

Understanding & Evaluating Corrosion in Wastewater Collection Systems

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Understanding & Evaluating Corrosion in Wastewater Collection Systems

Part 1:

The problem of corrosion in wastewater systems

Part 2:

Evaluating corrosion through proper inspection & condition assessment

Focus will be on gravity pipelines and manholes

Corrosion is a big problem!

- A primary cause of failure in wastewater systems
- Causes billions of dollars of damage annually
- Out-of-site, out-of-mind asset management approach not helping!

ASCE assigned a grade of “D” to our nation’s wastewater infrastructure in 2013.



Corrosion is a big problem!

\$298 Billion is needed over the next 20 years for America's wastewater infrastructure!

Key Concerns:

Capacity

Corrosion

Capital

What can corrode in wastewater systems?

Does Corrode:

- Unlined concrete manholes, pipes, structures
- Steel & metallic pipe, structures , components
- Mortar in brick manholes & pipes

Does Not Corrode:

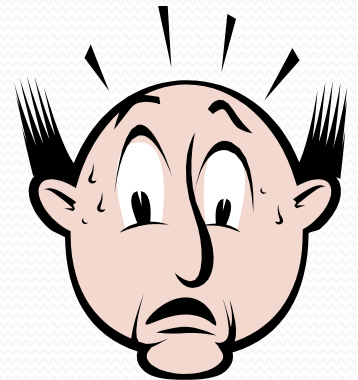
- PVC, HDPE & plastic pipe, structures, components
- Fiberglass/ FRP, composite pipe, lining & structures
- Clay pipe and bricks
- High performance coating/ lining materials

Why is my wastewater system corroding?

Possible Common Reasons:

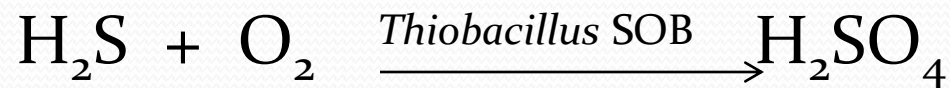
- **Microbial-Induced Corrosion (MIC)**
- Corrosive Soils
- Highly corrosive industrial waste dumping
- Cathodic protection issues (*metallic only*)

Most common cause of corrosion in wastewater pipelines and manholes is due to MIC



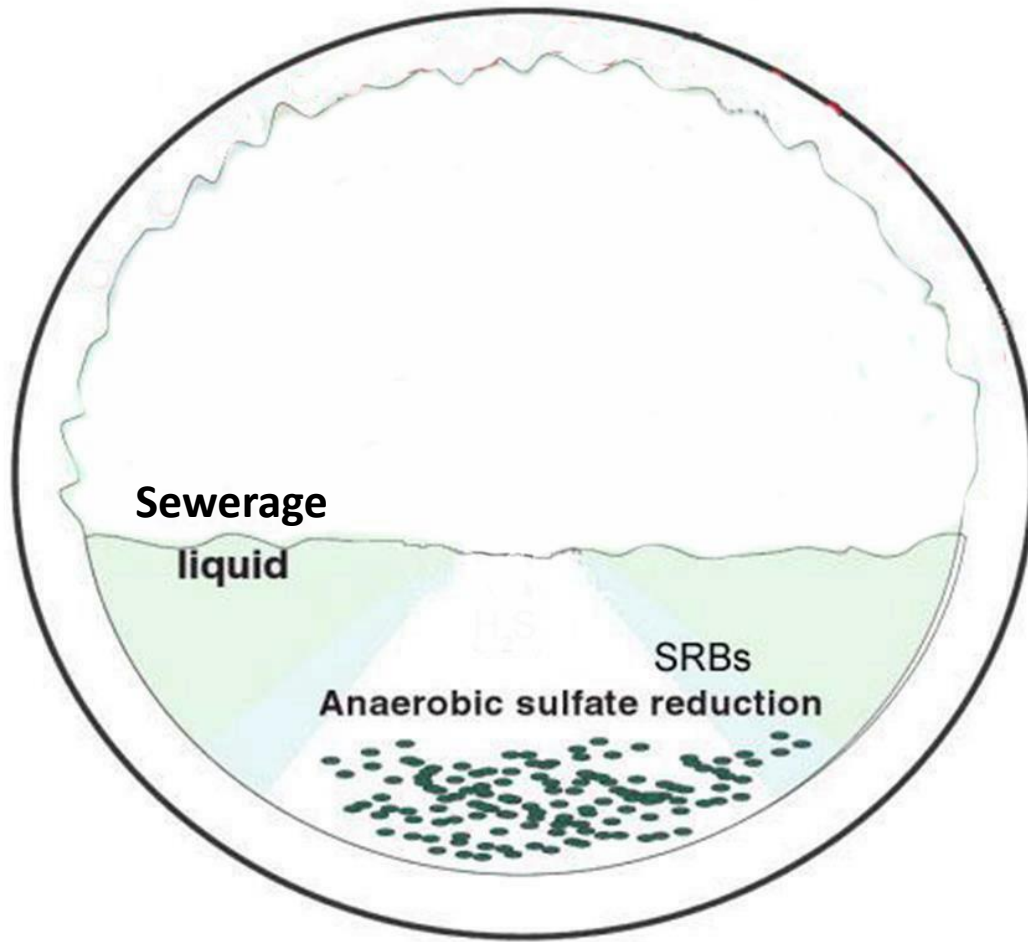
Microbial-Induced Corrosion (MIC)

- Deterioration of wastewater collection systems from biogenic sulfide corrosion
 - Headspace (vapor phase) environments above flow of the waste stream
 - Characterized by elevated levels of hydrogen sulfide (H₂S)
 - Biological oxidation of H₂S to H₂SO₄ within headspace areas of enclosed wastewater structures



- H₂SO₄ attacks the matrix of the concrete above the waterline (*i.e.*, pipe crowns, walls, etc)

Microbial-Induced Corrosion (MIC)

