AGENDA

Problem Statement: Aging Infrastructure

- Exfiltration and Sewer Overflows

Characterization of SSOs

Sewer Evaluation: Where Do I Start?

- Risk Based Approach

Sewer System Evaluation Survey

Sewer Evaluation Tasks

Sewer Rehabilitation

Questions
Problem Statement:
Aging Infrastructure

America's Infrastructure Scores a D+
Underground utilities are out of sight and out of mind
Municipal sewer systems are continually aging.
Aging Manufacturing Facilities = Aging Infrastructure

Aging Manufacturing Facilities

- < 5 years: 3.40%
- 5-10 years: 16.80%
- 11-20 years: 7.40%
- > 20 years: 72.40%

Source: Industry Week / Manufacturing Performance Institute Census of Manufacturers
Pipeline Deterioration

Characterization of SSOs

- 15,582 active sanitary systems
- 4,846 satellite systems

Sanitary sewer systems:
- Serve approximately 146 million people
- Includes estimated 584,000 miles of pipe
Characterization of SSOs

EPA SSO data management system:

Populated by 25 states currently tracking SSOs electronically

Estimate 25,000 to 75,000 per year

<table>
<thead>
<tr>
<th>Causes of SSO Events</th>
<th>Percent</th>
<th>Total Volume (Million Gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blockages</td>
<td>48%</td>
<td>69</td>
</tr>
<tr>
<td>Wet weather and I/I</td>
<td>26%</td>
<td>1,860</td>
</tr>
<tr>
<td>Mechanical or power failures</td>
<td>11%</td>
<td>157</td>
</tr>
<tr>
<td>Line breaks</td>
<td>10%</td>
<td>239</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5%</td>
<td>199</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>2,524</strong></td>
</tr>
</tbody>
</table>
Environmental and Human Health Impacts

Source: EPA Report to Congress ’04
<table>
<thead>
<tr>
<th>Pollutants</th>
<th>At Risk Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Microbial Pathogens</strong></td>
<td>Swimmers, bathers, waders</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Subsistence and recreational fishers</td>
</tr>
<tr>
<td>Viruses</td>
<td></td>
</tr>
<tr>
<td>Parasites</td>
<td>Wastewater workers</td>
</tr>
<tr>
<td><strong>Toxics</strong></td>
<td></td>
</tr>
<tr>
<td>Metals</td>
<td></td>
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<tr>
<td>Synthetic organic chemicals</td>
<td></td>
</tr>
<tr>
<td><strong>Biologically Active Chemicals</strong></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Infiltration and Exfiltration
Infrastructure failures pose significantly more risk for industrial facilities.

OPERATIONAL IMPACTS
Facility shutdown

ENVIRONMENTAL IMPACTS
Air, soil, and water

HEALTH AND SAFETY IMPACTS
Community
Personal injury... or worse
Sewer Evaluation

Where do I start?

Risk Based Approach

Sewer System Evaluation Survey (SSES)

Capacity, Management, Operations, Maintenance (CMOM)
Phase 1 – Desktop Analysis

Risk Score \( (R1) = \text{Likelihood} \times \text{Consequence} \)

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Negligible</th>
<th>Low</th>
<th>Moderate</th>
<th>Significant</th>
<th>Catastrophic</th>
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</thead>
<tbody>
<tr>
<td>Frequent</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Probable</td>
<td>4</td>
<td>6</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Occasional</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Remote</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Improbable</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Develop Input Criteria
- Pipe Contents
- Pipe Material
- Pipe Age
- Pipe Location
- Potential Impact if Spilled
- Potential Spill Volume

Risk Based Assessment and Prioritization
Perform Field Inspections to Obtain Objective Data

- Closed Circuit Television
- Sonar Inspection
- 3D Laser Profile
- Acoustic Leak Detection
- Multi-Sensor Inspection
- Magnetic Flux Leakage
Objective Rehabilitation Prioritization

**Likelihood of Failure** – Based on PACP grading scale

**Consequence** – Impact of the failure on facility operations
SSES: Traditional Approach...Advanced Technologies

- Review Existing Information
- Groundwater Monitoring
- Flow Monitoring
- Rainfall Monitoring
- Inflow
- Infiltration
- Smoke Testing
- Manhole Inspections
- Night Flow Isolation & Measurement
- Dye Testing
- CCTV Inspection
- Cost/Benefit Analysis
- Rehabilitation Recommendations

Trimble GeoXH GPS Receiver

Hammerhead Pentop CPU

Web Posted Data

Data Management Software
Flow Monitoring

- Field confirm meter locations
  - Determine meter technology
- Installation/calibration
- Weekly upload/maintenance

QA/QC

Data analysis

**SSES**
Flow Monitoring

- Storm Analysis
- Dry Day Analysis
- RDII Analysis
Inspect all manholes
- Structural condition
- Evidence of inflow/infiltration

Obtain GPS coordinates

Quickview camera
- Improved efficiency, documentation, and safety
- Allows for line lamping

