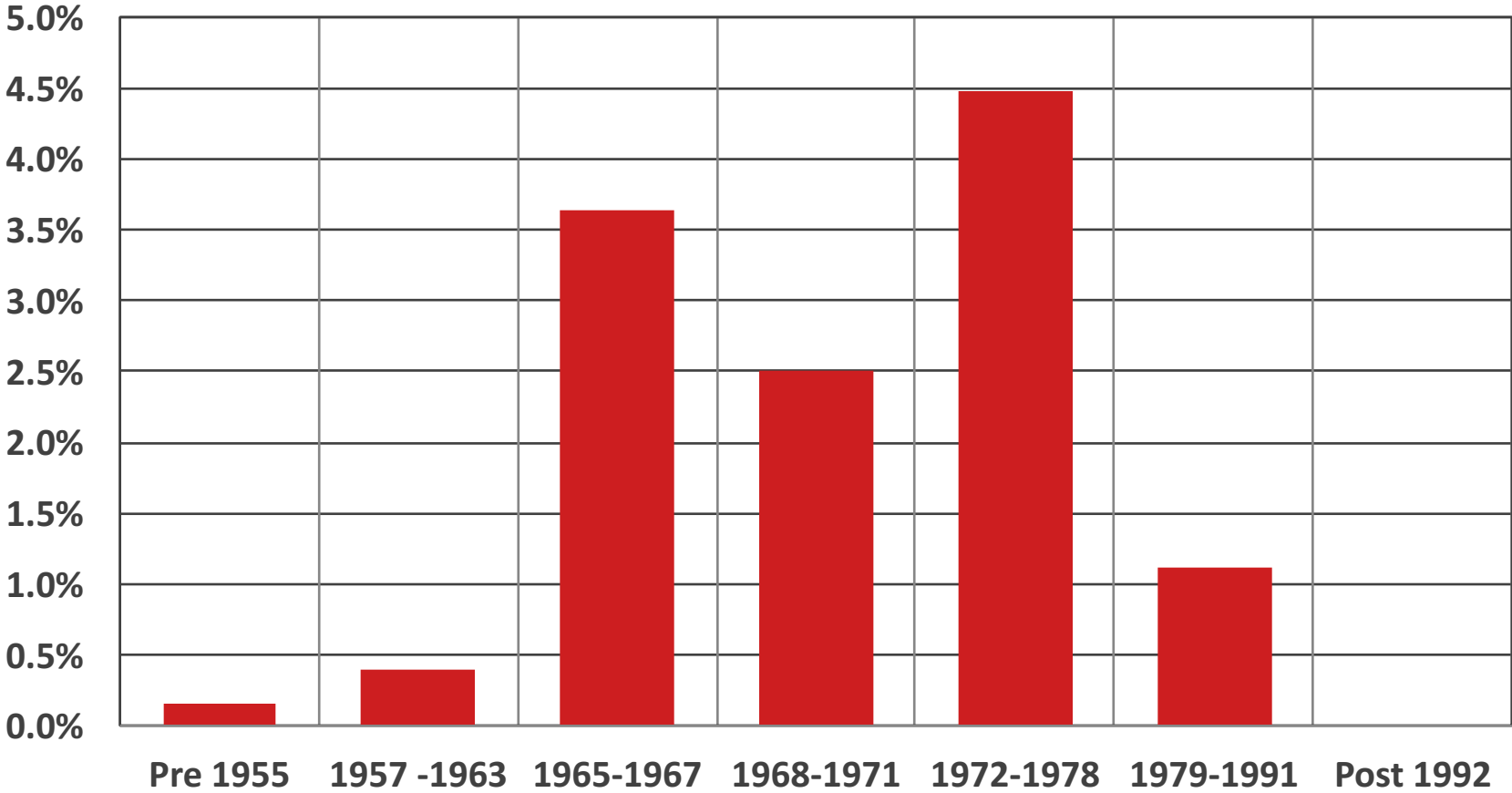
Statistical analysis incorporating inspection data and engineering analysis can be used to predict remaining useful life of PCCP force mains.

