Corrosion Condition Assessments of Force Mains

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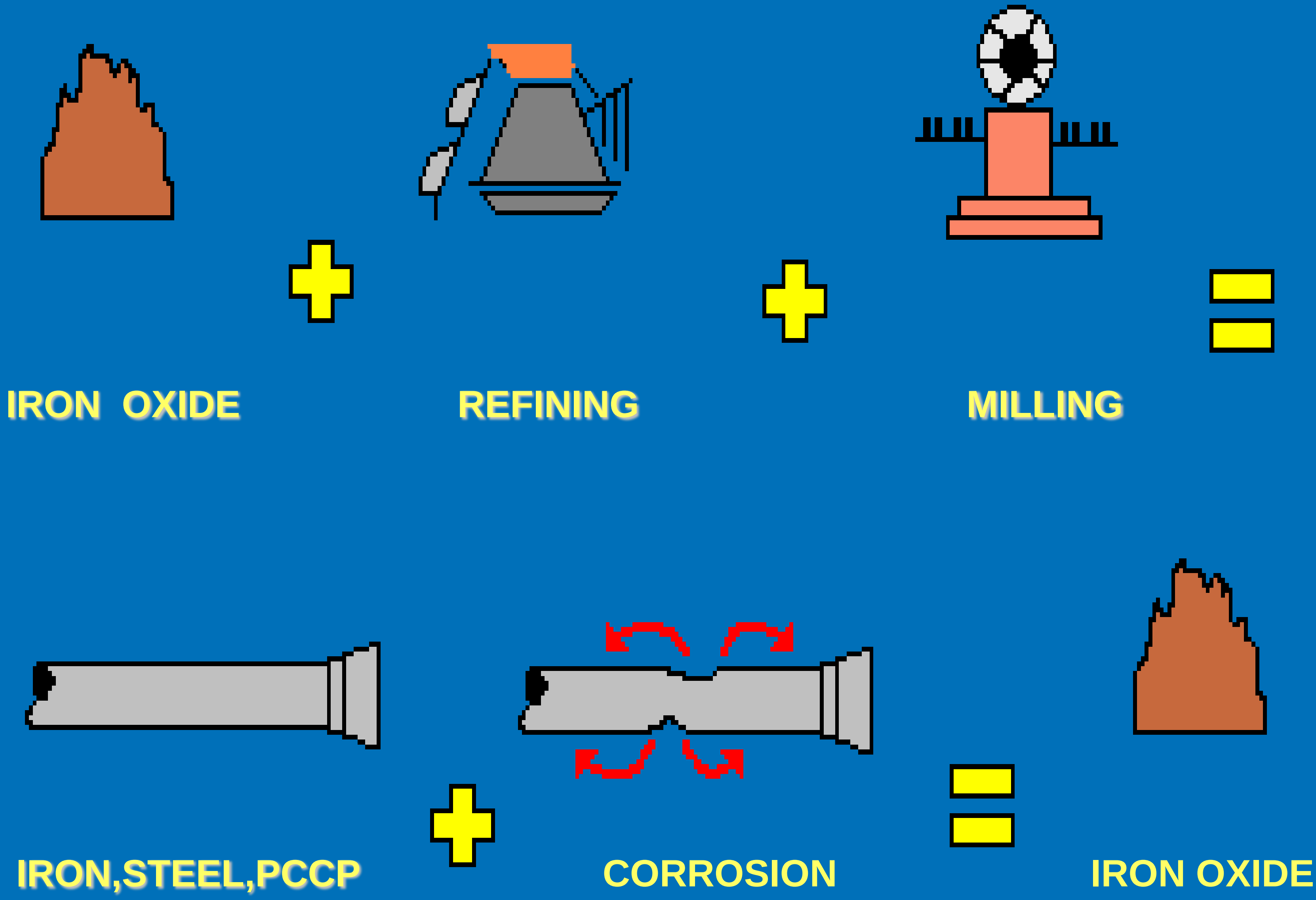
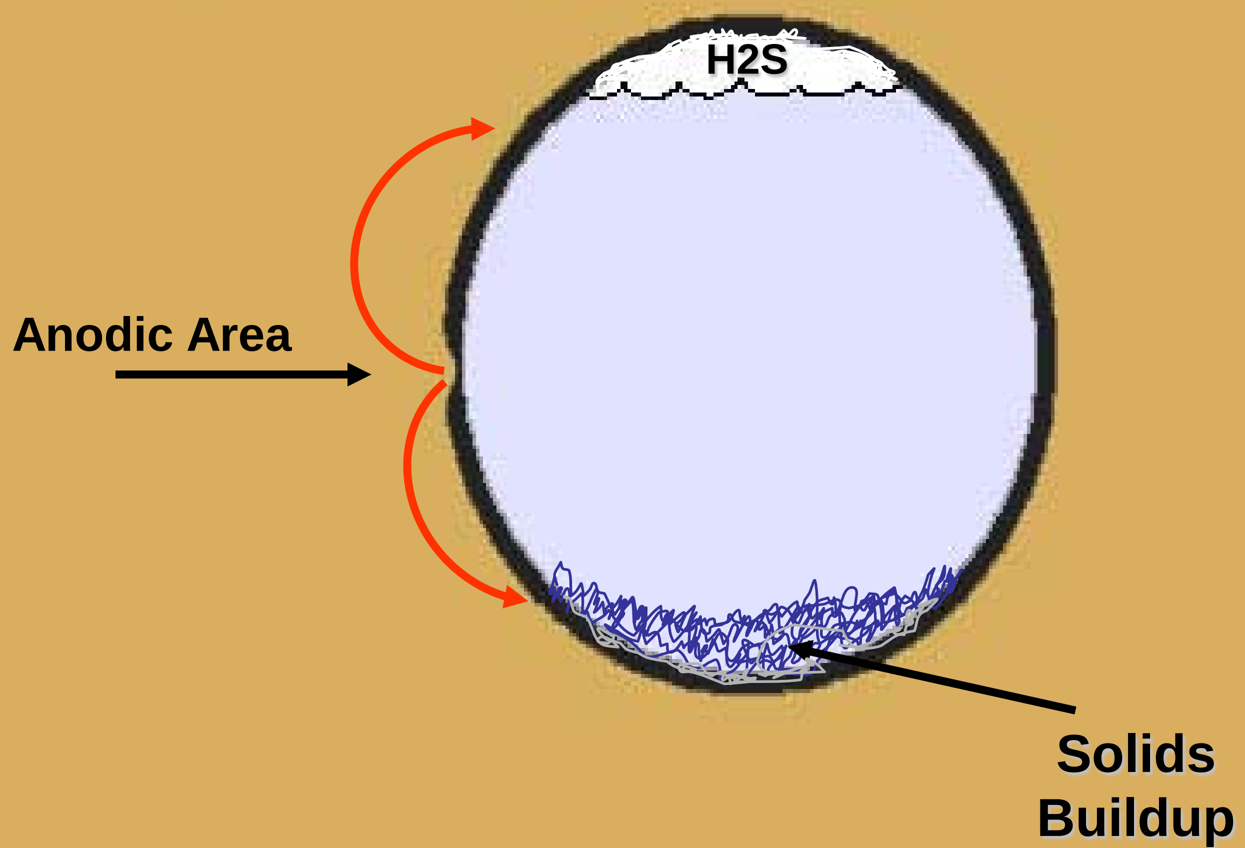


Corrosion Process

Internal & External Corrosion of Force Mains….



24" Ductile Iron Force Main

- Internal failure following loss of internal mortar lining
- Failure was along top of pipe due to formation of hydrogen sulfide gas

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Dual 26” Force Mains

- Internal failures at bottom of pipe
- Failure following loss of internal mortar lining
- Failures concentrated at low areas (dips) in pipeline alignment
- Cause is corrosion under accumulated solids

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36” Above Ground Crossing

- Failure of force main at above ground crossing
- Crown of pipe attacked by hydrogen sulfide gas

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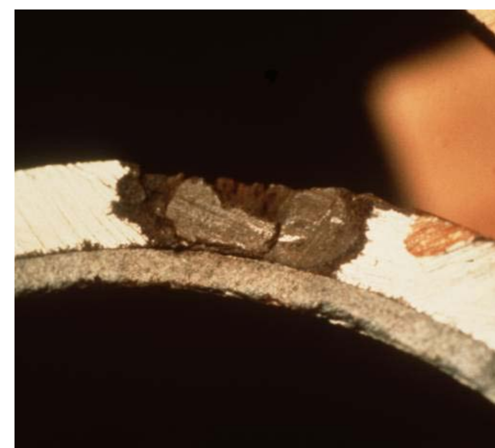
External Corrosion

