Safety Moment – First Aid App

• Studies show that most workplace first aid training is forgotten over 90 days after certification

• Mobile apps are available with easy-to-follow refresher modules

Download FREE Red Cross Mobile Apps today, in the Apple App Store or Google Play
Presentation Overview

• Industry Drivers
• Force Main Condition Assessment Strategies
• Operational Example
• Case Studies
Industry Drivers
Infrastructure Investment Outlook

Source: EPA Gap Analysis
Infrastructure Investment Outlook

Source: EPA Gap Analysis
Infrastructure Investment Outlook

- **Total Assets** - $1.0 trillion (Sanitary Sewers)
- **15-20% of Public Works Infrastructure**
- **Current Annual Rehab Spending**: ±$10 Billion

![Graph showing estimated rehab needs over years](chart.png)
Average emergency repair cost for > 20-inch = $500K (WRF 2013)

Structural rehab costs 130-200% of the cost of lining rehab (TTC 2003)

Condition assessment costs = 2-6% replacement value
Why the Gap?

Impediments to Proactive Approach

- Funding: 36%
- Technical Deficiency: 29%
- Time/Personell: 14%
- Lack of Strategy: 21%
Force Main Condition Assessment Strategies
Common Force Main Defects

- Leaks
- Pitting Corrosion
- Ruptures
- Tuberculation
- Coating/Lining Damage
- Joint/weld defects

- Air binding
- Deformation
- Abrasion
- Hydrogen embrittlement (PCCP Class IV wires only)
## Tiered Approach: Force Main Assessment

<table>
<thead>
<tr>
<th>Tier 1</th>
<th>Tier 2</th>
<th>Tier 3</th>
</tr>
</thead>
</table>
| - Non-destructive  
- Non-intrusive  
- Pipe remains in service  
- Survey-level information | - Semi-intrusive  
- Pipe remains in service  
- Portions of the pipe be exposed  
- Quantitative and detailed information | - Fully-intrusive  
- Instruments inserted through pipe  
- Flow must be controlled/drained  
- Most specific and detailed information |
Tiered Approach

Tier 1
- Soil survey
- Surface insp.

Tier 2
- Test pits
- Direct insp.

Tier 3
- Specialty Tools
- “Smart Pigs”

“Identify Suspects”
“Confirm Rehab Needs”
“Design Repair”

Lowest Cost, Identify Issues
Higher Cost, Design Data
Tier 1: Technologies

- Non-destructive
- Non-intrusive
- Pipe remains in service
- Survey-level information
Infrared Thermal

- Provides heat signature images which may indicate leaks in water lines or effluent discharges
- Survey level technology
- No excavation/special access needed
- Equipment commercially available, moderate training required
Acoustic Methods: Leak Detection

• Acoustic Correlator (Echologics)
  – Benefits
    • Locates leaks along the pipe
    • Pipe remains in service
    • Works on all pipe sizes/materials
  – Limitations
    • Does not quantify leak rate
  – Cost approx. $20-25K/mi

• Acoustic Microphones
  – Benefits
    • Locates leaks along the pipe
    • Pipe remains in service
    • Works on all pipe sizes/materials
  – Limitations
    • Does not quantify leak rate
    • Background noise can interfere
  – Cost approx. $300/mi
Soil Survey / Corrosion Analysis

• Benefits
  – Rapid, wide deployment
  – Measures resistivity of soils (corrosion potential)
  – Survey-level tool
  – Best used in conjunction with pipe excavation

• Limitations
  – Does not provide information on full pipe length
  – Data relevant for metallic pipes/appurtenances only

• Cost approx. $10,000/mi
Acoustic Methods: Wall Thickness

• Acoustic Correlator (Echologics)
  - Benefits
    • Measures average wall thickness between nodes (stiffness in non-metallic pipes)
    • Pipe remains in service
    • Works on all pipe sizes/materials
  - Limitations
    • Does not identify discrete defects
    • Minimum amount of measurements for accurate statistical analysis may vary
Acoustic Methods (Emission Monitoring)

• Advantages
  – Monitors sudden appearance or propagation of microscopic cracks
  – Monitors sudden break of a prestressed wire in PCCP