Pentop data acquisition
- Data dictionaries – MACP compliant
- Improved efficiency, documentation
SSES
Smoke Testing

Community relations

Liquid smoke system

GPS defect locations
Dye Testing

**PURPOSE**
Confirm inflow source
- Direct
- Indirect

**EXECUTION**
Simulate rainfall event
- Isolate areas identified as potential cross connections during smoke testing
- Flood the area with a dyed water solution
- Simultaneously inspect the sanitary sewer line via CCTV to identify exact location of defects
SSES
Night Flow Isolation and Measurement

PURPOSE
Find the “big leakers” (infiltration)
- 80/20 rule

EXECUTION
- Performed during off-peak hours
- Segregate areas into approx. 800 - 1,000' segments
- Isolate flows/install weir
- Calculate GPDIM rate

FISCALLY RESPONSIBLE
e.g. Basin with 50,000 lf exhibits excessive infiltration
- CCTV = $3/lf x 50,000 lf = $150,000
- NFI= $500/lset-up x 50 = $25,000
- CCTV 20% of 50,000lf @ $3/lf = $30,000
## Inspection and Assessment Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Pipe Diameter</th>
<th>Pipe Material</th>
<th>Line Preparation</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preliminary Screening Technologies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radar - External (GPR)</td>
<td>All</td>
<td>✓</td>
<td>✓</td>
<td>All</td>
</tr>
<tr>
<td>Radar - Internal (PPR)</td>
<td>18’ +</td>
<td>✓</td>
<td>✓</td>
<td>NA</td>
</tr>
<tr>
<td>Infrared Thermography</td>
<td>All</td>
<td>✓</td>
<td>✓</td>
<td>All</td>
</tr>
<tr>
<td>Accoustical Leak Detection</td>
<td>All</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Soil Corrosivity Testing</td>
<td>All</td>
<td>✓</td>
<td>✓</td>
<td>0 - 200 psi</td>
</tr>
<tr>
<td><strong>Direct Assessment Technologies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCTV (Borescope/pushcam)</td>
<td>&lt; 6”</td>
<td>✓</td>
<td>✓</td>
<td>&lt; 25%</td>
</tr>
<tr>
<td>CCTV (Crawler/Remote)</td>
<td>6” +</td>
<td>✓</td>
<td>✓</td>
<td>&lt; 25%</td>
</tr>
<tr>
<td>Sonar</td>
<td>6” +</td>
<td>✓</td>
<td>✓</td>
<td>0 - 100 psi</td>
</tr>
<tr>
<td>Laser Profile / Scan</td>
<td>6” +</td>
<td>✓</td>
<td>✓</td>
<td>0 - 100 psi</td>
</tr>
<tr>
<td>Coupon Testing</td>
<td>All</td>
<td>✓</td>
<td>✓</td>
<td>NA</td>
</tr>
<tr>
<td>Magnetic Flux Leakage (MFL)</td>
<td>All</td>
<td>✓</td>
<td>✓</td>
<td>All</td>
</tr>
<tr>
<td>Remote Field Eddy Current</td>
<td>4” - 36”</td>
<td>✓</td>
<td>✓</td>
<td>All</td>
</tr>
<tr>
<td>Electromagnetic</td>
<td>18” +</td>
<td>✓</td>
<td>✓</td>
<td>0 - 200 psi</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>All</td>
<td>✓</td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>
What Causes Pipelines to Fail?
### Deterioration Mechanisms

#### Stages of Sewer Collapse

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STAGE 1</strong></td>
<td>An initial, often minor, defect enables the deterioration process to begin.</td>
</tr>
<tr>
<td><strong>STAGE 2</strong></td>
<td>Deterioration process continues in and/or behind the weakened sewer wall. Soil particles are washed away due to the infiltration/exfiltration process.</td>
</tr>
<tr>
<td><strong>STAGE 3</strong></td>
<td>Loss of support from the surrounding soil allows the crown to drop. This deformation leads to pipe collapse.</td>
</tr>
</tbody>
</table>
### Standardized Condition Assessment Coding for:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural deficiencies</strong></td>
<td>cracks, fractures, broken pipe, holes, deformed pipe, collapsed pipe</td>
</tr>
<tr>
<td><strong>Operation and maintenance defects</strong></td>
<td>roots, deposits, grease, infiltration, corrosion, obstructions</td>
</tr>
<tr>
<td><strong>Construction features</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous features</strong></td>
<td></td>
</tr>
</tbody>
</table>
Condition Grading

- Costs ($)
- Rating
- Time

- Excellent Condition
- Unacceptable Condition
- Structural Grade
- Renew/Replace
- Replacement Costs

- Crack
- Fracture
- Broken
- Hole / Deformed
- Collapse

1 2 3 4 5
Closed Circuit Television Inspection

2" – 48", up to 400'

