How to Perform Condition Assessment of Water Piping Systems

Ahmad Habibian, Ph.D., P.E.
Global Technical Strategy Leader – Conveyance
CDM Smith

VA AWWA/CSAWWA Education Fall Webinar
State of Water Infrastructure, Part I
Learning Objectives/ Agenda

1) Why do you need a condition assessment program?
2) How to establish an inspection prioritization framework?
3) How to select the right technologies for inspection?
4) What are some of the available inspection technologies?
5) How to use the results of inspection?
6) How to get started?
Why do you need a condition assessment program?

- Aging Infrastructure
- Experiencing major failures
- Facing shortage of funding ($$$)

Source: ASCE
Asset Management Continual Life Cycle

Set Goals and Objectives

Asset Inventory

Inspection + Condition Assessment + Performance Modeling

Alternatives Evaluation and Program Optimization

Performance Monitoring (Feedback)

Program Implementation

Short- & Long-Range Plans (Project Selection)
How to establish an inspection prioritization framework?

Risk = Likelihood of Failure \times \text{Consequence of Failure}

- Physical Attributes
- Condition Attributes
- Environmental Attributes
- Operational Attributes
- Critical Customer
- Pipe Size
- Pipe Location
- Redundancy
Likelihood of Failure

- Physical Attributes
  - Age
  - Size
  - Material / linings / coatings

- Condition Attributes
  - Pipe condition
  - Joint condition

- Environmental Attributes
  - Soil condition
  - Groundwater table location

- Operational/performance data
  - Pressure
  - Fire flow / C-factor
  - Maintenance records
  - Breaks and leaks history

<table>
<thead>
<tr>
<th>Typical Weighting factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute Category</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Physical</td>
</tr>
<tr>
<td>Condition</td>
</tr>
<tr>
<td>Environmental</td>
</tr>
<tr>
<td>Operations &amp; Performance</td>
</tr>
</tbody>
</table>
Consequence of Failure

- Number of customers served by the pipe
- Proximity to hospitals
- Proximity to large users
- Serving business districts
- Road Type – Interstate, State, Local
- Environmental impact
- Potential for adverse publicity
- Ease of repair
- Redundancy
  - Existing parallel pipe or existing loop
Risk Allocation Matrix

<table>
<thead>
<tr>
<th>Likelihood Score</th>
<th>&lt; 50</th>
<th>50 - 75</th>
<th>76 - 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>76 - 100</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>50 - 75</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>&lt; 50</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>
What are some of the available inspection technologies?

CONDITION ASSESSMENT TECHNOLOGIES

DIRECT METHODS
- VISUAL INSPECTION
- LEAK DETECTION
- WALL THICKNESS MEASUREMENT

INDIRECT METHODS
- BREAK HISTORY
- CORROSION MONITORING
- SOIL TESTING
How to select the right technologies?

- Match inspection level with risk
- Consider cost versus effectiveness and coverage

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Basic Indirect Methods</td>
</tr>
<tr>
<td>Medium</td>
<td>Indirect Methods + Basic Direct Methods</td>
</tr>
<tr>
<td>High</td>
<td>Indirect &amp; Direct Methods</td>
</tr>
</tbody>
</table>

Cost versus Effectiveness & Coverage:

- Low: $50,000
- Medium: $100,000
- High: $300,000

Effectiveness

Coverage
# Collect Main Break Data

## AWWA Checklist

### Main Break Evaluation

#### Field Data for Main Break Evaluation: Project Number

<table>
<thead>
<tr>
<th>Date of Break:</th>
<th>Time:</th>
<th>AM</th>
<th>PM</th>
</tr>
</thead>
</table>

**Name of Person Filling the Form:**

**Type of Main:**

- Size (OD): mm
- Joint:
- Cover: ft
- Wall Thickness at Failure: in.

**Nature of Break:**

- Circumferential
- Longitudinal: Clock Position
- Both
- Leak
- Blowout
- Joint: Sleeve
- Split at Corporation
- Other

**Apparent Cause of Break:**

- Water Hammer (Surge)
- Defective Pipe
- Deterioration
- Corrosion
- Improper Bedding
- Operating Pressure
- Temperature Change
- Differential Settlement
- Contractor/Third Party
- Other

**Pipe Location Information:**

- Paved
- Unpaved
- Traffic: Heavy
- Medium
- Light
- Type of Street Surface: Concrete
- Weather: Sunny
- Cloudy
- Type of Soil: Clay
- Resistivity: ohms/m
- Electrolysis?
- Yes
- No
- Corrosion?
- Inside
- Outside
- Other

**Other:**

- Rocks
- Voids
- Proximity to Other Utilities:
- Depth of Frost: in.
- Depth of Snow: in.