- Caused by Aggressive soil conditions
- Galvanic Corrosion
- Stray DC Currents



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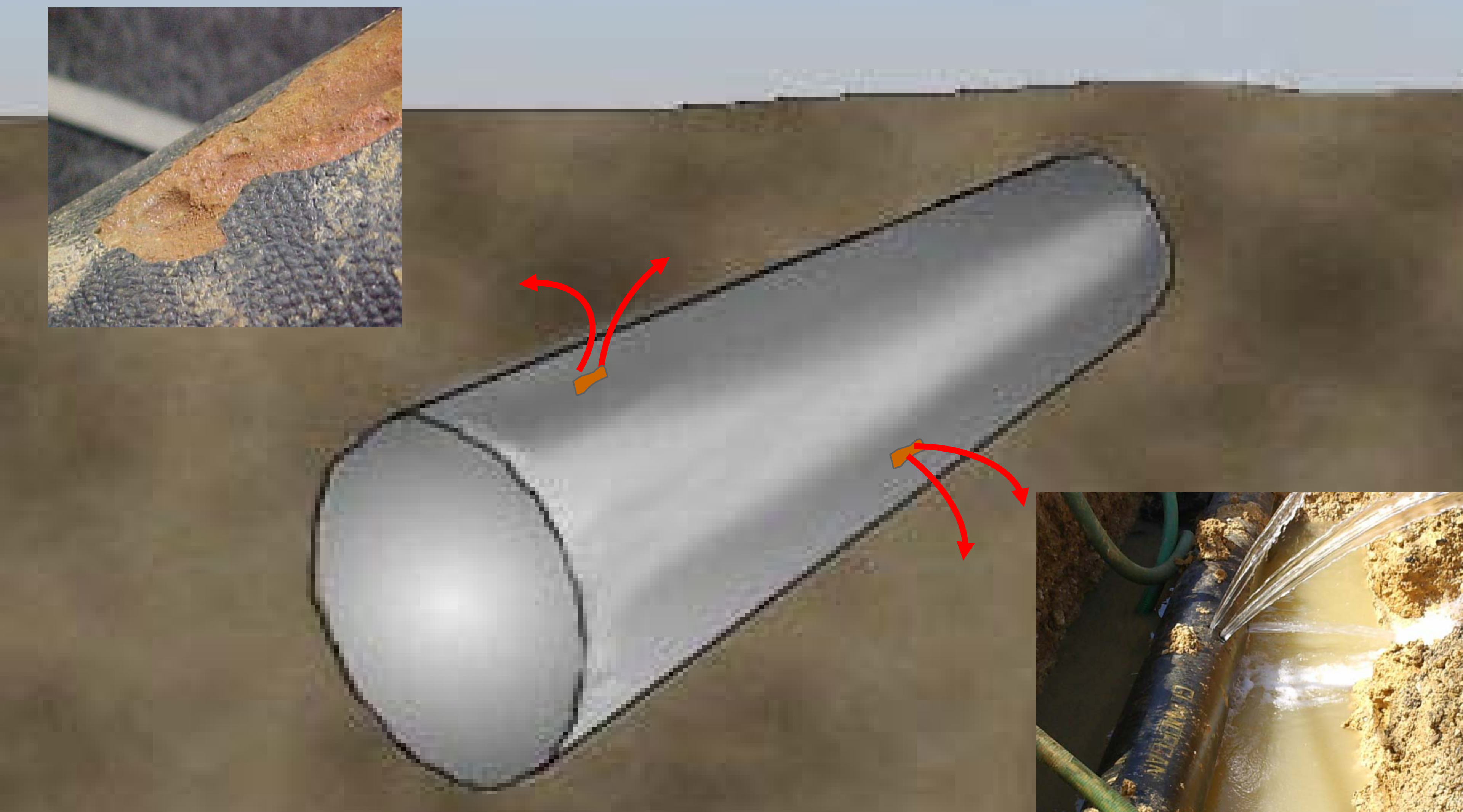
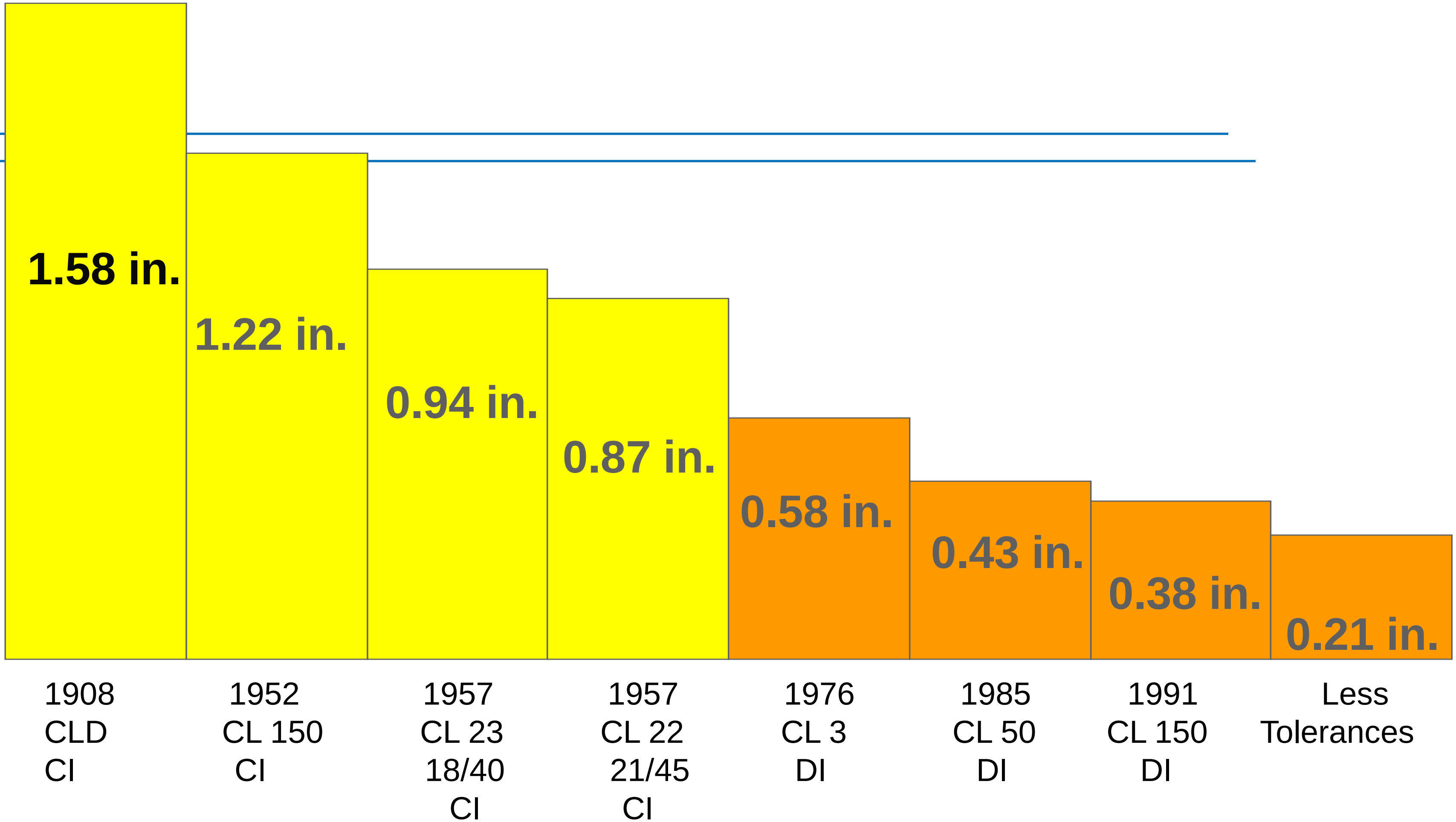
External Corrosion Attack





Actual size of AWWA Specification Thickness Reductions

for 36-inch Diameter Cast and Ductile Iron Pipe - 1908 to Present

(150 PSI Operating pressure)

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Cast Iron Pipe
(thicker walled pipe)

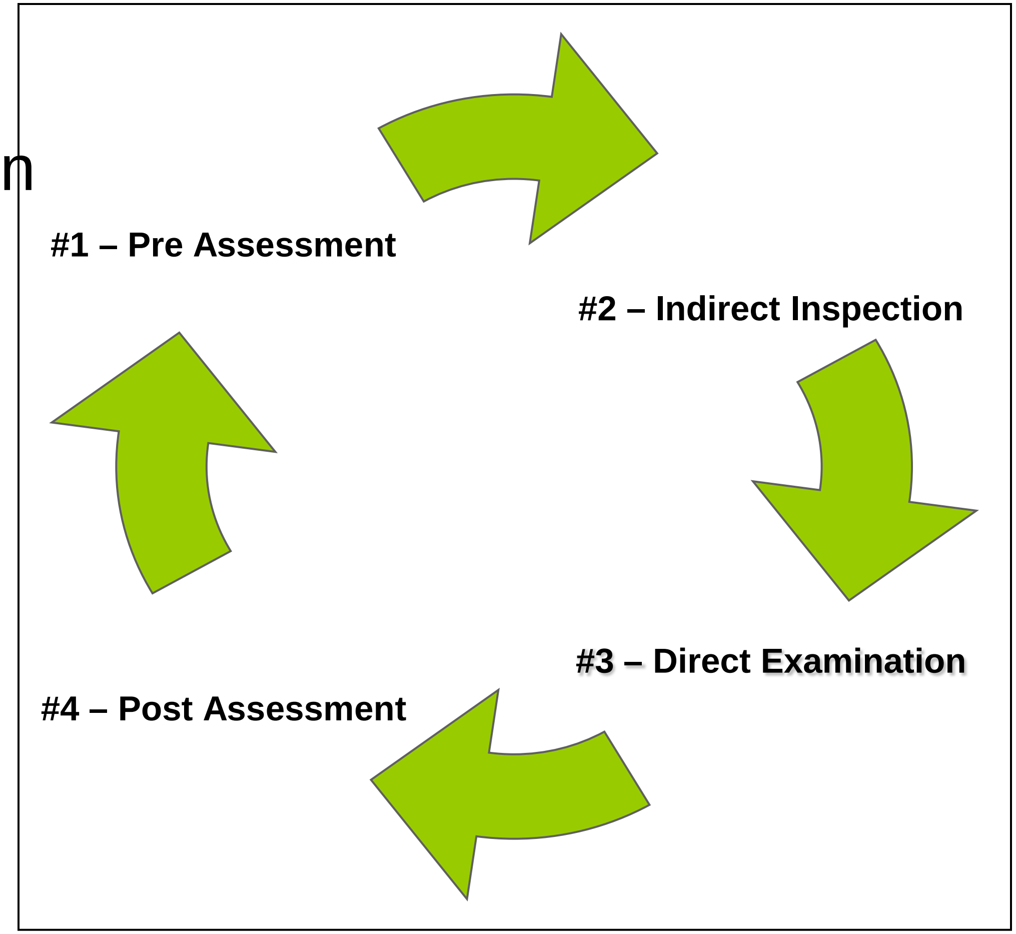
External pitting (concentrated) corrosion attack on thinner walled ductile iron pipe.