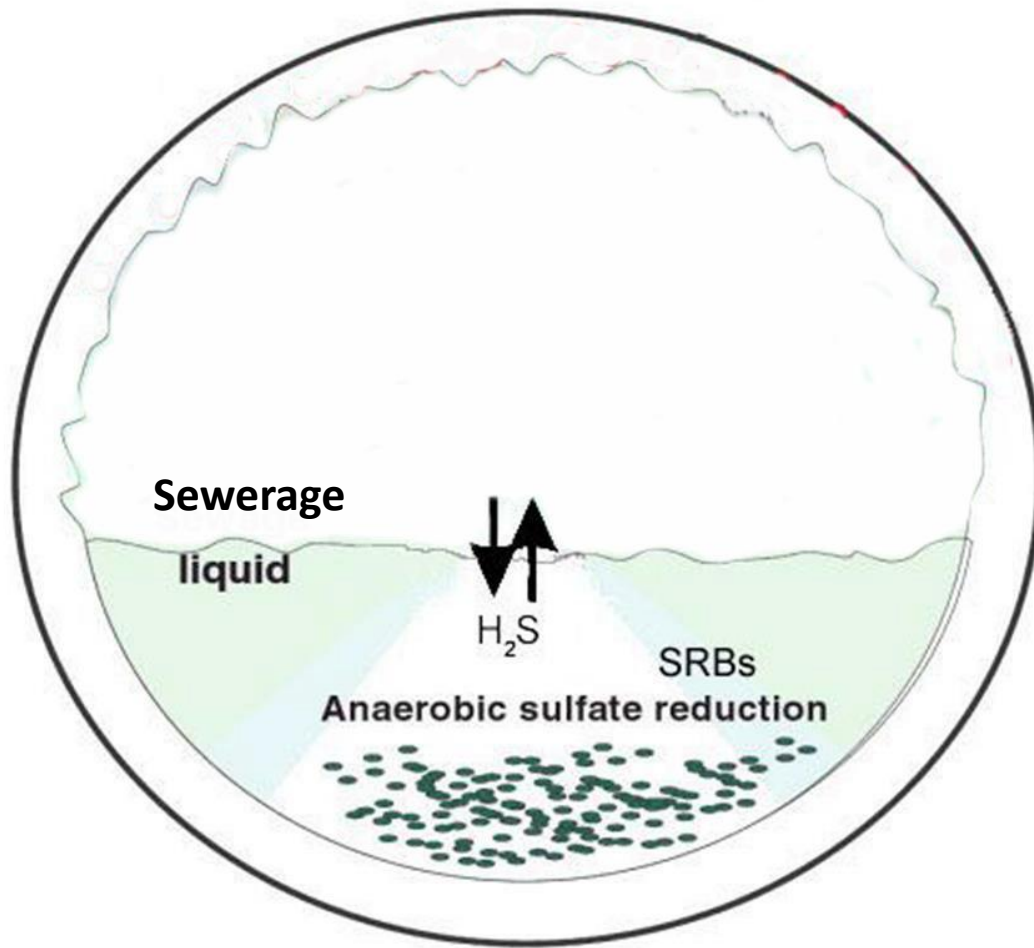


Sulfate Reduction

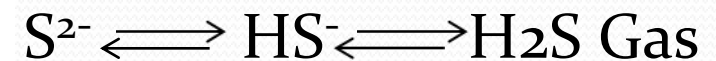


From Maier, Pepper and Gerba (2010)
Environmental Microbiology, AP

Microbial-Induced Corrosion (MIC)

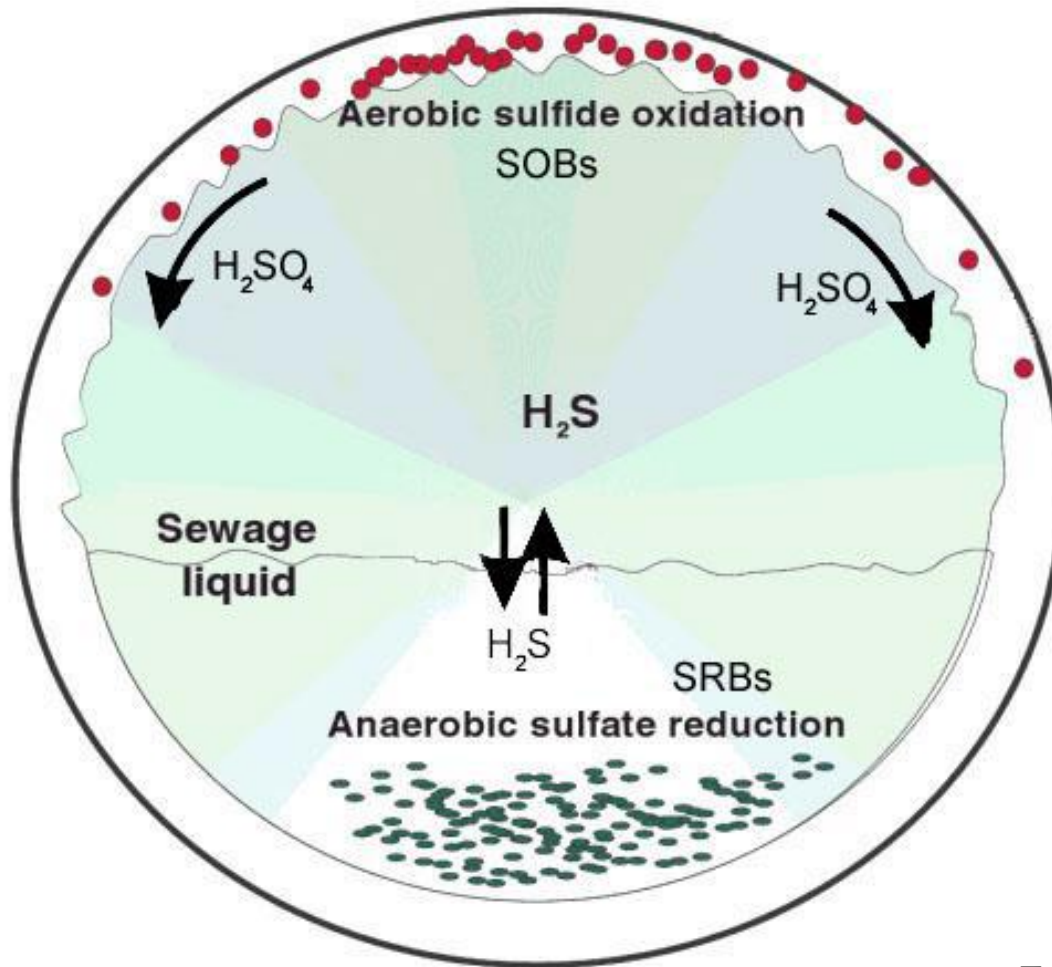


Sulfide Partitioning



From Maier, Pepper and Gerba (2010)
Environmental Microbiology, AP

Microbial-Induced Corrosion (MIC)