**Comments:**

---

#### Office Data for Main Break Evaluation: Project Number

**Name of Person Filling the Form:**

**Weather Conditions During Previous Two Weeks:**

- Yes
- No
- Average Temp: °F
- Rise: °F
- Fall: °F

**Sudden Change in Air Temp:**

- Yes
- No
- Average Temp: °F
- Rise: °F
- Fall: °F

**Historical Pipe Data:**

- Type of Main: 
- Class/Thickness: 
- Laying Length: ft
- Date Laid: 
- Design Operating Pressure: psi
- Previous Break Reported?
- Yes
- No
- Pressure at Previous Break: psi

**Historical Installation Data:**

- Bedding: 
- Gravel
- Sand
- Native Material
- Other

- Backfill: 
- Native Material
- Bank Run Sand and Gravel
- Rock
- Other

- Compaction: 
- Natural
- Water
- Compactors
- Vibrators
- Other

**Comments:**

---

#### Other Data

**Location of Break:**

**Map Number:**

**Reported By:**

**Damage:**

**Repairs (Equipment, Materials, Labor):**

**Repair Difficulties (if any):**

**Installing Contractor:**

---
Soil Corrosivity

# AWWA 10-Point System for Soil Corrosively Assessment

<table>
<thead>
<tr>
<th>Soil Characteristics Based on Samples Taken Down to Pipe Depth</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resistivity</strong>—ohm-cm (based on water-saturated soil box):</td>
<td></td>
</tr>
<tr>
<td>&lt; 1,500</td>
<td>10</td>
</tr>
<tr>
<td>≥ 1,500–1,800</td>
<td>8</td>
</tr>
<tr>
<td>&gt; 1,800–2,100</td>
<td>5</td>
</tr>
<tr>
<td>&gt; 2,100–2,500</td>
<td>2</td>
</tr>
<tr>
<td>&gt; 2,500–3,000</td>
<td>1</td>
</tr>
<tr>
<td>&gt; 3,000</td>
<td>0</td>
</tr>
<tr>
<td><strong>pH:</strong></td>
<td></td>
</tr>
<tr>
<td>0–2</td>
<td>5</td>
</tr>
<tr>
<td>2–4</td>
<td>3</td>
</tr>
<tr>
<td>4–6.5</td>
<td>0</td>
</tr>
<tr>
<td>6.5–7.5</td>
<td>1†</td>
</tr>
<tr>
<td>7.5–8.5</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 8.5</td>
<td>3</td>
</tr>
<tr>
<td><strong>Redox potential:</strong></td>
<td></td>
</tr>
<tr>
<td>&gt; 100 mV</td>
<td>0</td>
</tr>
<tr>
<td>+50 to +100 mV</td>
<td>3.5</td>
</tr>
<tr>
<td>0 to +50 mV</td>
<td>4</td>
</tr>
<tr>
<td>Negative</td>
<td>5</td>
</tr>
<tr>
<td><strong>Sulfides:</strong></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>3.5</td>
</tr>
<tr>
<td>Trace</td>
<td>2</td>
</tr>
<tr>
<td>Negative</td>
<td>0</td>
</tr>
<tr>
<td><strong>Moisture:</strong></td>
<td></td>
</tr>
<tr>
<td>Poor drainage, continuously wet</td>
<td>2</td>
</tr>
<tr>
<td>Fair drainage, generally moist</td>
<td>1</td>
</tr>
<tr>
<td>Good drainage, generally dry</td>
<td>0</td>
</tr>
</tbody>
</table>

*Ten points indicates that soil is corrosive to ductile-iron pipe; protection is needed.
†If sulfides are present and low or negative redox-potential results are obtained, add three points for this range.
Potential Surveys

\[ \rho = 2 \pi a (V/I) \]
Direct Assessment Technologies

- DIRECT CONDITION ASSESSMENT TECHNOLOGIES
  - VISUAL INSPECTION
    - CCTV
    - SWIMMING CAMERA
    - BORESCOPE
    - LASER PROFILING
    - EXTERNAL INSPECTION
  - LEAK DETECTION
    - LDS1000
    - SAHARA SYSTEM
    - SMART BALL
    - ACOUSTIC MONITORING
    - GUIDED WAVE
    - ULTRASONIC
    - REMOTE FIELD TECHNOLOGY
    - BROADBAND ELECTROMAGNETIC
    - MAGNETIC FLUX
    - COUPON SAMPLING
  - WALL THICKNESS MEASUREMENT
    - ACOUSTIC MONITORING
    - GUIDED WAVE
    - ULTRASONIC
    - REMOTE FIELD TECHNOLOGY
    - BROADBAND ELECTROMAGNETIC
    - MAGNETIC FLUX
    - COUPON SAMPLING
Guidance Resources