Temporary Fix ?

- The rate and magnitude of corrosion depends on a number of factors:
  - Pipe Material and Characteristics
  - Operating Conditions
  - Construction Methods
  - Environment (age not a good primary metric)
  - Internal or External Corrosion Attack

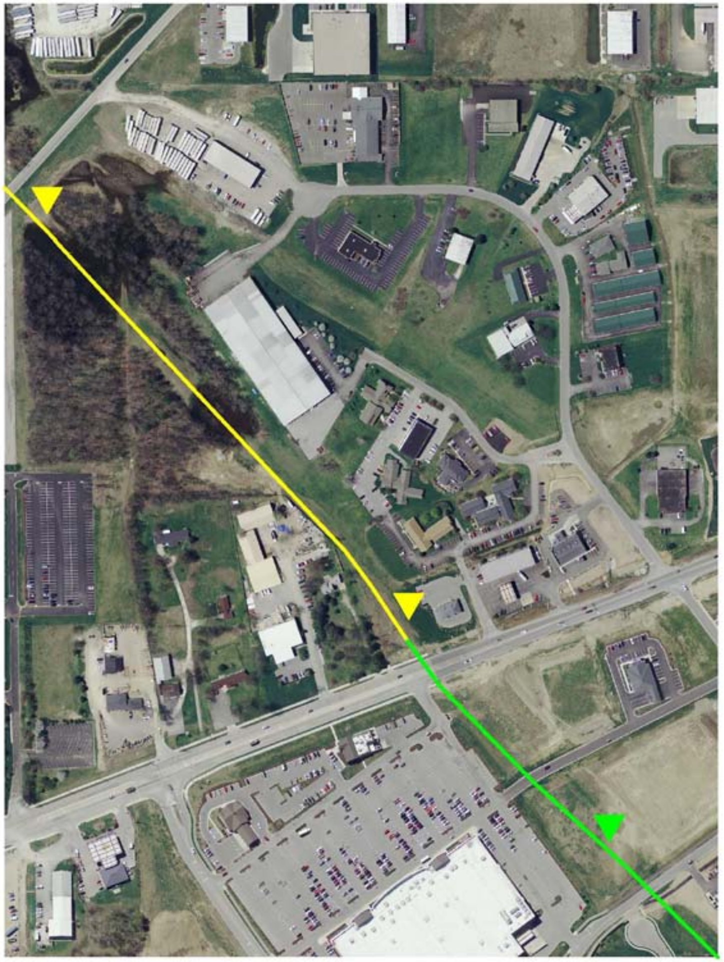
Pipeline Condition Assessment Process

- Initial development driven by federally regulated pipeline integrity rules
- Methodology also quite applicable to water / wastewater



#1 Pre-Assessment:

- Define pipe segments by construction contracts and similar characteristics, e.g. material, construction practices
- Identify specific locations along the pipeline
  - Air Release Points/Man ways
  - Pipeline crossings
  - Known area where piping failures have occurred



#1 -Pre-Assessment Data Gathering & Planning:

- "Good listening" – operating history, criticality, consequences of failure
- Leak & Repair Records
- Pipe "Bone Yard"
- Coordination of Condition Assessment Efforts With Other Activities
  - Excavations
  - Repairs

- Project construction drawings and specifications
- Pipe materials and characteristics
  - Wall thickness
  - Pressure rating
  - Flow Rates
  - Air Release points/operational status
  - Coatings and Linings
- Bedding and backfill material
- As-built documentation
- Soil corrosivity, e.g. resistivity, pH, chlorides, moisture
- Adjacent utilities and crossings
- Sources of stray current corrosion
  - Nearby cathodic protection systems
  - Direct current powered transit systems
  - High voltage overhead AC power lines

#2 - Indirect Inspection:

Indirect Inspection techniques:

- In-Situ Soil Resistivity Measurements
- Soil Sample Collection and Analysis
- Ultrasonic Thickness Measurements (if applicable)
- Direct Examination of Exposed Pipe Sections
- Stray Current Evaluations

#2 - Indirect Inspection:

- Integrate all data along pipeline alignment
- Analyze Data and Rank Indications:
  - Severe
  - Moderate
  - Minor
- Select at sites for direct inspection – locations should be where corrosion activity is most likely
- Select control site where corrosion activity is the least likely

#3 - Direct Examination

- Excavating the pipe
- Performing physical inspection & photograph
- Evaluating integrity of coating/wrap, if present
- Testing the pipe surface, e.g. corrosion pitting
- UT measurements
- Measuring dimensions of corrosion defects
- Analyzing surrounding soil / groundwater
- Performing root cause analysis

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Force Main Pipeline Inspection Report

Inspector name_________ Date____ Address of pipeline inspection ________________ Leak? Yes____ No____ File Number:_____________

1) Type of Pipe: cast iron_____ ductile iron____ carbon steel___ copper______ carbon steel_____ non metallic_____ concrete________other____

2) Diameter of pipe _____" Pipeline Name_________Service Type: Water____ Wastewater____ Estimated date of pipe installation______ Depth of pipe______'

3) Type of Pipe: Distribution____ Transmission____ Service_____ Hydrant _____ Mechanical joint_____ Fasteners_____ Other____ Unknown____

4) Type of Coating: Polyethylene Encased____ Shop applied coating___ No Coating____ Tape Wrap____ Unable to determine____

5) External Pipe Condition: Very Good____ Good____ Poor____ comments:____

____

6) Ultrasonic Thickness Measurements and comment______________________________ Internal Lining Present _____ Yes ____No comment_________________

6) Is corrosion pitting evident? ____ Yes ____ No Number of Pits______ Typical Size of Pits______ Quantity of pits:______

7) Is graphitization evident (longitudinal or circumferential breaks) ____Yes ____ No

8) Is the pipe installed in (check off appropriate items): Industrial area____ Residential area____ Rural area____ Near street or road ____
Near creek or waterway ____ In reclaimed land___ Near oil or gas pipelines____ Near high voltage lines ____.

8) Describe soil conditions where inspection occurred: wet____ dry____ clay soil ____ rocky soil____ cinders ____ other____________________

9) Where soil samples obtained, sealed and analyzed for chlorides, moisture content, pH, sulfides, resistivity? If yes results were: _____________________________

10) Were previous repairs made on the pipeline (leak clamps, etc) Yes____ No ____. Was new pipe installed____ Yes ____ No.

11) Was a repair clamp installed on the pipe during inspection ___ Yes ___ No

12) Was a galvanic anode installed as part of the inspection process? ___ Yes ___ No, if yes size and quantity

13) Please relay additional comments:

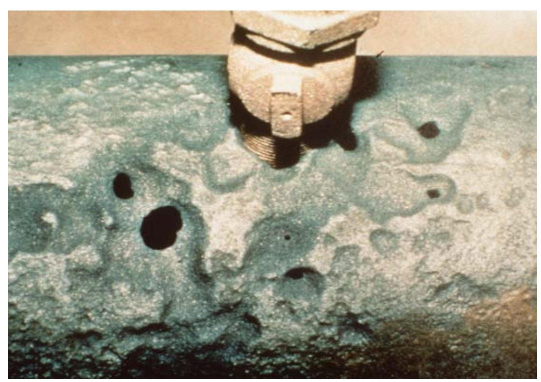
____
____
____

14) Plan of Action_____________________________

15) Insert digital photos below:

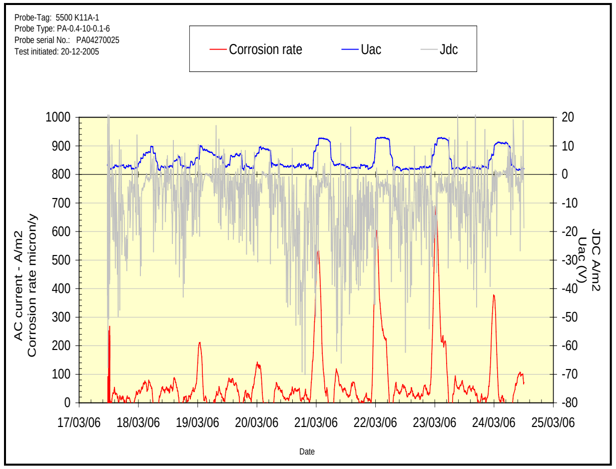
#3 - Direct Examination:

- When corrosion is found, perform a root cause analysis
- Implement localized corrosion protection
- Install instrumented test station for future assessment of corrosion activity, e.g. corrosion rate probes



#4 – Post Assessment:

- Calculate remaining life
  - Pit growth rate and wall thickness
  - Internal or External Corrosion
  - Coupons
  - Electrical resistance (ER) probes
- Maximize benefit by
  - Capture ideas for improvement
  - Determine need/timeframe for update evaluations
  - Identify corrective action options