• Limitations
  – Can only detect what is happening during monitoring period (no indication about past deterioration)
  – Installation of sensors may need interruption of service
  – Quantitative information (e.g., size) about the crack is not available
Pressure Flow Monitoring

Ultrasonic Transit-time Strap-on

• Benefits
  – No in-line insertion required
  – Accuracy +/- 2%

• Limitations
  – Average flow rate
  – Best with clean water applications

Electromagnetic Insertion

• Benefits
  – Accuracy +/- 2% point velocity
  – Bi-directional flow
  – Remote data transmission

• Limitations
  – Access to 1" tap/ball valve
  – Challenging high-pressure insertion
  – Pipe diameters 8"-78"
Tier 2: Technologies

- Semi-intrusive
- Pipe remains in service
- Portion of the pipe be exposed
- Quantitative and detailed information
Internal Hydrophones

• JD7 “Investigator” / “LDS1000”
  – Benefits
    • Locates leaks and gas pockets
    • Pipe remains in service
    • Works on all pipe sizes/materials
  – Limitations
    • No pipe wall assessment data *Yet*
    • No pipe wall assessment data

• Pure Sahara
  – Benefits
    • Locates leaks and gas pockets
    • Pipe remains in service
    • Works on all pipe sizes/materials +6” (2” access)
    • Measures specific defect location
  – Limitations
    • No pipe wall assessment data *Yet*
    • Deployment distance limited by number of bends in pipe
    • Tethered system requires numerous access points
Free-Swimming Internal Hydrophones

- Pure “SmartBall”
  - Benefits
    - Locates leaks and gas pockets
    - Pipe remains in service
    - Works on all pipe sizes/materials +6” (4” access)
  - Limitations
    - Defect location is approximate
    - No pipe wall assessment data

- JD7 “Bullet”
  - Benefits
    - Locates leaks
    - Pipe remains in service
    - Works on all pipe sizes/materials
    - Records visual images
  - Limitations
    - Defect location is approximate
    - No pipe wall assessment data
    - Tethered system for retrieval
Ultrasonic / Pit Depth Measurement

• Benefits
  – Quantitative measurement
    • Pipe wall thickness
    • Pit depth
  – Simple methods and tools

• Limitations
  – Exposure of pipe exterior required
  – Difficult to determine localized metal loss inside pipe with ultrasonic
  – Most commonly used on metallic pipes

• Cost approx. $15,000/mi
Guided Wave

• Benefits
  – Screening of long lengths of pipe
  – 100% of pipe wall is inspected
  – Detects corrosion in insulated and buried pipes

• Limitations
  – Variable Range: 1”-60” and 60-1,000LF
  – Exposure of pipe exterior required
  – Applies to metallic pipes only
  – Extensive data post-processing
Broadband Electromagnetic

• External Method
  – Benefits
    • Measures localized wall thickness
    • Pipe may remain in service
    • Measures through linings/corrosion
  – Limitations
    • Ferrous pipe only
    • Must expose pipe
    • Extensive data post-processing/interpretations
Magnetic Flux Leakage (External)

• Advantages
  – Tools available for small and large diameter pipes
  – Identifies remaining wall thickness
  – Identifies size and location of defects (including pits)

• Disadvantages
  – Excavation of buried pipes and replacement of coating or insulation are required, which make it economically questionable
  – Still emerging as technology for water pipelines
Bracelet Probe (PICA)

• Benefits
  – Hand-held
  – Reads through coatings/linings
  – Identifies wall pitting locations, and in some instances can estimate pit depth/size
  – Faster post processing

• Limitations
  – Newer technology
  – Best used for “spot checks”
  – Production rate 10 ft/min

• Cost approx. $15,000/day
Tier 3 Technologies

- Fully-intrusive
- Flow must be controlled/drained
- Instruments inserted through pipe
- Most specific and detailed information

Structural Condition

- Internal CCTV
- Internal Laser
- Internal Electromagnetic
- Acoustic Impact Echo
- Coupons
Coupons

• Benefits
  – Multiple structural and metallurgic tests may be run on the coupon
  – Most definitive data set
  – Possible to remove coupons from an operational main by using tapping technologies

• Limitations
  – Provides discrete point information only
  – Requires portion of the pipe to be exposed
Ultrasonic Pig