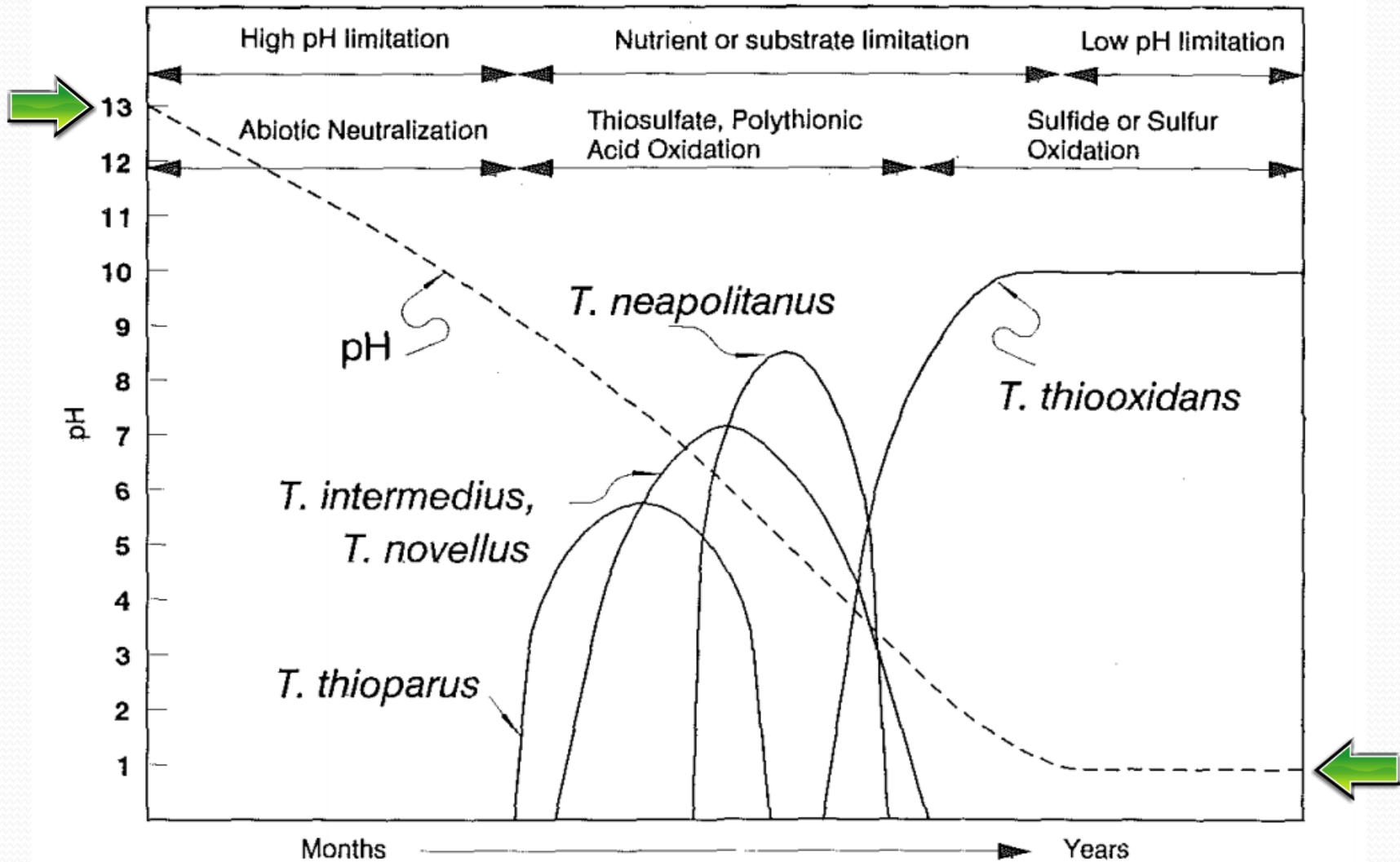


Sulfide Oxidation



From Maier, Pepper and Gerba (2010)
Environmental Microbiology, AP

MIC Corrosion Bacterial Progression



Wastewater Corrosion Culprits

Contributing factors of MIC wastewater corrosion:

- Elevated H₂S, CO₂, ammonias, other sewer gases
- Turbulent flows
- High sulfide levels
- Elevated temperatures
- High BOD sources
- Industrial waste
- Stagnant, septic sewerage



Typical Wastewater Corrosion Hotspots

Elevated H₂S levels & MIC sulfide corrosion common in:

- Forcemain outfall locations
- Locations with turbulent flows
- Areas with poor air handling
- Drop manholes
- Junction structures
- Wet wells
- Siphons
- Larger systems



Microbial-Induced Corrosion (MIC)



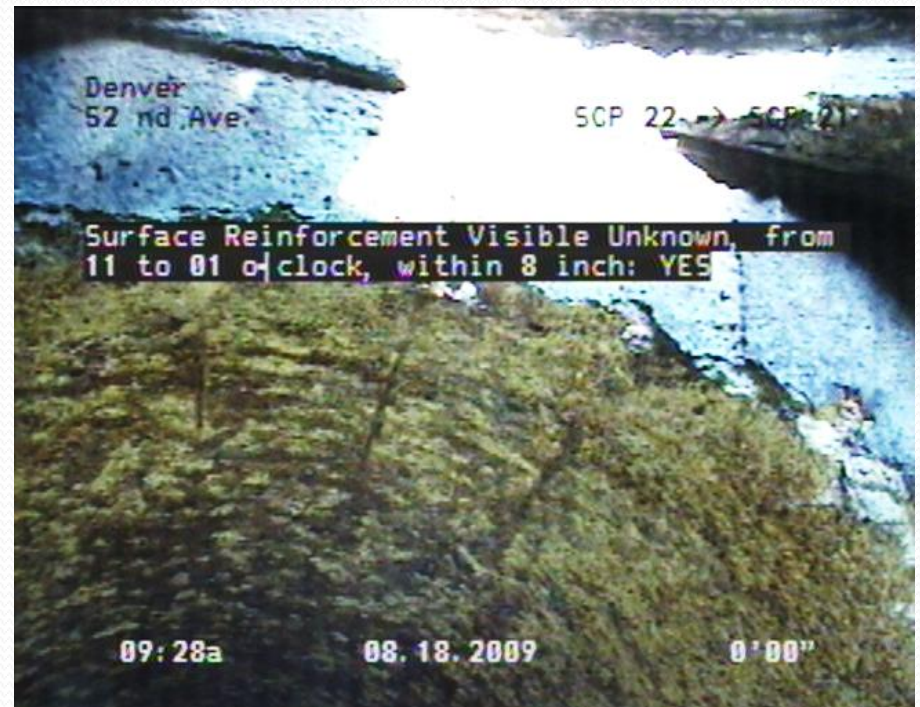
Corrosion in concrete manholes

Microbial-Induced Corrosion (MIC)