High resolution

Pan and tilt capability

Lateral launch capability

Low flow or isolation required

Provides visual inspection/documentation

Allows for defect coding (PACP)
CCTV Inspection

Hinge Fractures

Broken Pipe

Hole in Pipe

Collapsed Pipe
3D Laser triangulation profilometer

Applicable to all pipe materials (8" – 36")

Pipe geometry/ovality assessment

Identifies and quantifies defects and corrosion to 1mm

Requires pipeline to be taken out of service
Sonar Inspection

Ideal for lines that cannot be taken out of service

Provides pipe ID, defect measurement, debris mapping

Accurate to within ¼"
Gravity Sewer Leakage Testing – Electroscan

All pipe types

Open channel and pressure pipe

6" – 60"

Can be enhanced with sounding rods
Acoustical Leak Detection – Pressure Pipe

**Traditional Correlator**
- Non-invasive
- Ferrous, pressure pipes

**SmartBall**
- Free-swimming in-line assessment
- Requires insertion/catching means
- Quickly identifies leaks as small as 1 gpm
Radar

External (Ground Penetrating)
- Non-invasive
- Pipe location/leak detection
- Up to 30' in depth

Internal (Pipe Penetrating)
- Assesses wall thickness
- Identifies reinforcement
- Identifies infiltration/voids
# Pipeline Rehabilitation

## Why Rehab?

<table>
<thead>
<tr>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost effective</td>
</tr>
<tr>
<td>Asset management</td>
</tr>
<tr>
<td>Improve operations</td>
</tr>
<tr>
<td>Prevent catastrophic failure</td>
</tr>
<tr>
<td>Respond to failure</td>
</tr>
</tbody>
</table>

*Proactive beats reactive!*
<table>
<thead>
<tr>
<th></th>
<th>Rehabilitation Design</th>
<th>Decision Process Based on Evaluation of Considerations in Four Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physical Considerations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condition assessments</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Hydraulic Considerations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capacity assessments</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Surface Considerations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Congested urban areas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sensitive environmental areas</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Subsurface Considerations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Congested utility corridors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difficult soils or high groundwater conditions</td>
<td></td>
</tr>
</tbody>
</table>
Rehabilitation Alternatives

- Spiral Wound Lining
- Pipe Bursting
- Cut and Fill
- Sliplining
- Cured-in-Place Pipe
- Manhole Rehabilitation
## Comparative Characteristics of Pipeline Rehabilitation

<table>
<thead>
<tr>
<th>Rehabilitation Method</th>
<th>Cost</th>
<th>Bypass Pumping Required</th>
<th>Surface Disruption</th>
<th>Lateral Interruption</th>
<th>Upsizing Possible?</th>
<th>Impact on Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sliplining</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cured-in-place Pipe</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spiral Wound Lining</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipe Bursting</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

### Comparative Scale

- **Highly Desirable**
- **Moderately Desirable**
- **Least Desirable**
Pipeline Replacement

Traditional “Cut and Fill” Installation

**PROS**

Control of:
- Pipe materials
- Pipe size
- Pipe slope
- Pipe alignment

**Inspection confidence**

**CONS**

- More expensive
- Surface disruption
- Service Interruption
“The installation or rehabilitation of underground utilities by means which reduce or eliminate the need for excavation”
Why Trenchless?

- Reduced surface disruption
- Reduced cost
- Reduced construction schedule
- Reduced service interruption
Sliplining

- Reduced disruption, requires insertion pit
- Low cost
- Some flexibility in materials
- Adversely affects hydraulic capacity
**Cured-in-Place Pipe**

- Felt liner impregnated with thermosetting resin
- Provides seamless, impermeable barrier between host pipe and water
- Meets ANSI/NSF 61
- Custom manufactured (up to 48")
  - Various thicknesses
  - Various resin and tube materials
Cured-in-Place Pipe

Liner installation
<table>
<thead>
<tr>
<th><strong>Curing Methods</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HOT WATER CURE</strong></td>
<td>Minimize damage to liner/host pipe</td>
</tr>
<tr>
<td><strong>STEAM CURE</strong></td>
<td>Time efficiency</td>
</tr>
<tr>
<td><strong>UV CURE</strong></td>
<td>Strength/thickness</td>
</tr>
</tbody>
</table>
Pipe Bursting

The only trenchless method currently available which allows for size increase without complete excavation

Utilizes force + tapered bursting head to displace host pipe while pulling new line

Types of bursting: static, pneumatic, hydraulic
Wide choice of replacement pipe:
- Polyethylene
- PVC
- Fiberglass
- Steel
- Ductile iron

Variables/limitations:
- Service connections
- Valves
- Soil/depth dependent
Spiral Wound Lining

- Interior pipe lining with plastic strips
  - Inter-locking and water tight
- Manual installation or mechanical
- Addresses non-circular pipes
- Generally expensive
### Why Rehab?

- Critical access structures
- Health and safety concerns
- Inflow abatement
- Infiltration abatement
- Operational improvements
- Structural reinforcement

*Proactive beats reactive!*
Questions?
Robert.Bell@obg.com