### Minimum Data Required

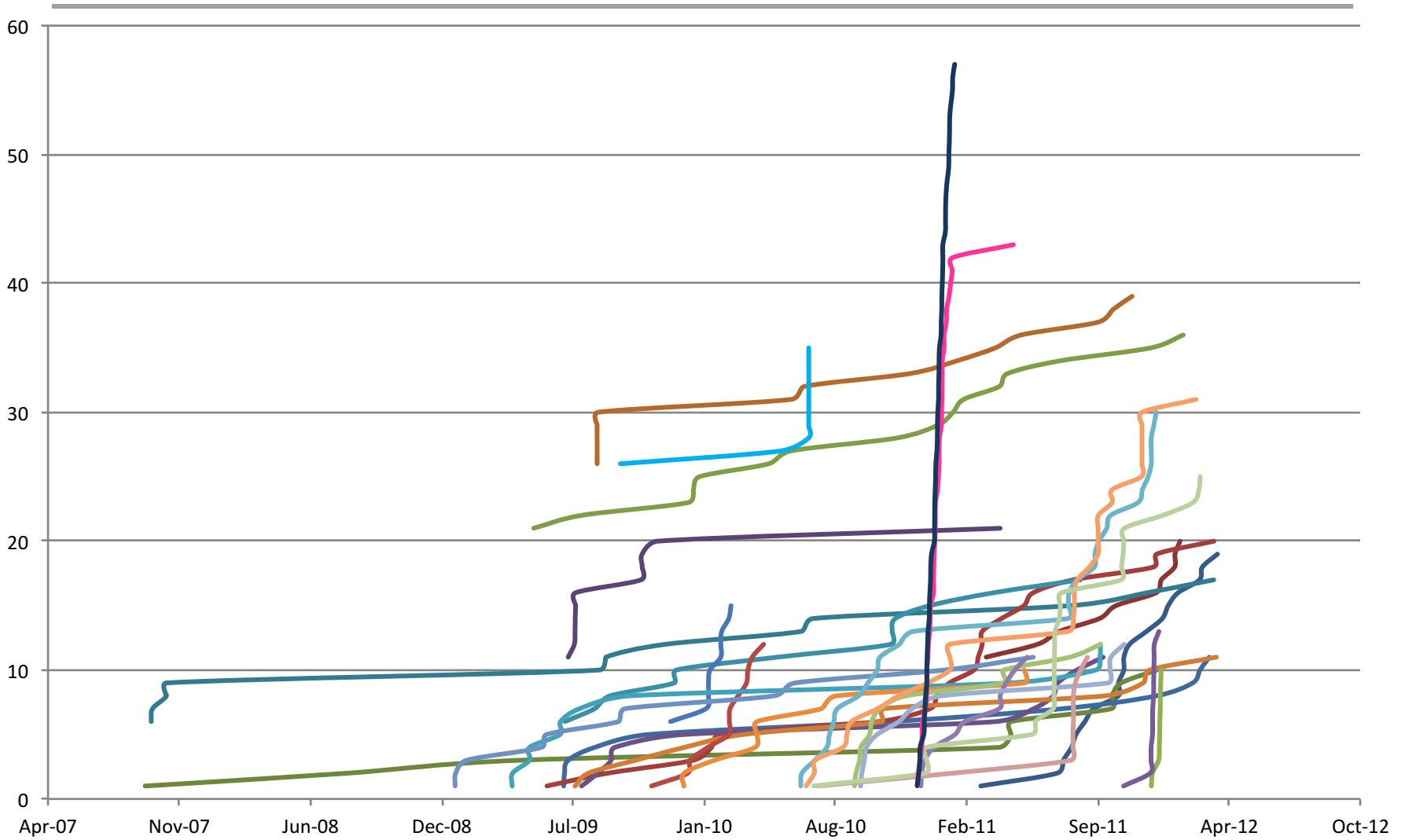
- number of integrity measurements to achieve desired confidence level
- adequate data collection methodology to ensure representative sampling
- structural analysis based on design standards, current loading and operational conditions
- utilize known industry data on material history

# PCCP Inspection Data Findings

*Percent of PCCP Pipe Sections with Distress*



# Wire break patterns in PCCP = there is no pattern...



# Case Study

- 3 miles of 24/30-inch Ductile Iron Pipe
- October 2015: SmartBall and PipeDiver