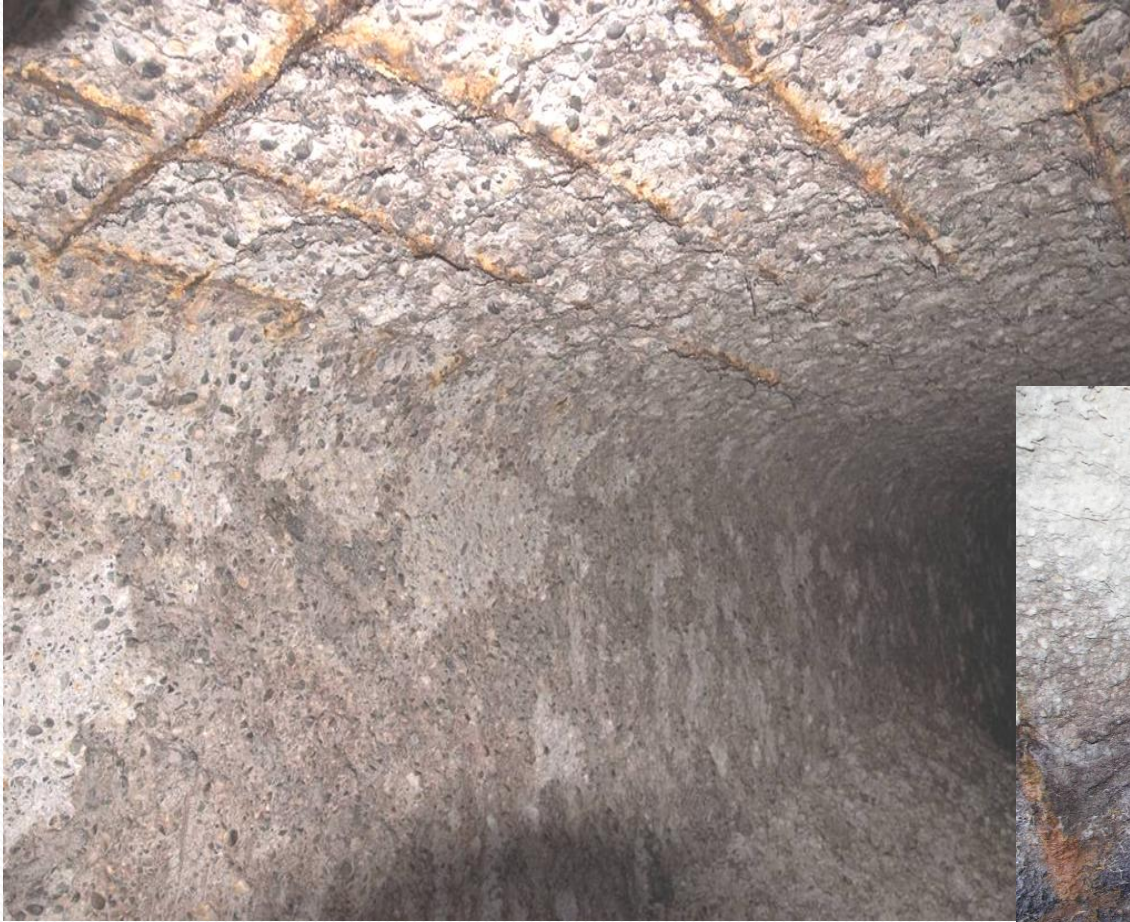
Corrosion in concrete manholes

Microbial-Induced Corrosion (MIC)



Corrosion in concrete pipelines

Microbial-Induced Corrosion (MIC)



Corrosion in wastewater vault structure

Microbial-Induced Corrosion (MIC)



Corrosion of mortar in brick manholes

Microbial-Induced Corrosion (MIC)



**Corrosion of metallic manhole
frame & cover**

How to conquer corrosion problems:

- Education, training and experience
- Implement comprehensive inspection & condition assessment programs to identify corrosion problems before failures occur
- Proactive, instead of reactive asset management
- Understand your system, understand the problems...

Find the solution!



Education and Training

NACE (National Association of Corrosion Engineers)

- Extensive corrosion training & certification programs
 - CIP – Coatings Inspector Programs
 - Corrosion Technologist Programs
 - Cathodic Protection Specialist Programs
 - Pipeline Corrosion Integrity Management Programs
 - Corrosion General Education



NACE (National Association of Corrosion Engineers)

- Standards & Publications
 - Substrate corrosion evaluation standards
 - Surface preparation standards
 - Quality control standards
 - Published corrosion education materials
- Task Groups
 - Industry specific focus
 - TG 466 – Wastewater Corrosion



NACE (National Association of Corrosion Engineers)

- Task Group 466
 - “Identifying Corrosion Problems and Mitigation Strategies in Wastewater Systems”
 - Comprehensive document written by top industry experts
 - Wastewater corrosion overview
 - Rehabilitation solutions
 - Balloting in progress



SSPC (Society for Protective Coatings)

- Training & Certification Programs
 - Protective Coatings Specialist (PCS)
 - Concrete coatings/ linings inspection programs
 - Inspector and contractor training & certification programs
 - Coatings/ linings, corrosion education
- Standards & Publications
 - Surface preparation standards
 - Quality control standards
 - Published educational materials



Other good resources:

- NASTT (North American Society for Trenchless Technology)
 - Condition assessment educational resources
 - Trenchless rehabilitation educational resources
 - No-Dig Conference and numerous short-course programs
- NASSCO (National Association of Sewer System Contractors)
 - PACP/ MACP/ LACP condition assessment inspector training
 - CIPP pipe rehab inspector training & certification
 - Educational resources

Finding the Solutions...

