See the Whole Picture

Condition Assessment, Asset Management and Trenchless Rehabilitation Planning
Who We Are: Inversa

• Inversa is an engineering company providing non-destructive condition assessment tools for Civil Infrastructure and Oil and Gas markets.

• Patented technology and procedures used to develop asset management programs.

• Assist clients in optimizing asset life extension and maximizing budgets.

• Civil Infrastructure: Primary focus on condition assessment, asset management and rehabilitation planning
  – Storm Systems, Roadway Culverts, Levees
Industry Trends and Needs

• Asset management is a focus
• Aging assets and limited budgets are a reality
• Trenchless rehabilitation is a growing trend
• Innovative technology can support asset management and maximize budgets
Managing Buried Infrastructure

Asset Management Fundamentals

• What assets do you own and where?
• What are they worth?
• What condition are they in?
• When does action need to be taken?
  – Continued Monitoring/ Repair/ Rehabilitation/ Replacement
• What action should be taken for optimal life extension?
  – Inspection frequency/ Repair type/ Rehabilitation Method/ Replacement
• ROI analysis to minimize life cycle cost
Specific CMP Problem

Soil Voids Leading to Structural Instability

- The soil envelope is load bearing
- Soil instability will compromise the entire structure
- Early pipe deformation limits rehabilitation options
- Voids create stress risers in the pipe
- Ultimately leads to deformations in the roadway and potential failure
Soilsight™ - Three Part Condition Assessment:

1. Visual Inspection
2. Acoustic Inspection
3. BCT Imaging with Insight™
   - Conclusive and Quantifiable data
   - Complete optimized information for repair, replace, decision
1: Visual Inspection

**Visual Inspection** based on a review of inspection protocols from 15 North American Jurisdictions

- Software driven
- 10 point visual inspection process
- 1-5 rating system (1- As Built; 5-Failed)
- Public Service Accounting Board (PSAB) compliant.
- Forced rank system
  - Uses no subjective
  - Ranks based on measurable information
  - designed to give high repeatability, trendability and objectivity.
2: Acoustic Inspection

Acoustic Inspection:
• 100% coverage of acoustic anomaly identification
• Digitally trended data is presented on a to-scale culvert map
• Used to guide the location selection of BCT imaging
3: BCT Imaging

No Void  Transition to Void  Void

Soil

Void
Sample Pipe Map - Overview

Acoustic Anomalies are designated as rectangles and are assigned an ID number. The X and Y position is recorded and displayed in the table for the corresponding pipe segment.

BCT Images are assigned an ID number and represented as red diamonds. Once an acoustic anomaly is scanned, it is verified as void or solid backfill. The X and Y position is recorded and displayed in the table for the corresponding pipe segment. Photos are included in the visual assessment section.

Visual Indicators are shown as black squares and assigned an ID number. The X and Y position is recorded and displayed in the table for the corresponding pipe segment.
Sample Pipe Map - Segment

![Sample Pipe Map](image)

<table>
<thead>
<tr>
<th>Visual Indicators</th>
<th>X1 (m)</th>
<th>X2 (m)</th>
<th>Clock 1</th>
<th>Clock 2</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>V-3</td>
<td>51.12</td>
<td>6:00</td>
<td></td>
<td></td>
<td>Rust and water intrusion at overlap</td>
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</table>

<table>
<thead>
<tr>
<th>Acoustic Anomalies</th>
<th>X1 (m)</th>
<th>X2 (m)</th>
<th>Clock 1</th>
<th>Clock 2</th>
<th>Comments</th>
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<td>A-13</td>
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<td>A-14</td>
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<td>A-16</td>
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<td>7:00</td>
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<table>
<thead>
<tr>
<th>Insight™ BCT Images</th>
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<th>Clock</th>
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<th>Verdict</th>
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<td>2703</td>
<td>No Void</td>
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<td>BCT-18</td>
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<td>4:30</td>
<td>2704</td>
<td>Void 3cm×1cm</td>
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<tr>
<td>BCT-19</td>
<td>40.44</td>
<td>40.64</td>
<td>4:30</td>
<td>2705</td>
<td>Thin Void 4cm in valley of corrugation</td>
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<td>BCT-20</td>
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<td>No Void</td>
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Conventional Open Trench Culvert Replacement
Based on the condition state and expected future use, an optimal rehabilitation method can be chosen.