Condition Assessment Strategies and Protocols for Water and Wastewater Utility Assets

Nondestructive, Noninvasive Assessment of Underground Pipelines

Subject Area: Distribution Systems
Visual Inspection (Internal)

- Man-entry for large pipes
- CCTV with shutdown/dewatering
- CCTV without dewatering/shutdown
  - SAHARA
  - JD-7 Investigator
  - LDS1000
  - Swimming ROV
  - Mini Cameras
Leak Detection – Acoustic Monitoring

- Correlators
  - Mobile units
  - Continuous monitoring with data transmission by wireless technology
  - LeakFinder
- SAHARA
- Smart Ball
- Investigator
- LDS1000

\[
A = \frac{C}{2} + V \times DT / 2 \\
B = \frac{C}{2} - V \times DT / 2
\]
Leak Detection – Helium Injection

- High purity helium gas is injected into the live water system.
- Helium escapes through water leaks in the pipe wall and rises to the surface where it is measured above ground.
- High levels of helium above ground identify the location of the leak.
- A single injection of Helium gas travels a long distance throughout the water system and remains for several days allowing monitoring of long lengths of pipe.

Source: Utility Service Group
Acoustic Monitoring

- Provides an indication of average wall thickness between the two measuring points, not providing location or clock position of defect
- Good as a screening tool and for detecting widespread corrosion and wall loss
- Non-intrusive
- Low cost
- Most effective for AC pipe due to uniform degradation

\[
\frac{V}{V_w} = \frac{1}{\sqrt{1 + \frac{D}{t} \left( \frac{K_w}{E_p} \right)}}
\]

Source: Echologics
Ultrasonic Thickness Measurements

- Handheld devices
  - Provides wall thickness measurement at discrete point
  - Coating & lining could interfere with measurements
  - Good for spot check of results
  - Low cost
- Continuous monitoring
  - Can provide wall thickness profile
Remote Field Eddy Current

- Provides metal wall loss with location & clock position
- Can negotiate bends
- Dewatering not needed
- Fast
- Access for large pipes can be costly

Source: PICA
Magnetic Flux Leakage

- Comprehensive inspection tool
- Mostly for large diameter pipe
- Provides metal loss with location & clock position
- Requires shut-down
- Requires removal of pipe section for deploying the tool
- Slow
- Expensive

Source: Pure Technologies
Broadband Electromagnetic

- External scanning requires excavation and exposure of external surface
- Internal Inspection
  - Shutdown required
  - A section of pipe should be completely removed to allow deployment
- Slow
- Expensive
what to do with the collected data?

Small diameter cast iron pipe
Fails at a higher rate
Analyze Failure Data
Learn about your system

Break Rate Analysis

Spatial Analysis

Thermal Effects
How to use the results to develop and prioritize RRR projects?
Elements of Condition Assessment Program

- Organization
  - Staffing (field, office), Budget
- Information systems
  - GIS, CMMS
- Resources
  - Equipment
- Protocols
- Action Plan
  - What, Where, When, Who, How, Cost?
Organization

Fully Staffed
- Program Manager
  - Admin Assistant
  - Engineer
  - Engineering Assistant (s)
  - Field Technician(s)
  - GIS Technician(s)

Basic
- Program Manager
  - Admin Assistant
  - Engineering Assistant
  - GIS Technician
  - Field Technician

Bare Bone
- Program Manager
  - Admin Assistant
  - Field Technician
Action Plan

- Prioritized list of projects for condition assessment with associated scope, budget & schedule
- In-house projects based on available in-house resources
- Process to retain consultants (ex: RFPs) to assist and/or complement in-house resources
- Process to obtain the services of inspection providers (ex: sample specifications and contract documents)
- Emergency Action Plan (EAP)
Emergency Action Plan

- Retain on-call contractors
- Have adequate supply for pipe repair:
  - Repair kits
  - Spare parts
  - Bypass pumps
  - Clean-up kits
- Identify isolation valves in your system
- Develop a valve exercising program
- Develop specific EAP for your very high-risk pipes
How to get started?

- Identify a champion – Program Manager
- Establish steering committee (planning, engineering, operation, maintenance)
- Develop inventory/maps
- Perform risk analysis
- Establish priorities/ action plan
- Implement action plan

Consider engaging a consultant to help you jump start your program
Questions/Answers

Ahmad Habibian, Ph.D., P.E.
habibiana@cdmsmith.com
703-691-6535