Understanding corrosion, understanding your system

- Proper inspection & condition assessment provides foundation for asset management and rehabilitation
- Understanding your rehabilitation options:
 - Choosing correct rehabilitation/ repair methods & products
 - Benefits of rehabilitation
 - Importance of surface preparation
 - Importance of qualified contractors
 - Understanding limitations
- Rehabilitation design QA/QC

Do it right the first time!





Evaluating Corrosion through Proper Inspection & Condition Assessment

Importance of Inspection & Condition Assessment

- Key component of successful asset management programs
- Proactive condition assessment prevents failures
- Basis for informed, risk management decision making
- Improves budgeting & capital management
- Critical for selecting rehabilitation/ repair methods

Collecting & analyzing data is relatively straightforward; Understanding what to do with it and how to apply the results requires experience.



Different Wastewater Assets Require Different Condition Assessment Approaches:

- **Gravity Pipelines**
 - CCTV, Advanced Multi-Sensor Systems, Entry Inspection
 - **Manholes**
 - Surface inspection, Entry inspection, Advanced Systems
-
- Various inspection & condition assessment techniques should be considered *tools for the tool box*
 - Total system understanding is important
 - Focus initial inspections around “hot spots”

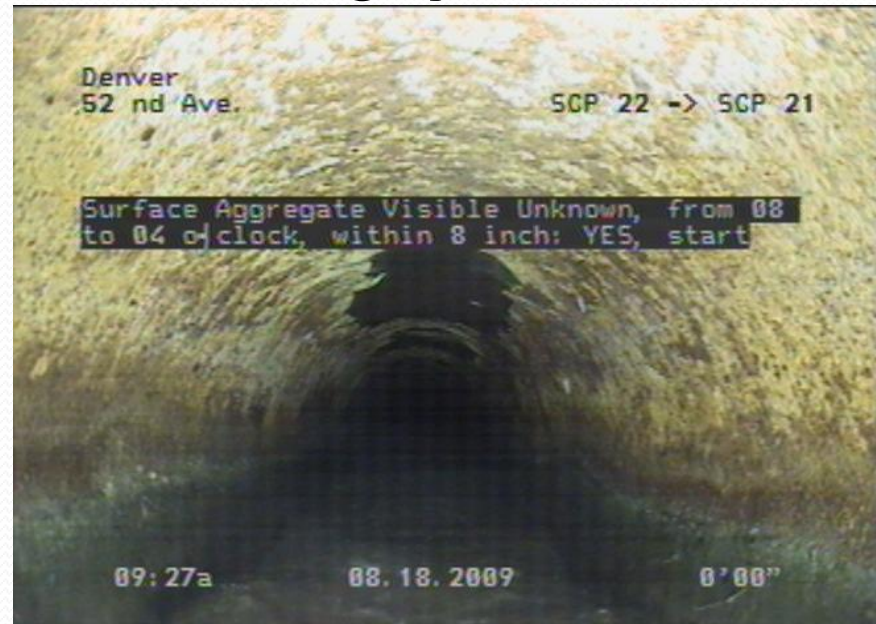
Regardless of approach taken and structure type inspected, having an expert involved with a trained eye is critical to performing inspection & condition assessment tasks properly.



Pipeline Inspection & Condition Assessment

CCTV Inspection

- Most pipeline condition assessment data today is collected using CCTV systems
- Basic visual inspection information, above the waterline
- Basis for NASSCO PACP/ LACP rating system
- Cost effective
- Readily available
- Helps identify defects
- *Non-quantifiable* info



Pipeline Inspection & Condition Assessment

NASSCO PACP Pipe Condition Rating System

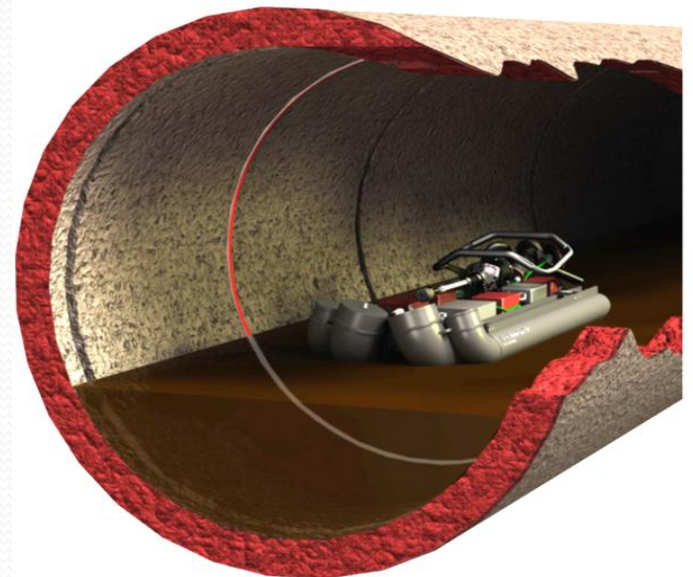
- Pipeline Assessment Certification Program
- Standardized condition assessment rating system for wastewater pipes
- Pipe condition & defects rated from 1 to 5 (1= good, 5= poor)
- Lateral condition assessment rating system (LACP)
- Features specific, detailed defect coding
 - Pipe structural defects (cracking, breakage, etc)
 - Corrosion
 - Infiltration
 - Deformation
 - Roots



Pipeline Inspection & Condition Assessment

Advanced Pipeline Condition Assessment Technology

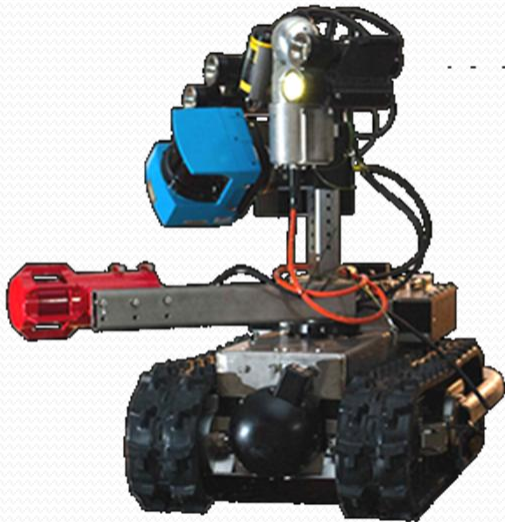
- Cutting edge robotic, multi-sensor systems
- Provides comprehensive, *quantifiable* inspection data
- Most accurate, but most expensive
- Less reliant on defect identification by operator
- Long & deep deployments
- Composite results package
- All systems include CCTV



Pipeline Inspection & Condition Assessment

Advanced Pipeline Condition Assessment Technology

- Multi-sensor systems feature Laser Profiling, SONAR, Pipe Penetrating RADAR, HD-CCTV, Gas Detection, etc.