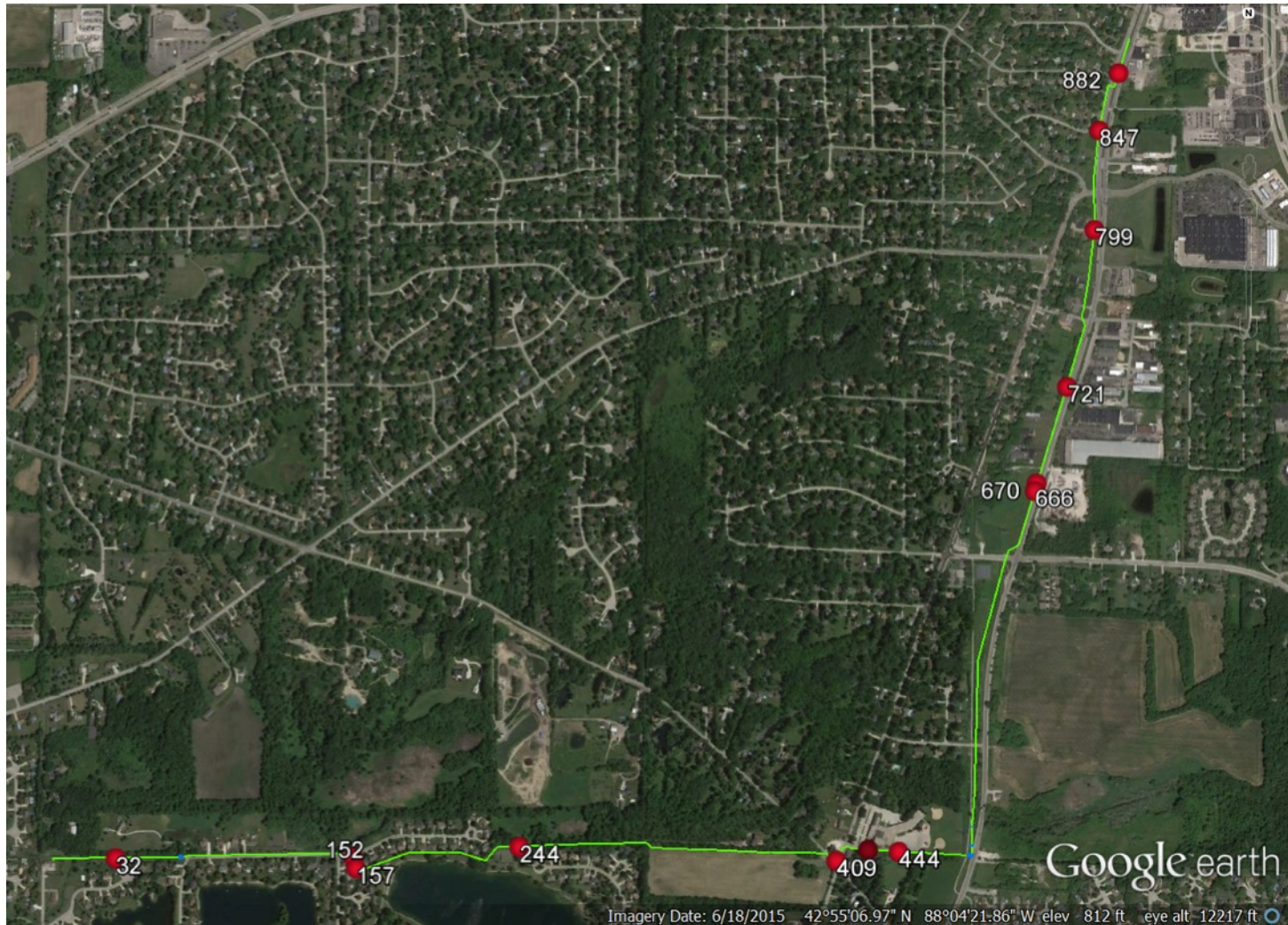
# Electromagnetic Inspection Results

## Pipe Sections with EM Anomalies



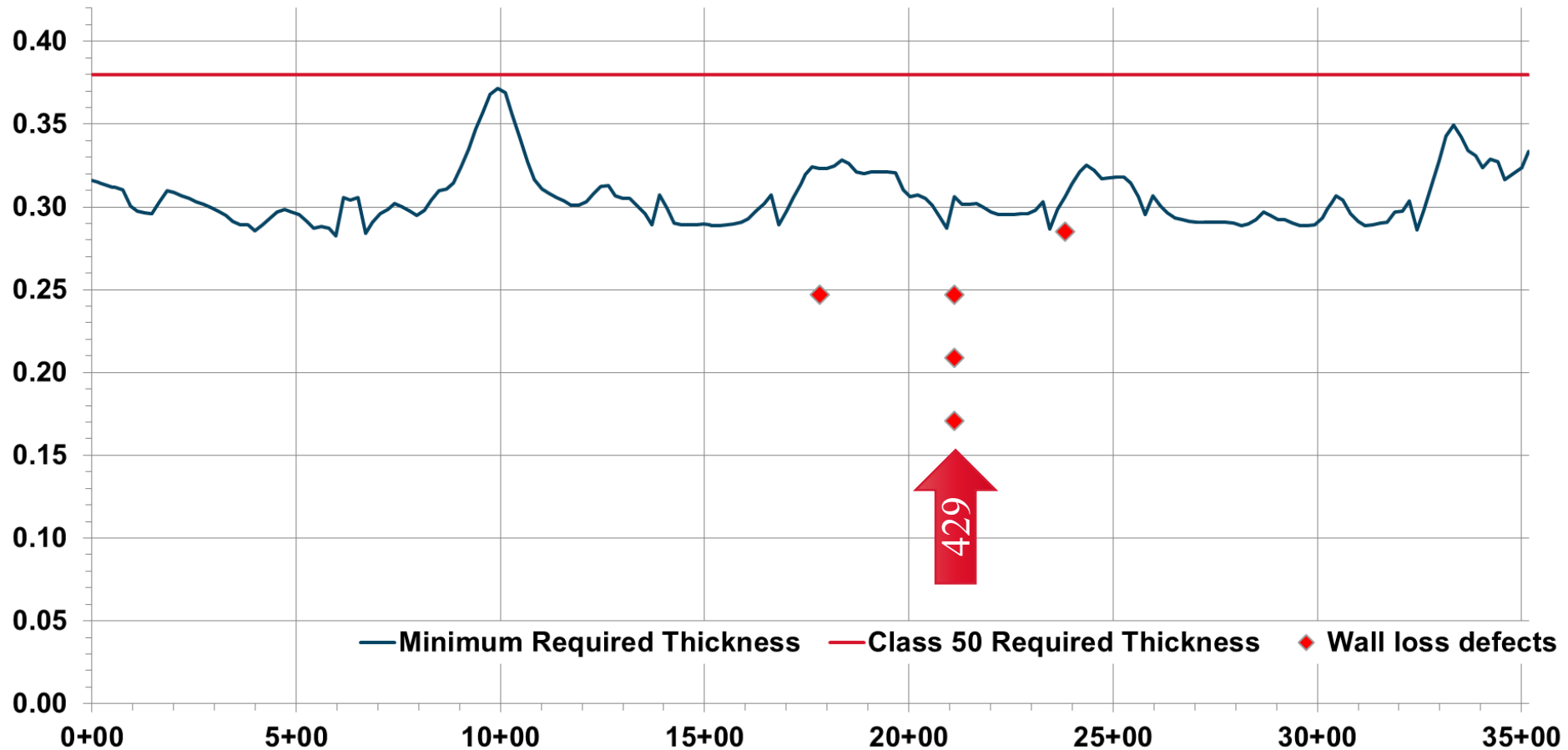


# Electromagnetic Results



# Structural Analysis

**AWWA C150 Minimum Required Thickness  
Franklin-Muskego Force Main  
24-inch DIP (Pipe 306 through Pipe 507)**