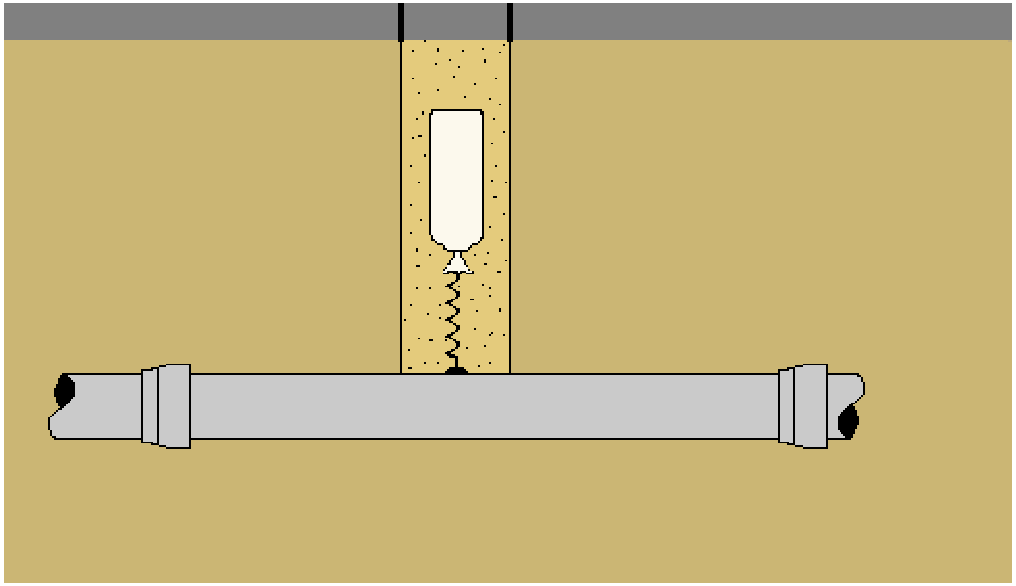


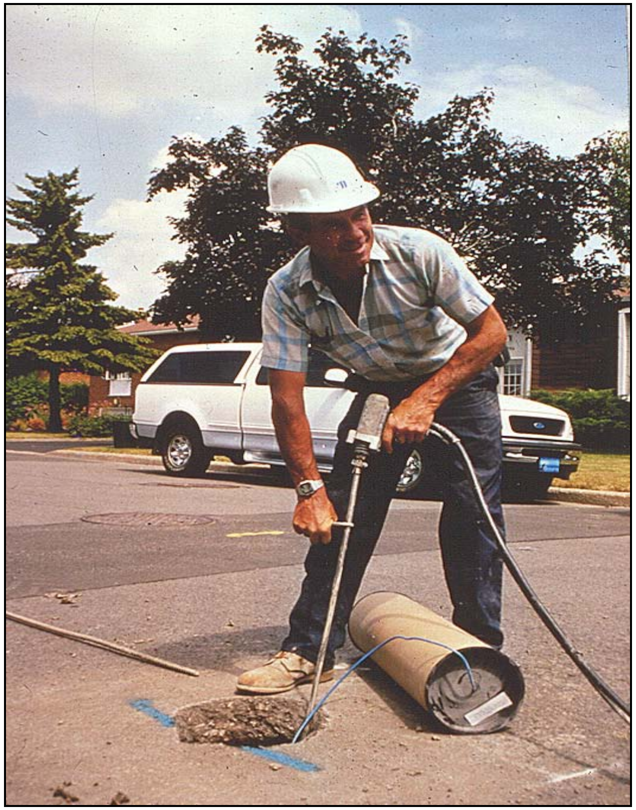
#4 – Post Assessment Recommendations:

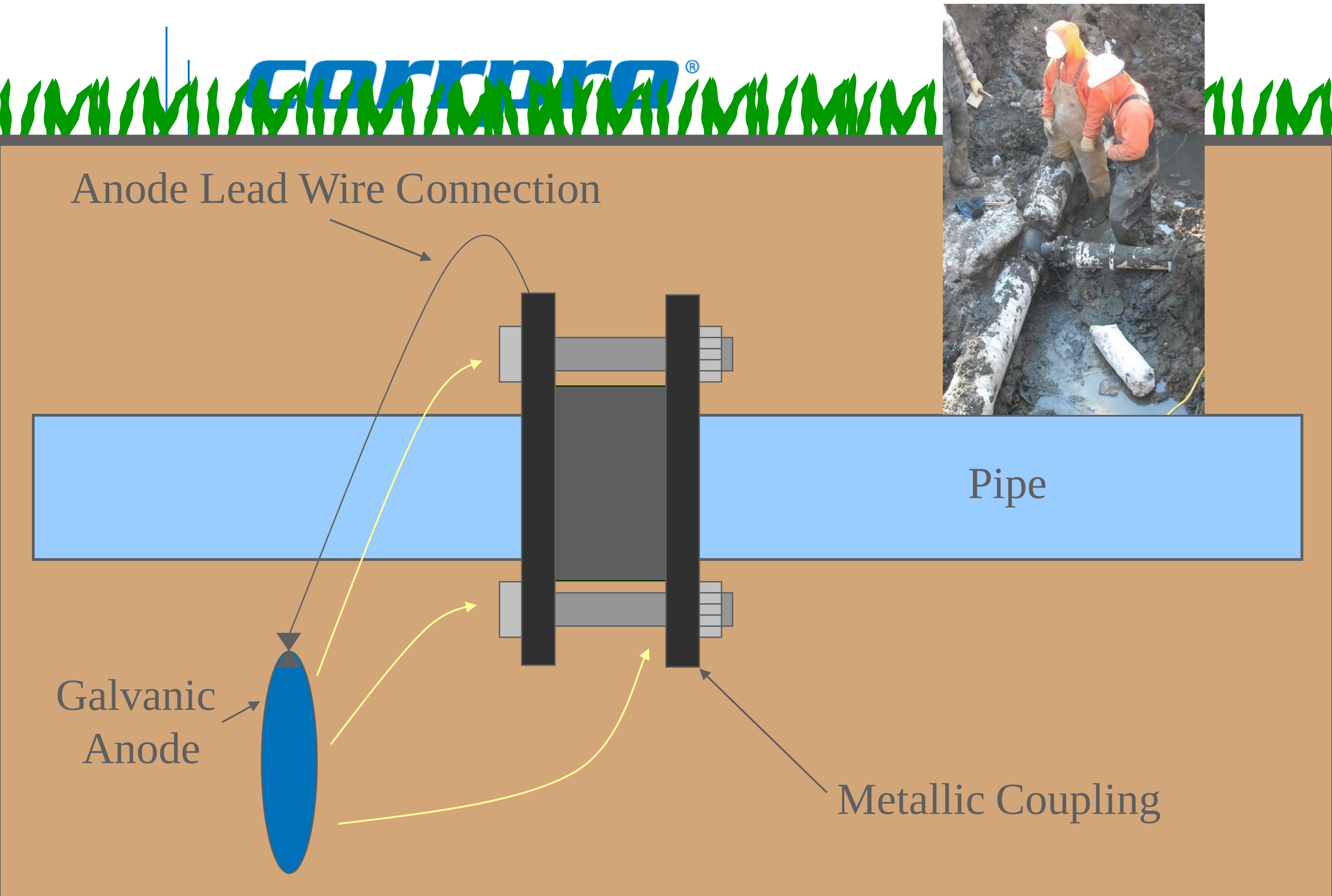
- Identify Corrective Options
  - Operational Procedures
  - Treatment Practices
  - Internal Lining
  - Cathodic Protection
  - Stray Current Mitigation
  - Pipeline Replacement
  - Pipeline Monitoring

Program for Existing Mains

Break Reduction Life Extension Through Cathodic Protection







Cathodic Protection of Metallic Fitting

Meter Vaults

(Keep dry if possible)

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Impressed Current CP System on Oil/Gas Lines can Create Stray Current Problem on Water Lines

Summary

- Effective management of force mains pipeline includes understanding and managing the risk of corrosion
- A systematic approach to condition assessments results in the most value at the lowest cost
- Retrofitting with accepted industry practice such as internal linings, treatment programs, operational adjustments, or cathodic protection may be a cost effective options for extending the life of existing mains
- A key asset management strategy is to include suitable corrosion control in the design of new force mains

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Other Structures

Thank You

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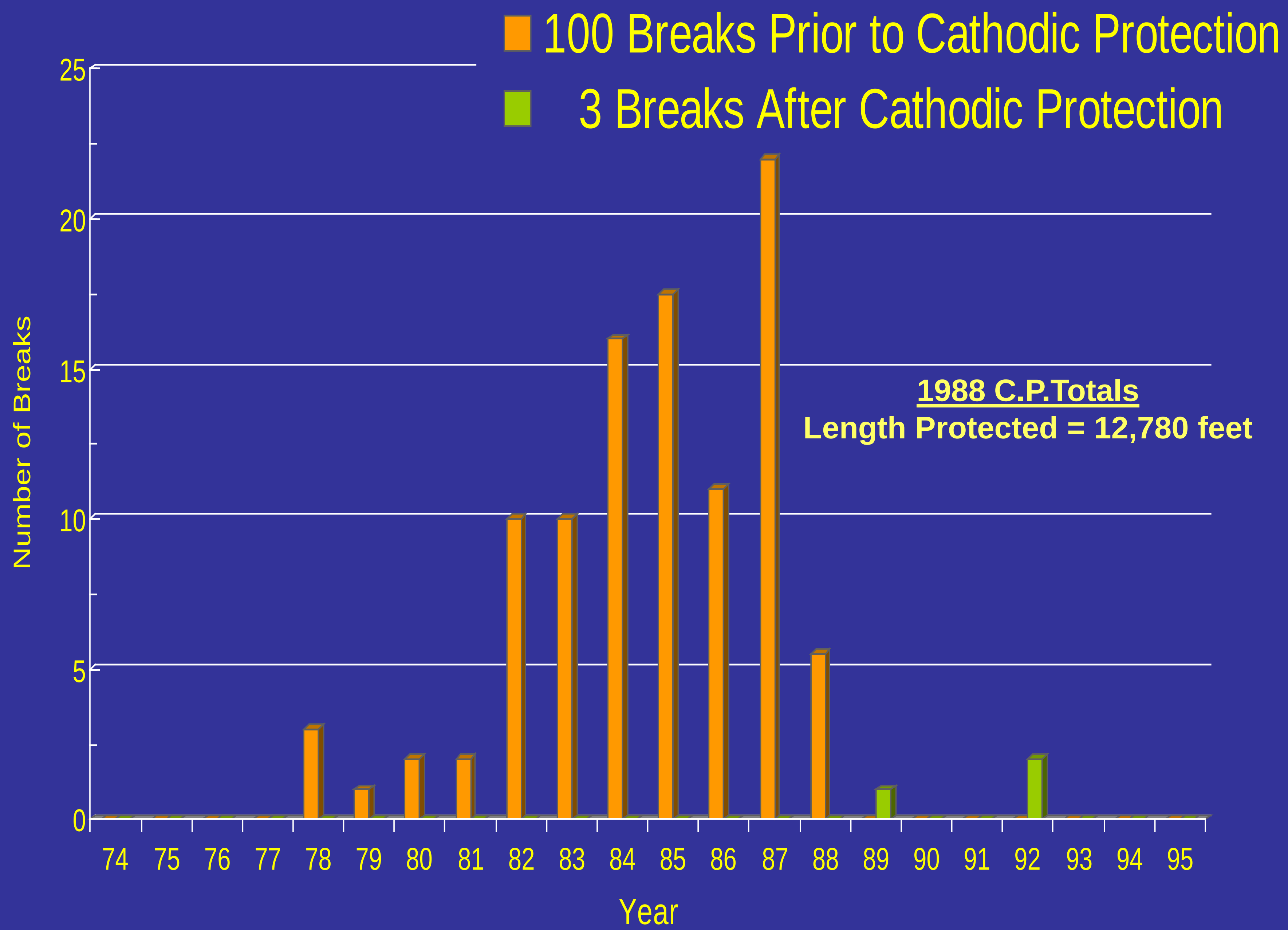
Prioritizing Distribution Systems