Pipeline Inspection & Condition Assessment

Advanced Pipeline Condition Assessment Technology

- *LASER Profiling*– Detects defects in 3-D, ovality, corrosion damage, deflection, and material loss
- *SONAR*– Detects defects under water, debris quantification
- *Pipe Penetrating RADAR*- Ability to “see through” pipe wall, assess rebar condition, corrosion extents, detects defects
- *HD-CCTV*- Higher quality CCTV picture that is correlated to multi-sensor data
- *Gas detection*- Can detect H₂S gas levels within pipe, can be used to correlate corrosion patterns

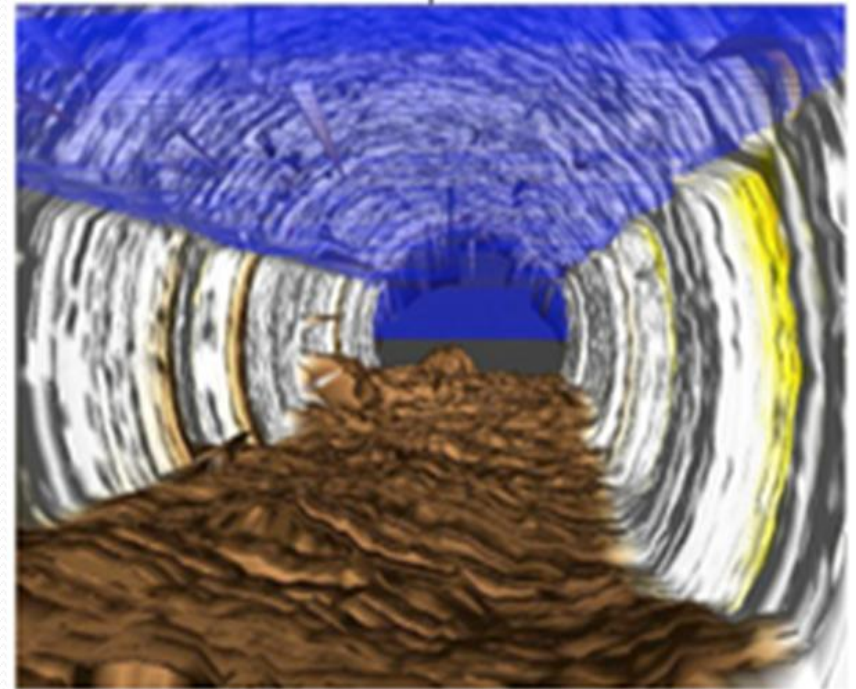
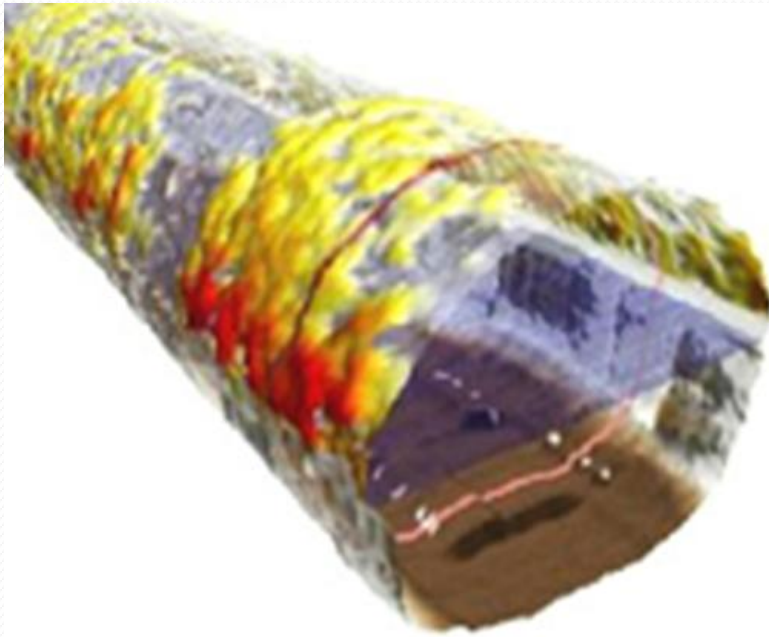
Pipeline Inspection & Condition Assessment