• Benefits
  – Measures localized wall thickness
  – Free swimming or tethered

• Limitations
  – No leak/gas pocket detection
  – Cannot measure through linings
  – Cannot detect pitting
  – Large insertion assemblies required
  – Extensive cleaning required
  – Ferrous pipe only
Broadband Electromagnetic (Internal)

• Benefits
  – Measures localized wall thickness
  – Measures through linings/corrosion

• Limitations
  – Pipe must be dewatered & cleaned
  – Time consuming (non-continuous scan)
  – Unable to detect pin-holes/pits
  – Large insertion assemblies required
  – Extensive post-processing/interpretation
  – Ferrous pipe only
Electromagnetic (Internal)

- Pure PipeDiver/Robotic
  - Benefits
    - Locates broken prestressed wires in PCCP
    - Locates areas of extensive wall loss in metallic pipes
    - Free swimming and tractor options
  - Limitations
    - Must control flow rate
    - Large insertion assemblies required
    - Not suitable for detecting pitting corrosion or joint defects

- PICA SeeSnake
  - Benefits
    - Measures localized wall thickness and pitting
    - Measures through linings
    - Free swimming or tethered
  - Limitations
    - Must control flow rate
    - Large insertion assemblies required for +24” sizes
    - Extensive cleaning required
    - Metallic pipe only
Magnetic Flux Leakage (Internal)

• Advantages
  – Precise comprehensive inspection
  – Identifies remaining wall thickness
  – Identifies size and location of defects (including pinhole pitting)

• Disadvantages
  – Pipe must be dewatered, and cleaned (some exceptions)
  – Still emerging as technology for water pipelines
  – Ferrous, unlined pipes only (some exceptions)
  – High cost
Acoustic Impact Echo

• Benefits
  – Detects delamination of concrete pipes
  – Detects voids beyond the pipe wall
  – Lower-cost inspection method
  – Works through paint/coatings
  – Only one side of the structure needs to be accessible for testing

• Limitations
  – Requires dewatered pipe
  – Most applicable for concrete structures
  – Discrete point measurements only
Laser

• Benefits
  – High-precision scan of pipe interior dimensions to measure deformation
  – Contributes to design for CIPP, sliplining, swagelining, etc.

• Limitations
  – Only functions above water level
  – Cannot distinguish scanned materials (can be influenced by tuberculation or buildup)
Operational Example
Operational Example

- Force Main Network (20 miles)
- DIP and CCP
- Corrosive soils
- Leakage concerns
Operational Example

• Tier 1
  – Soil survey
  – Appurtenance inspection

• Tier 2
  – Test pits

• Tier 3
  – Electromagnetic
Operational Example

WWTP
Tier 1 – Soil Survey & Appurtenance Inspection
Tier 1 – Soil Survey & Appurtenance Inspection Results

Hot Soils

Multiple Leaks

WWTP
Tier 2 – Test Pits
Tier 2 – Test Pit Results

Pipes in good condition: Leaks not related to corrosion

Extensive Pitting

WWTP
Tier 3 – Electromagnetic

Continue monitoring
Tier 3 – Electromagnetic Results

Less severely damaged: Phase 2 Rehabilitation

Most severely damaged: Phase 1 Rehabilitation

WWTP
### Cost Comparison: 20 mile force main network

<table>
<thead>
<tr>
<th>Assessment Technology</th>
<th>Conventional</th>
<th>Tiered Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Survey/Appurtenance Inspection</td>
<td>N/A</td>
<td>$200,000</td>
</tr>
<tr>
<td>Test Pits</td>
<td>N/A</td>
<td>$200,000 Assume 50% of major force mains are investigated</td>
</tr>
<tr>
<td>Advanced Investigations (Electromagnetic)</td>
<td>$1,000,000</td>
<td>$200,000 Assume 50% major force mains investigated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10% requires advanced assessment</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1,000,000</td>
<td>$600,000</td>
</tr>
</tbody>
</table>
Project Background

- 9,800 LF of 36”-54” diameter C301 PCCP (Lined-Cylinder Pipe)
- Constructed in early 1970s
- Approx. 4,300 LF subaqueous, up to 60 ft depth
- Portions of subaqueous pipe uncovered
- Wastewater can reach 140°F
- Average flow 18-24 MGD
- Facility only has two days per year of low flow < 4 MGD
Portions of Subaqueous Pipe Uncovered