Program for Existing Mains

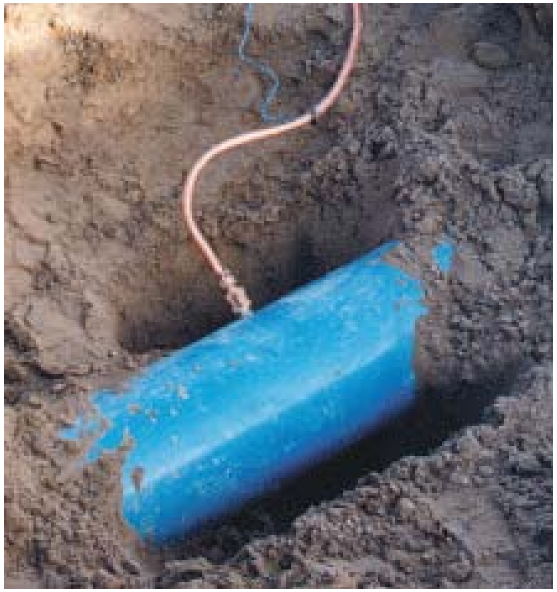
***B**reak **R**eduction **L**ife **E**xtension Through Cathodic Protection*

Anode Installation

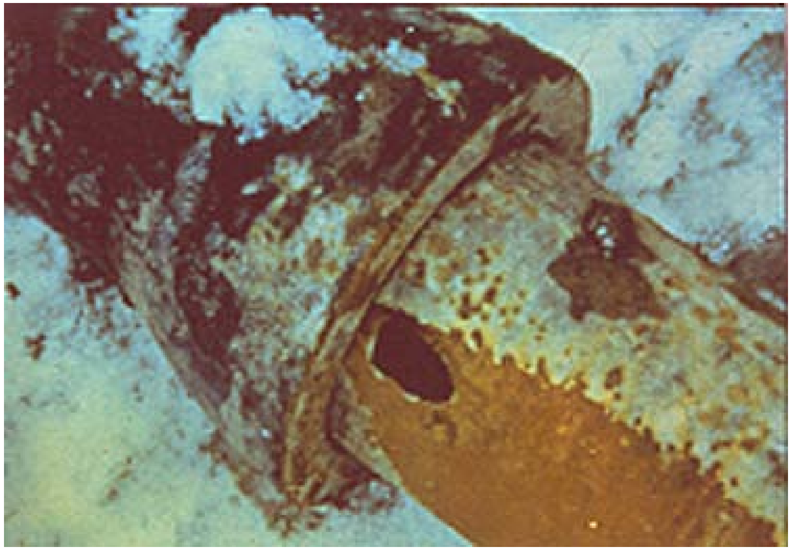


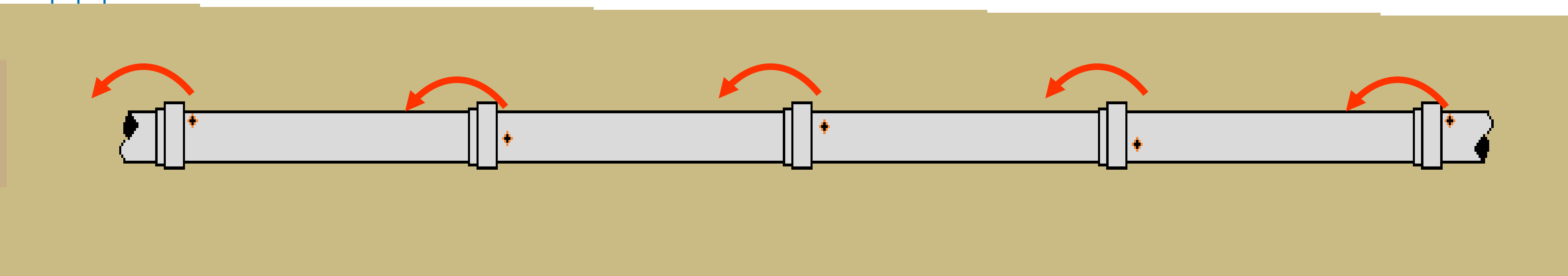
100 Breaks Prior to Cathodic Protection
3 Breaks After Cathodic Protection
1988 C.P.Totals
Length Protected = 12,780 feet
Number of Breaks
25
20
15
10
5
0
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
Year

Copper Service Connections



Stray Current





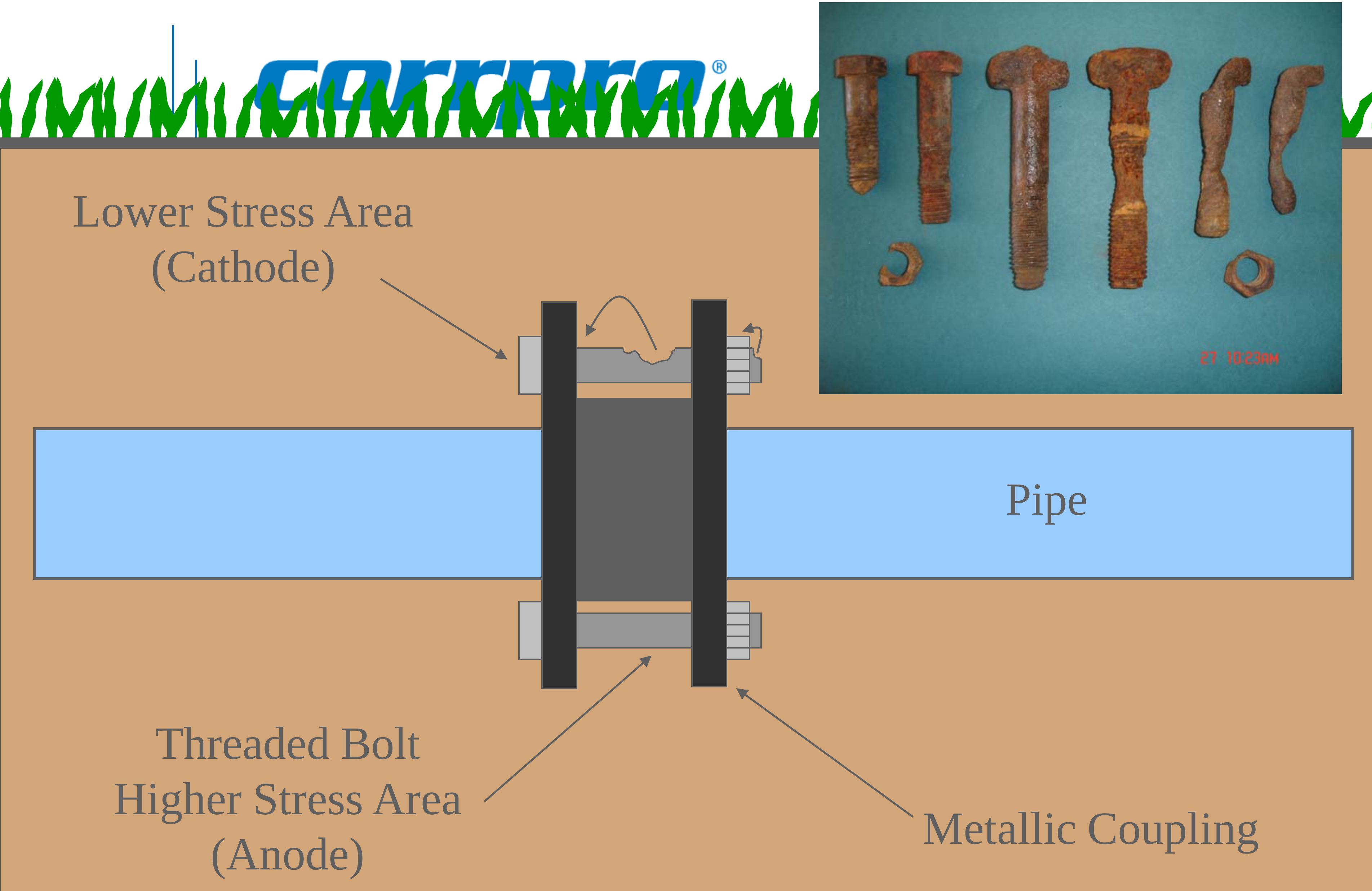
Polyethylene Encasement of Ductile Iron Pipe

-Follow DIPRA installation procedures
-Clean pipe before installing polywrap
-Repair tears or damage to encasement
-Engage an inspector to oversee installation

Insituform

Repair of Break Should Include Anode Installation

Completed Repair



Stress Corrosion

Polyethylene Encasement of Ductile Iron Pipe

-Follow DIPRA installation procedures
-Clean pipe before installing polywrap
-Repair tears or damage to encasement
-Engage an inspector to oversee installation

Force Main Recommendations

- Use coatings and cathodic protection for external corrosion control of steel and ductile iron pipe
- Replace pipe at failure sites with PVC, HDPE or fiberglass
- For long sections of deteriorated pipe, replace with PVC, HDPE or fiberglass, or, internally line with cured in place polyester resin (CIPP)
- Where metallic piping must be used, line with ceramic epoxy.