Example inspection data from CCTV



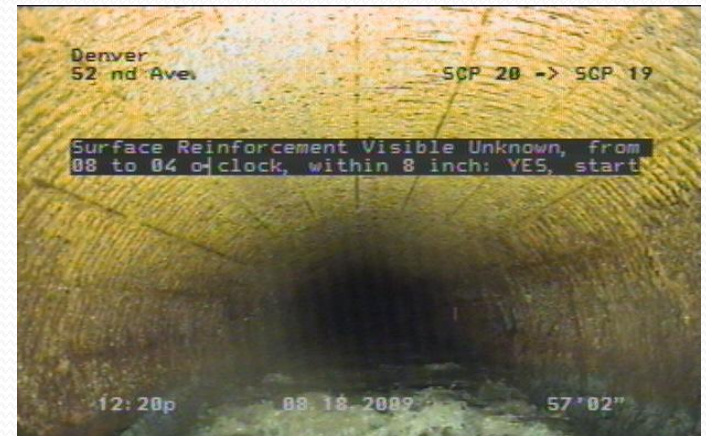
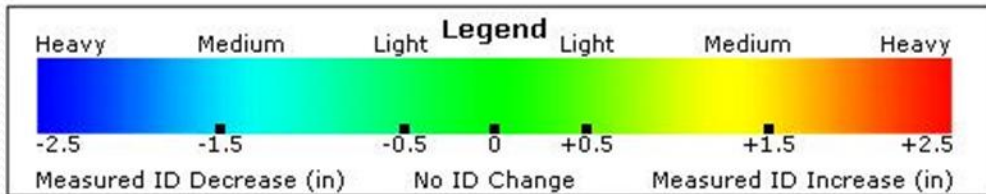
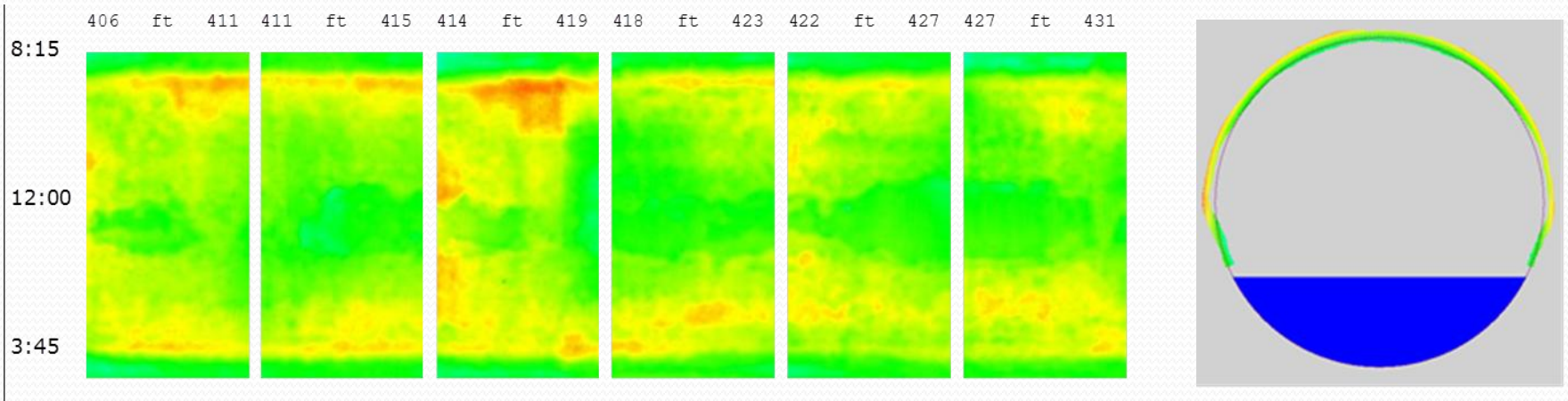
Pipeline Inspection & Condition Assessment

Example 3-D inspection data from LASER profile/
SONAR system



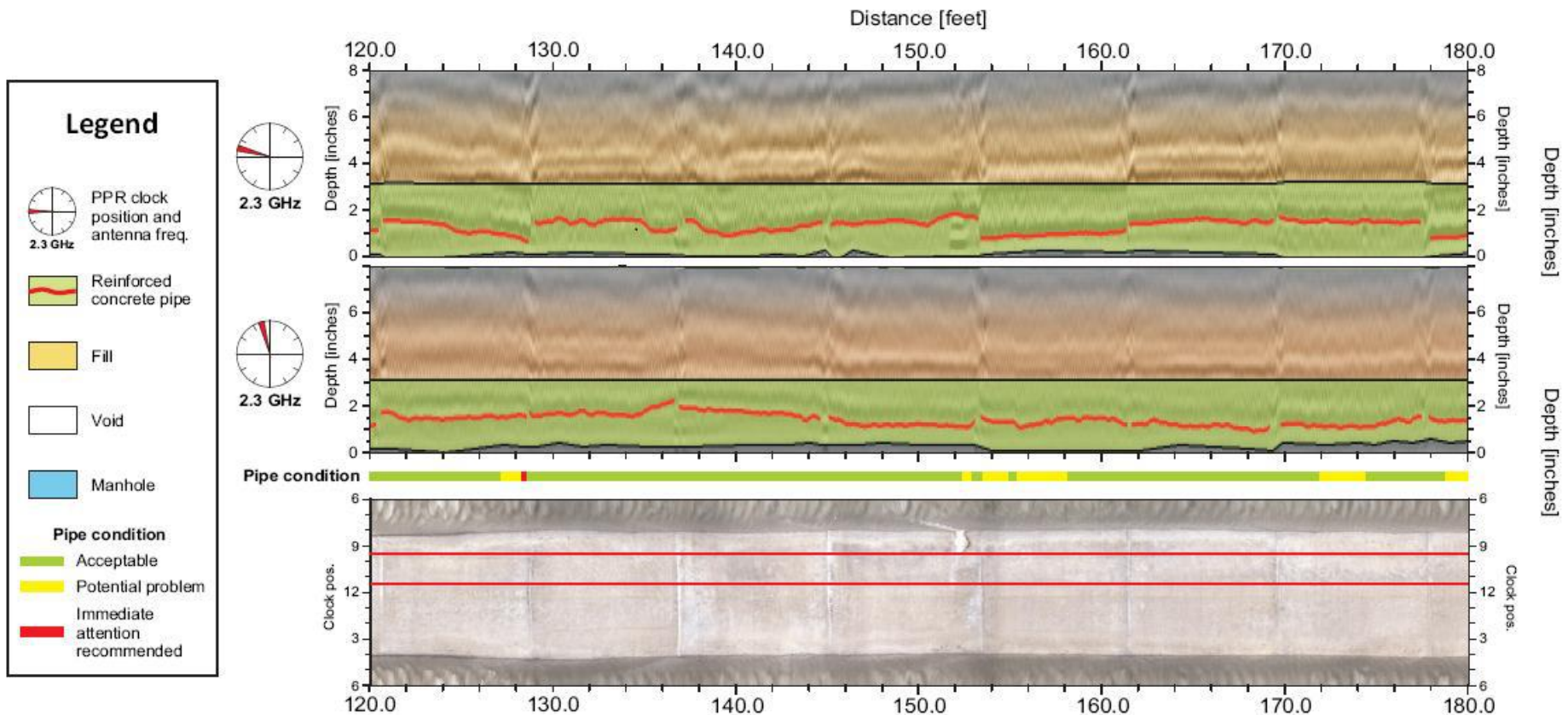
Pipeline Inspection & Condition Assessment

Example flat graph inspection data from LASER profile/ SONAR system, with HD-CCTV image



Pipeline Inspection & Condition Assessment

Example inspection data from PPR system



Manhole Inspection & Condition Assessment

Surface Inspection (Level 1)

- Provides basic visual impression of MH condition
- Faster & safer than entry inspection, but less accurate
- Requires no confined space set up & equipment
- Basic inspection info & be used to determine if entry inspection is necessary
- Inspection probes may be utilized



Manhole Inspection & Condition Assessment

Entry Inspection (Level 2)