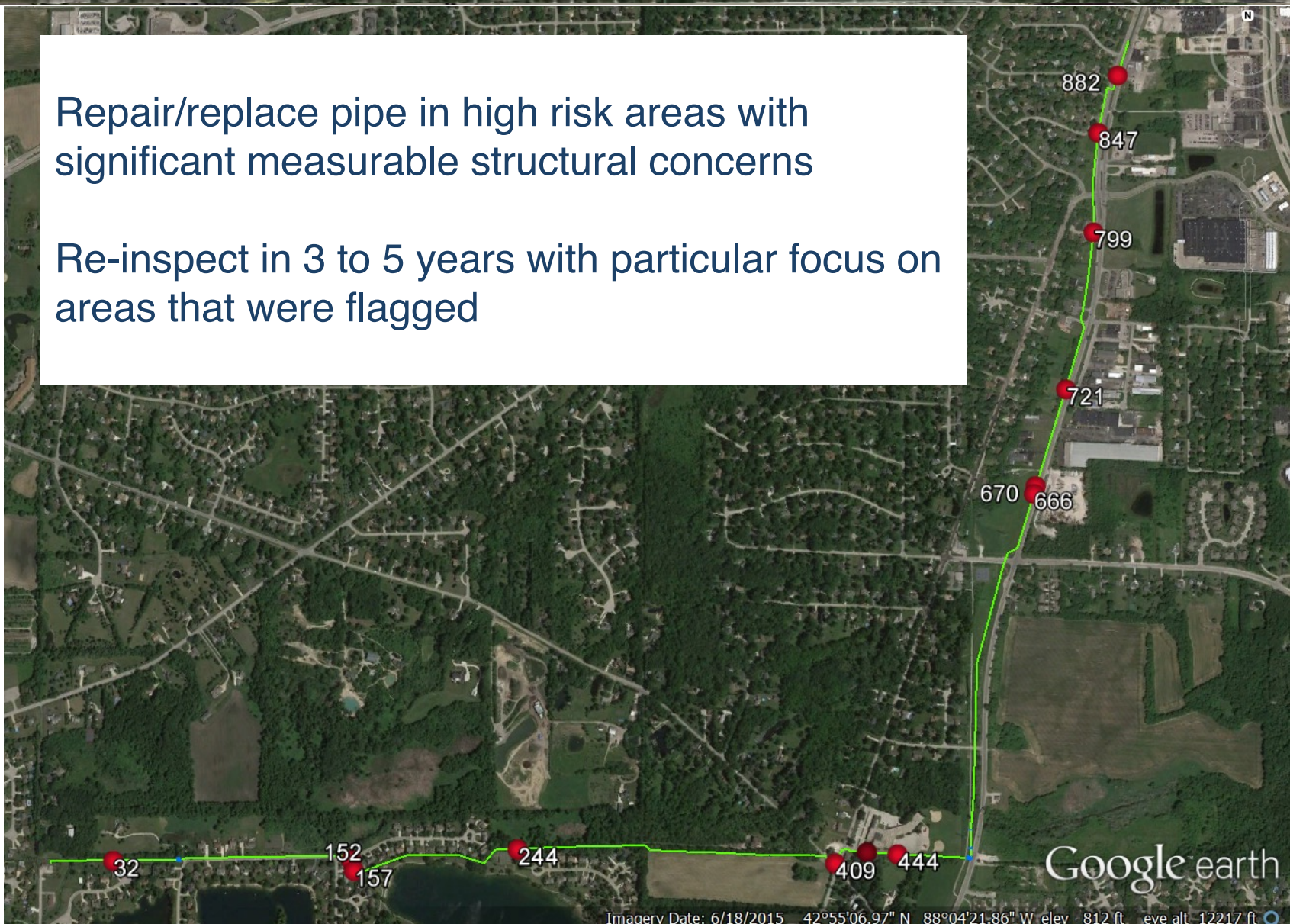




# Recommendations

Repair/replace pipe in high risk areas with significant measurable structural concerns

Re-inspect in 3 to 5 years with particular focus on areas that were flagged



## Final Thoughts

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Over **1000 miles** of force main condition assessment data has told us a few things...

- **Understand** failure modes
- Use **risk** to drive **data** collection
- Collect the **right data** to make good decisions
- **Proper data** analysis is **critical**
- Allow condition, **risk**, and cost to drive **long-term decisions**



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