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History of Iron Pipe

Cast Iron

Ductile Iron


27 10:32AM

Anode Installed on Metallic Fitting

Investigative Structure (Existing)

Corrosion Assessment

- Review of General Characteristics of Water System

- Review Break / Leak History
- Field Survey

- Data Analysis & Risk Management
- Priority Index (Identification of Opportunities to Reduce Replacement / Repair Costs)

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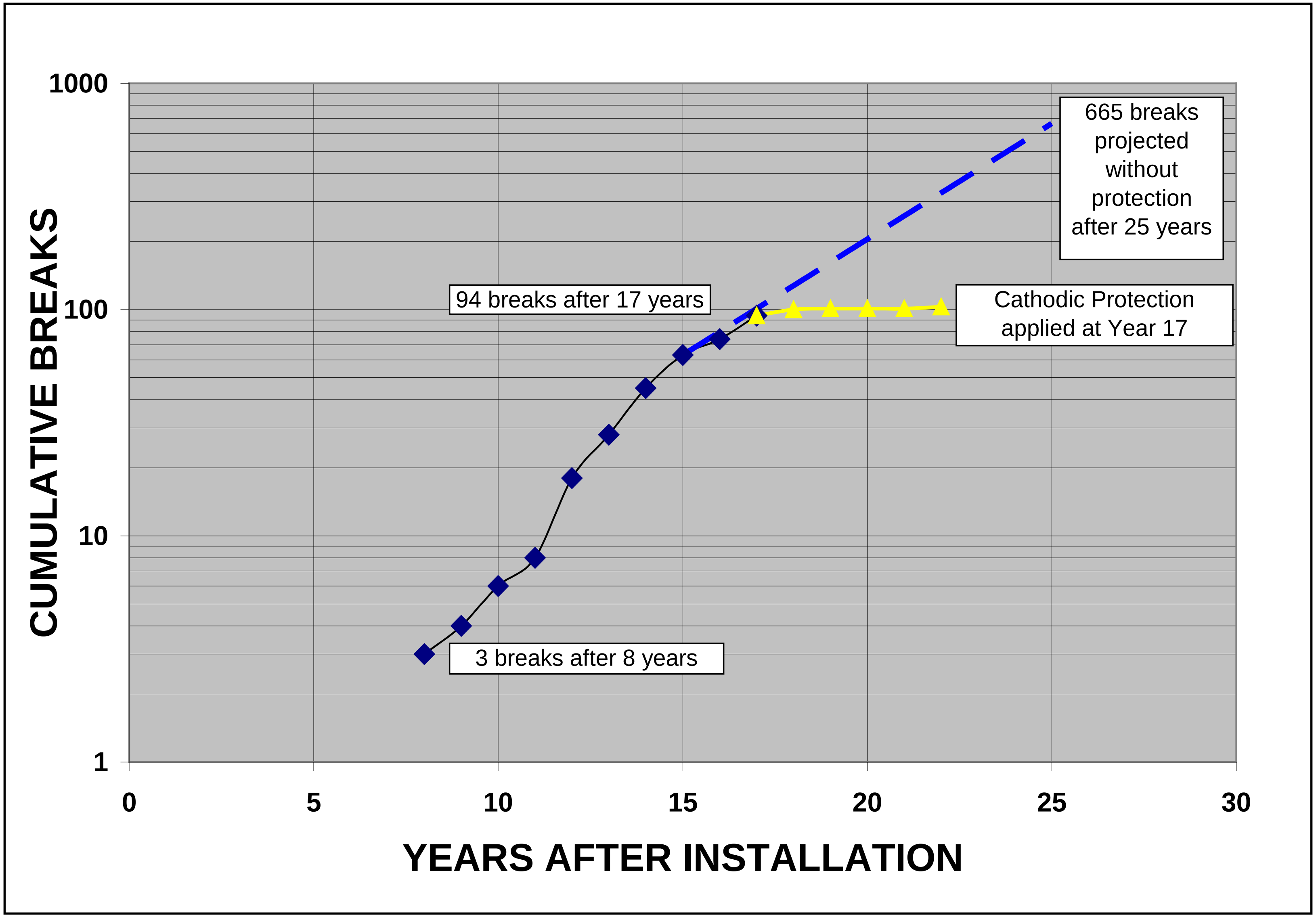
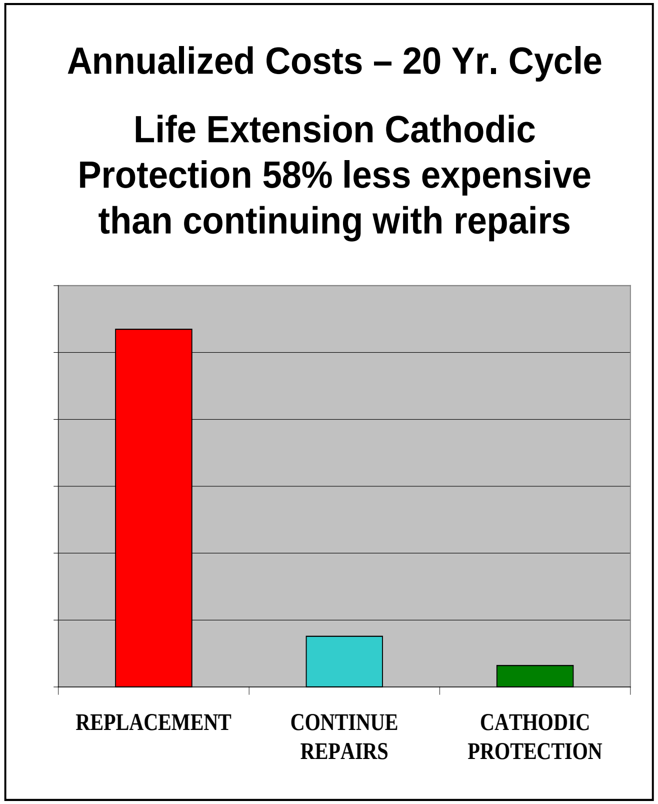
Effectiveness of Well Designed Corrosion Management Programs



Benefit to Cost Ratios ($ saved/ $ spent):

City of Houston, TX	8
Marin Water District, CA	9
East Bay MUD, CA - All Facilities	7
East Bay MUD, CA - Steel Pipelines	24
Chicago Area Utility	25



Existing Force Mains:

- Internal Corrosion is likely the leading cause of main breaks
- External Corrosion may also be a factor

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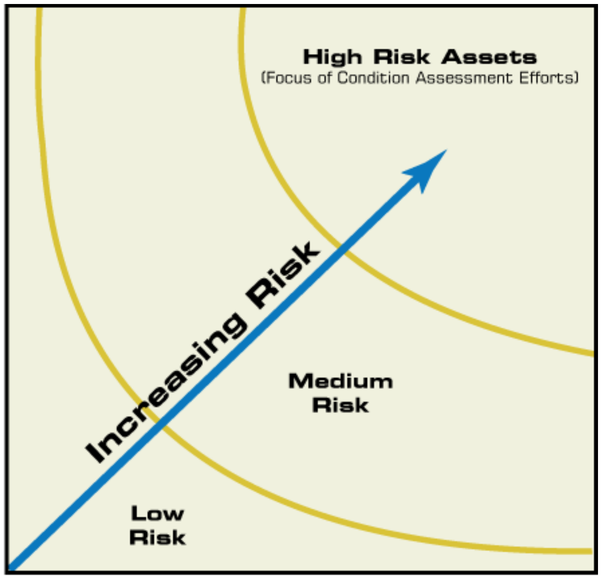
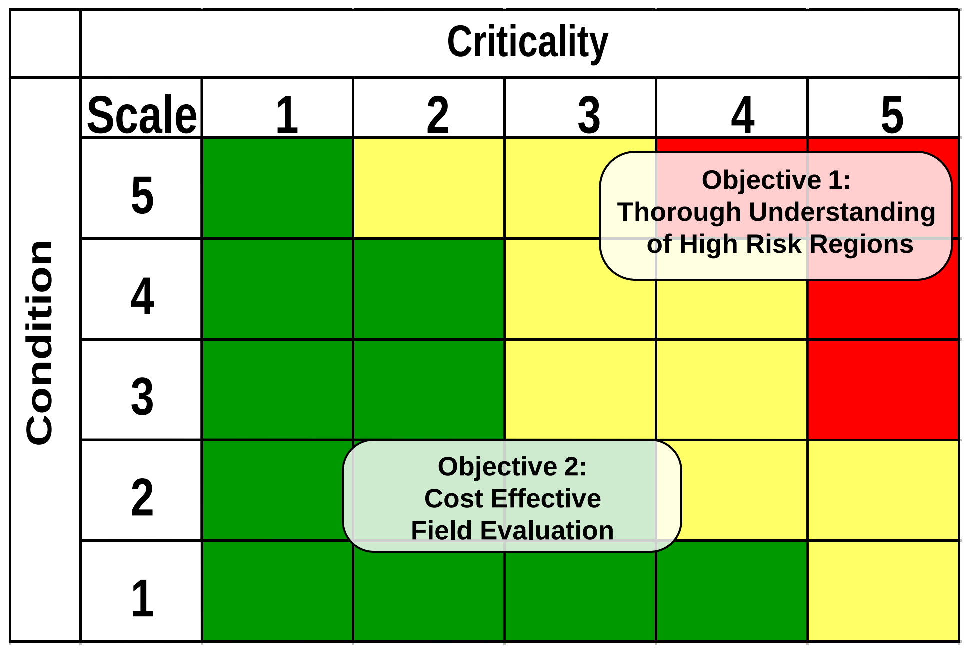
#2 – Indirect Inspection:
Non-Invasive Over-the-Line Techniques