- Original construction included both restrained and unrestrained joints
- Installation was performed by commercial divers into a dredged trench
- Prior surveys indicated erosion had exposed portions of the water crossing
Project Drivers

- Industrial asset management strategy included condition assessment of critical pipelines
- Increased regulator sensitivity due to river crossing and constituency of industrial wastewater
- Approaching presumed half-life for PCCP
- Potential replacement costs on the order of +$15M
Condition Assessment Approach

Tier 1 – Site Reconnaissance and Appurtenance Inspection
- Identified locations most susceptible to external corrosion
- Scouting locations for possible access improvements

Tier 2 – Test Pits and Coupons
- Confirmed possible deterioration of PCCP

Tier 3 – Electromagnetic Methods
- Devices inserted into the pipe at special access structures
- Electromagnetic sensors detect prestressed wire breaks
- In-line acoustic sensors listen for leak frequencies and gas pockets
Condition Assessment Approach

• Final Tier 3 Technology Selection
  – Paid companies for visit; improves correspondence and pre-planning
  – Electromagnetic “smart pigs” determined viable
  – Tethered/powered crawlers selected to minimize risk of equipment loss
  – Transponders map the pipeline location
  – Would required special access to deploy robotic equipment
  – Very narrow 1-week plant shut-down window for prep, access, inspection, and restoration
Special Access Installations

New Access Installation

New Access Installation
Design Layout for 24” Access Taps
Providing Condition Assessment Access

Downstream Access Tap & Flow Diversion

24” Pipe Coring

Upstream Access Tap
Special Access Ways Required Geotechnical Support
Electromagnetic Robot Deployment
In-Line Acoustic Equipment Deployment
Sonde Tool Deployment

• Difficulty tracking crawler from the surface
• Portable detection sensors limited by surface topography
• Future technology generations may include specific underground transponders and location sensor networks (like those used for HDD operations) to accurately track the device and map the alignment.
## Inspection Results and Analysis

### Number of Wire Breaks

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Location</th>
<th># Breaks</th>
<th>Break Length</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2230</td>
<td>50/3B</td>
<td>10</td>
<td>12.0</td>
<td>Left SP in by sheets. Data indicates 16</td>
</tr>
</tbody>
</table>

- [Detailed table of inspection results](table).

### Analysis

- Preliminary analysis suggests potential stress concentrations.
- Further investigation is recommended for areas with 10 or more breaks.

---

**Figure 3.8:** Stresses in 42-inch Class A PCCP with 100 Wire Breaks.

---

**Concrete Core**

**Mortar Coating**

- [Visual representation of stresses.](image)
Seven Pipe Segments on 42” PCCP Adjacent to Aerated Lagoon Recommended for Replacement
Owner Elected Conservative Approach to System Improvements and Replaced Total 800 LF Reach

Pipe Condition

- At-Risk
- Good Condition

Decided Action

- Replacement
- Monitoring
Owner Elected Conservative Approach to System Improvements and Replaced Total 800 LF Reach

Replace Existing 42"

Aerated Lagoons
Hot Line Tapping Bypass
PCCP-DIP-HDPE Repair Combination
Couplings are Key
Making Connections and Restraining Forces
## Overall Project Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe Access Construction</td>
<td>$166,000</td>
</tr>
<tr>
<td>Electromagnetic Inspection</td>
<td>$260,000</td>
</tr>
<tr>
<td>Pipe Repairs</td>
<td>$850,000</td>
</tr>
</tbody>
</table>
Project Challenges, Lessons Learned, and Next Steps

• Challenges
  – High level of regulatory interest (typical for large diameter forcemain water crossings)
  – Limited access
  – Extremely tight and critical activity schedule
  – High temperature wastewater

• Lessons learned
  – Constructing access ways requires thoughtful planning, design, installation
  – Industrial wastewater stream resulted in thick layer of buildup
  – Core sample and petrography tests important to validate NDE
  – Introduction of repair/rehabilitation products different than the host pipe requires special accommodations (restraint, thermal effects, etc.)

• Next Steps
  – Ongoing forcemain monitoring and contingency plan
Thank You

Dan Buonadonna, PE
Daniel.Buonadonna@CH2M.com