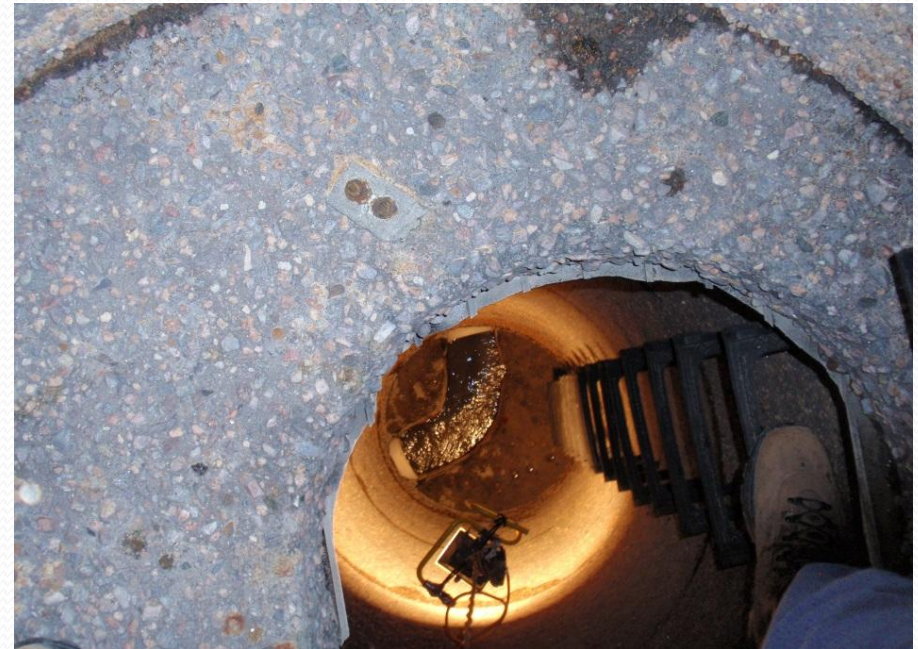
- More accurate than surface inspections
- Comprehensive inspection from top to bottom
- Requires confined space entry
- Proper safety procedures **MUST** be followed
- Multi-person crew required



Manhole Inspection & Condition Assessment

Inspection information is only as good as the expertise of the people doing the actual inspection work and subsequent data assessment

Proper training, experience & safety is essential!



Manhole Inspection & Condition Assessment

Gathering Essential Information: Step by Step

Manhole Inspection Procedures

All Confined Space regulations
are to be followed as per OSHA
1910.146

Courtesy of Joe Nuciforo - JPCI Services

Manhole Inspection & Condition Assessment

Step 1 – Inspect MH Frame & Cover, Exterior

Photo A



Missing chunks & cracks

Photo B



No mating surface due to rusting/ corrosion

Manhole Inspection & Condition Assessment

Photo C



Photo D



Good flat mating surface minimum of 5/8" in width. Clean with minimal rust

Courtesy of Joe Nuciforo - JPCI Services

Manhole Inspection & Condition Assessment

Photo E



Rounded, tapered edge from rust and wear

Photo F



Clean flat edges for load transfer.

Courtesy of Joe Nuciforo - JPCI Services

Manhole Inspection & Condition Assessment

Step 2 – MH Interior Inspection, Major Defect Identification & Safety Assessment



Missing barrel section

Exposed , Sharp Rebar



Manhole Inspection & Condition Assessment

Step 3 – MH Entry Inspection – Measure & Quantify Extents of Corrosion



Courtesy of Joe Nuciforo - JPCI Services

Manhole Inspection & Condition Assessment

Step 4 – Determine Total Material Loss due to Corrosion

- Clean spot on each side of manhole to solid concrete
- Measure distance across MH for new I.D.
- Typical 5' dia. MH = 59" to 61" new
- $(\text{New MH dia.} - \text{measured MH dia.}) / 2 = \text{Material lost on walls}$

Example :

New I.D. 67" $67" - 61" = 6"$ $6" / 2 = 3"$ lost

A new concrete barrel section is typically 6" to 7" thick so you know you have lost approximately $\frac{1}{2}$ of the mass of the manhole.

Manhole Inspection & Condition Assessment

Step 5 – Inspect Bench, Invert, and Pipes

- Probe bench & channel walls to measure extents of corrosion
- Inspect invert for irregular flow patterns
- Inspect pipe opening for cracks, failing PVC, other defects



Courtesy of Joe Nuciforo
- JPCI Services

Bench has deteriorated and there is no invert left

Manhole Inspection & Condition Assessment

NASSCO MACP Manhole Condition Rating System

- Manhole Assessment Certification Program
- Standardized condition assessment rating system for wastewater manholes
- MH condition & defects rated 1 to 5 (1= good, 5= poor)
- Features specific, detailed defect coding
 - Structural defects (cracking, missing sections, etc)
 - Corrosion issues
 - Frame & Cover Condition
 - Infiltration
 - Steps



Manhole Inspection & Condition Assessment

Advanced & Emerging MH Inspection Methods

- Pole Cameras

- Close visual inspection from surface
- Multiple people can see inspection footage
- No confined space entry



Manhole Inspection & Condition Assessment

Advanced & Emerging MH Inspection Methods

- Rapid Deployment 3-D Manhole Inspection Technologies
 - Rapid deployment from surface
 - Complete capture of geometric and visual data
 - No confined space entry
 - 3-D Model verifies diameter & defects



The Importance of Doing Things *Correctly*...

- Inspection & Condition Assessment information are the basis for rehabilitation/ repair designs
- Critical asset management & budgeting decisions are based on the condition assessment info & prioritizations
- Often times, inexperienced junior office & field staff perform inspection work and condition assessment ratings
- Poorly managed inspection and condition assessment programs can lead to costly problems!



The Importance of Doing Things *Correctly*...

Getting *true experts* involved in your condition assessment & asset management programs will ensure:

- High quality, reliable inspection data is gathered
- Condition assessment ratings & prioritizations are accurate
- The right repair/ rehabilitation approach is recommended
- Proactive asset management strategies are implemented
- Less failures due to corrosion & fewer costly surprises
- More accurate budgeting, scheduling, and cost estimates
- Better details of existing conditions to contractors, thus reducing risk and ultimately bid prices
- More successful projects, better prices, less change orders

Your asset management program is only as good as the information and expertise you are working with.

Thank You!

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