Existing Force Mains: Condition Assessment

…need to cost effectively understand and manage pipeline condition and operational risk…





The four fundamental elements of a successful coating system involve:

1. Material Selection
2. Specification
3. Application
4. Inspection

Technologies

- Material Selection
- Protective Coatings
- Cathodic Protection
- Stray DC Current Control
- AC Interference Mitigation

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24" DIP

- Multiple failures at Buffalo Bayou on bottom of pipe
- Performed ultrasonic thickness measurements in lift station
- Cases of failure are scouring and turbulent flow

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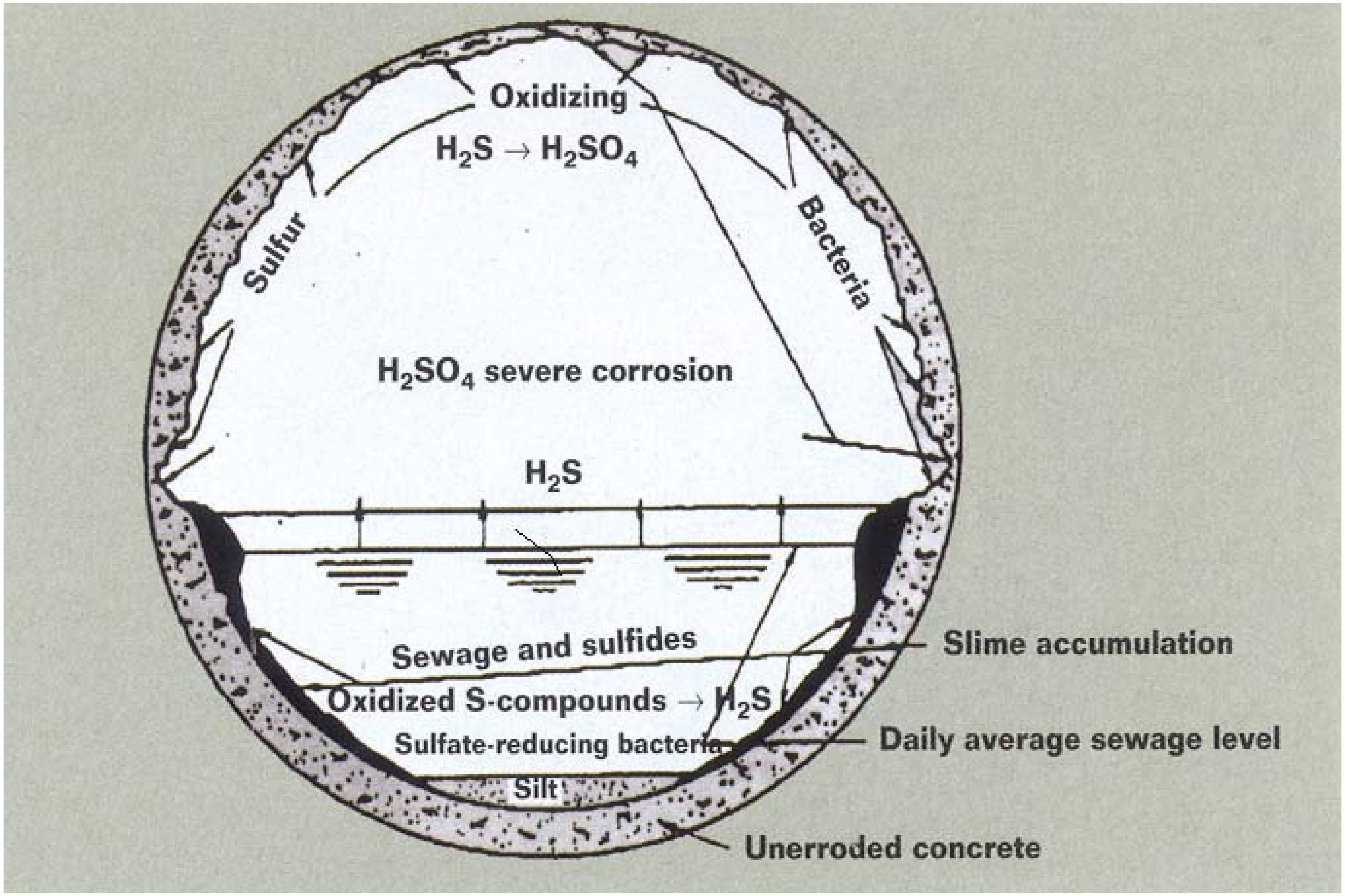
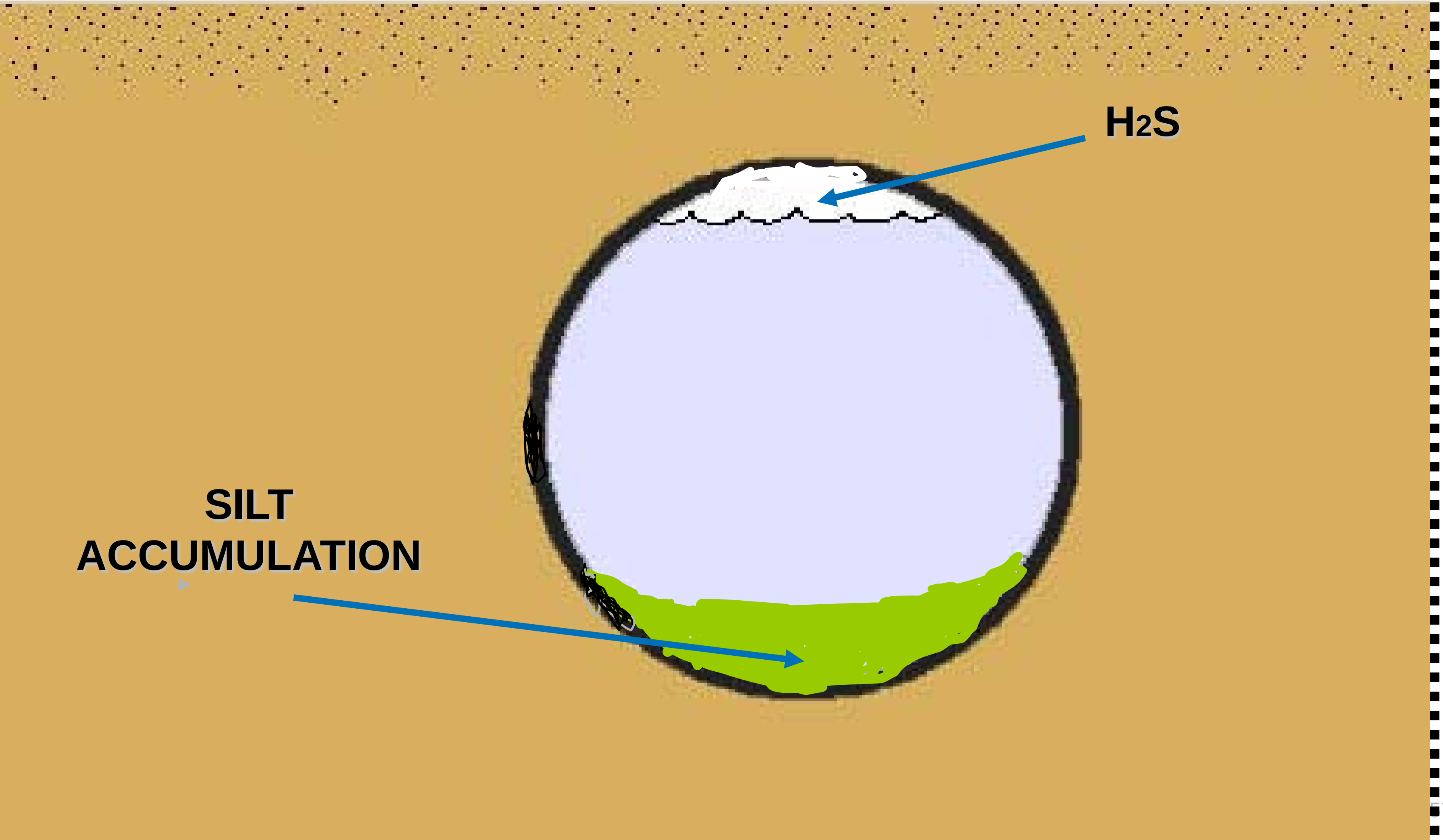
Force Main Corrosion Mechanisms



30” Ductile Iron

- Internal corrosion failure at crown of pipe.
- Hydrogen sulfide gas formed sulfuric acid which attacked the mortar coating and then the underlying metal surface.

H_2S & Silt Accumulation May Cause Internal Corrosion Problem….

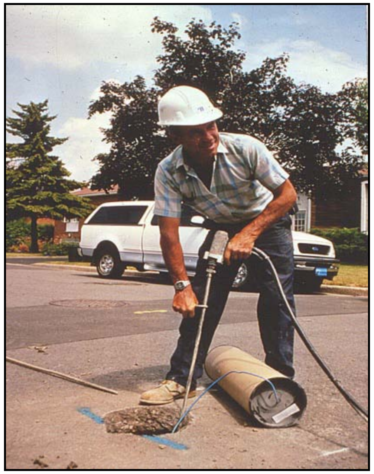


Piping Inspection Phases

1. **Identification of Problem or High Consequence Areas**

2. **Field Study/Inspection**

3. **Post Assessment/Identify Corrective Options**



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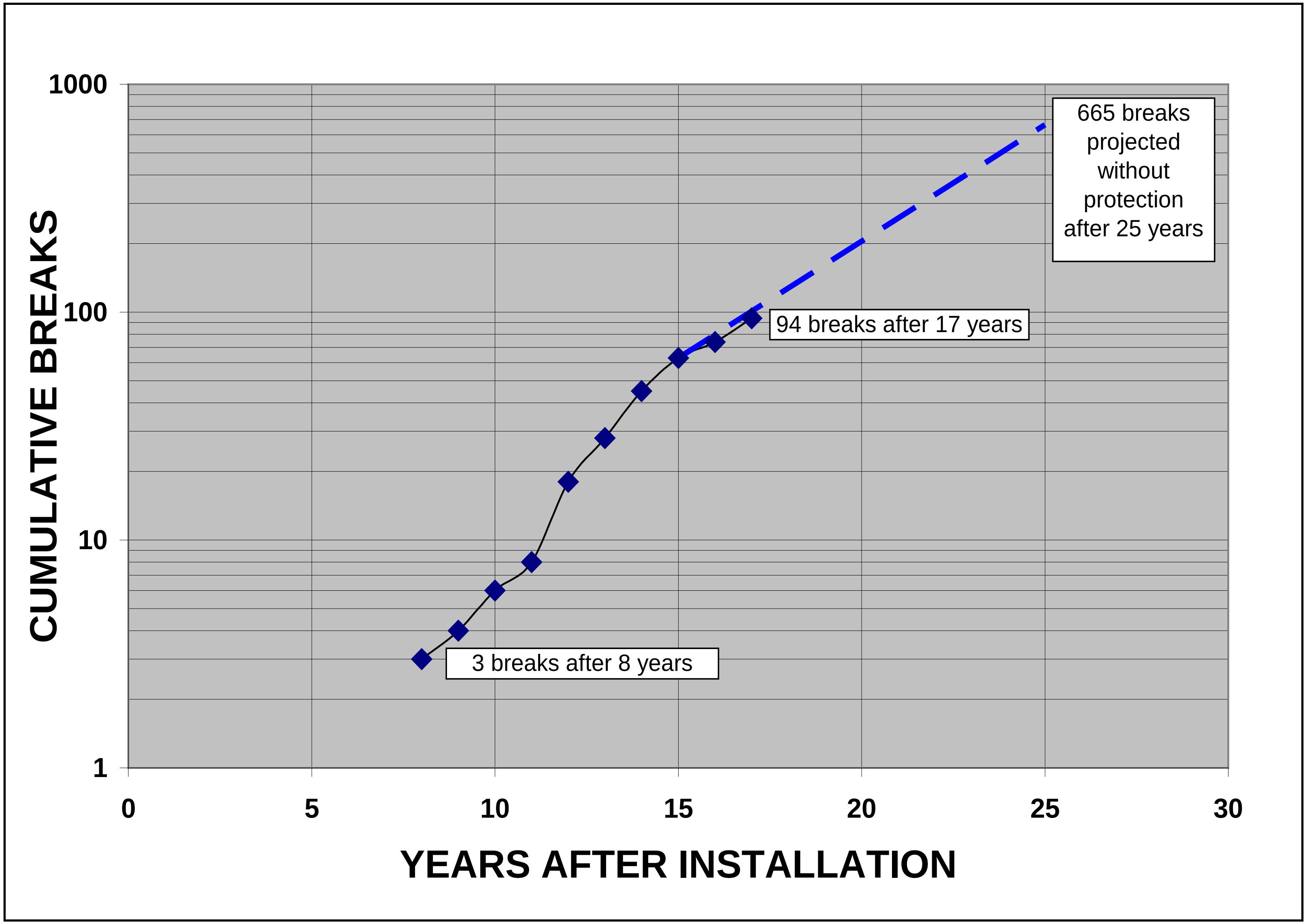
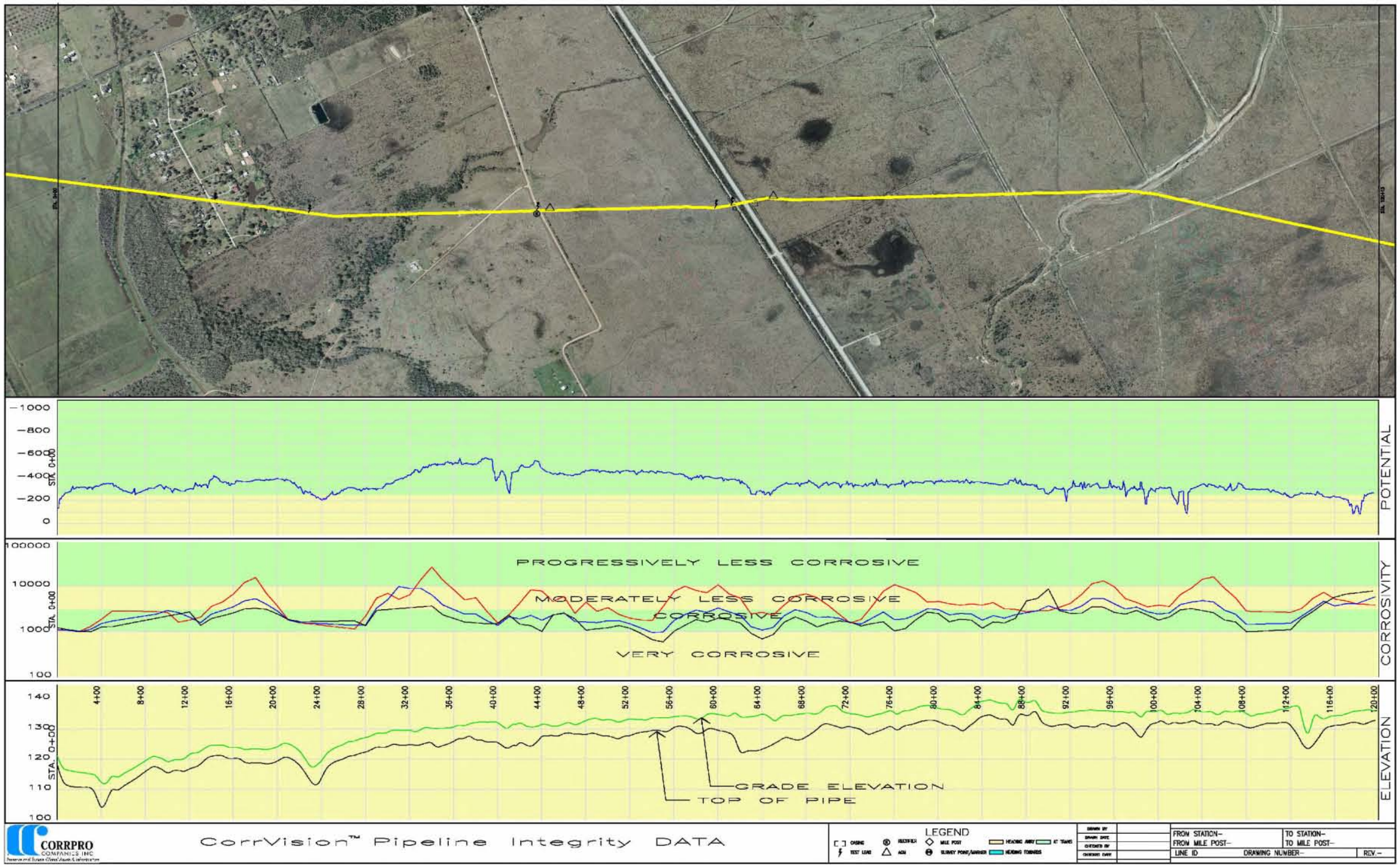
Accurate leak records are an invaluable predictive tool



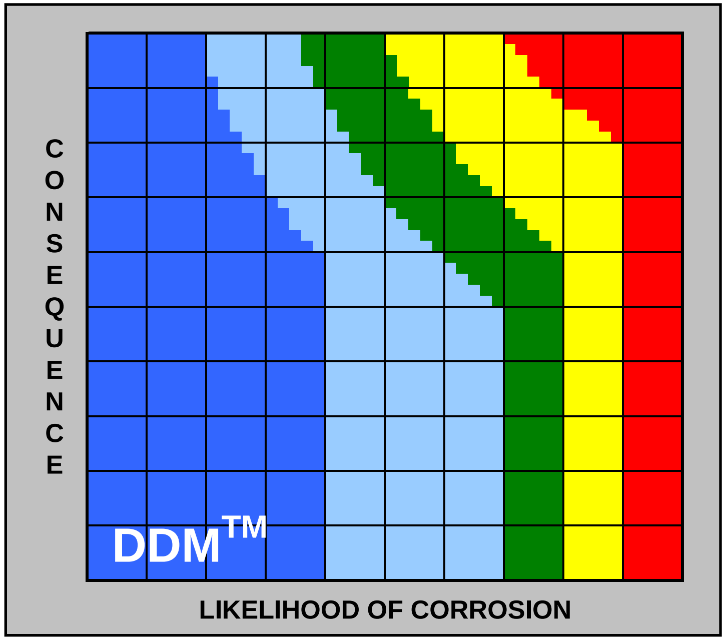
#2 – Indirect Inspection:
Data Integration for Non-Invasive Over-the-Line Techniques



#2 - Indirect Inspection:

Available decision-assisting tools, among others:

- DDM™ – Risk-based “Design Decision Model”
- MTCF℠ – “Mean Time To Corrosion Failure” Predictive Model



#3 - Direct Examination:

- Excavating the pipe
- Performing physical inspection
- Evaluating integrity of coating/wrap, if present
- Ultrasonic Testing of the pipe surface
- Measuring dimensions of corrosion defects
- Analyzing surrounding soil / groundwater
- Obtain coupon
- Performing root cause

24" DIP & Steel

- Internal pipe failures along crown of pipe
- Failures following loss of internal mortar lining
- Cause is formation of hydrogen sulfide gas

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#3 - Direct Examination:

Procedures for data collection

- Physical Examination
- Photographic Documentation
- Pipe-to-Soil Potential Measurements
- Bi-metallic Connections, e.g. services
- Soil, Bedding, Backfill and Groundwater Tests
- Coating Assessment (if applicable)
- Mapping and Measurement of Corrosion Defects
- Ultrasonic Thickness Measurements
- AC and DC Stray Current Measurements