Important factors include:
- Size of pipe
- Depth of bury
- Condition state of pipe barrel
- Condition state of supporting soil
- Future use requirements
  - Weight capacity, flow capacity, life expectancy
- Budget
Several practical trenchless options exist for rehabilitating deteriorated pipe, some include:

1. Centrifugally Cast Concrete
2. Spray in Place Pipe
3. Cured in Place Pipe
4. Slipline

These methods each have strengths and are best used in certain situations.

Good condition assessment provides the information necessary to choose the ideal solution for the specific case.
• **PHASE 1**: Condition Assessment
• **PHASE 2**: Asset Specific Rehabilitation Design
• **PHASE 3**: Rehabilitation Application
PHASE 1: Condition Assessment

1. Asset Selection
   - DTI selected 14 assets based on the following criteria to be included in this project.
     - Large diameter
     - Deeply buried
     - Limited deformation
     - Strategic corridors

2. Condition Assessment
   - July 2015 DTI initiated a project with Inversa which included
     - Visual, Acoustic and BCT imaging
PHASE 2: Rehabilitation Planning and Asset Management

1. Rehabilitation recommendations were made based on the condition assessment information.
2. ROI calculations for rehabilitation versus dig and replace
   • 1 Asset recommended for replacement
   • 4 recommended for continued monitoring
   • 9 recommended for trenchless rehabilitation
PHASE 3: Rehabilitation

1. Construction Preparation
   - Environment permitting
   - Engineering design plans
   - Logistics
   - Material order
   - Sub contracting

2. Rehabilitation Application
   - Site work
   - Project Management
   - Post Construction QA/QC
Of the 14 assets that were assessed the following recommendations were made:
- 9 were quality candidates for rehabilitation
- 1 dig and replace
- 4 on-going monitoring

Inversa’s technology was validated as a valuable tool in detecting soil voids which is a critical component in trenchlessly rehabilitating buried infrastructure.

Inversa has developed rehabilitation plans that will generate a minimum of $7 million in cost reductions for DTI.
<table>
<thead>
<tr>
<th>Asset Number</th>
<th>Length (m)</th>
<th>Diameter (m)</th>
<th>Burial Depth (m)</th>
<th>Replacement (Concrete)</th>
<th>Replacement (CMP)</th>
<th>Rehabilitation Cost</th>
<th>Rehabilitation Method</th>
<th>ROI (CMP)</th>
<th>ROI (Concrete)</th>
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<tr>
<td>(YU03)</td>
<td>38.65</td>
<td>2.85</td>
<td>5.1</td>
<td>$1,062,875</td>
<td>$483,125</td>
<td>$220,000</td>
<td>Slipline, infiltration repair, headwall repair, embankment repair</td>
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<td>(R675)</td>
<td>92.7</td>
<td>4.6</td>
<td>8</td>
<td>$3,461,789</td>
<td>$1,448,438</td>
<td>$660,973</td>
<td>CCCP 90mm (semi-structural), Infiltration repair, cleaning</td>
<td>$787,465</td>
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<td>(NQ11)</td>
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<td>2.4</td>
<td>$852,000</td>
<td>$355,000</td>
<td>$98,037</td>
<td>SIPP liner 4mm (semi-structural), perforation filling, cleaning, soil stabilization</td>
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<td>$650,000</td>
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<td>$781,240</td>
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<td>$857,813</td>
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<td>$1,762,186</td>
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<td>(B718)</td>
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<td>$280,000</td>
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<td>(M658)</td>
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<tr>
<td>(S849)* Concrete</td>
<td>103.8</td>
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<td>16</td>
<td>$4,585,884</td>
<td>$2,534,173</td>
<td>See Details</td>
<td>See Details</td>
<td>See Details</td>
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<tr>
<td>(G665) Concrete</td>
<td>19.81</td>
<td>3.66x3.51</td>
<td>2.5</td>
<td>$475,440</td>
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<td>(VP07) Concrete</td>
<td>42</td>
<td>1.8x1.5</td>
<td>9.5</td>
<td>$1,568,448</td>
<td>$820,302</td>
<td>Monitoring</td>
<td>Monitoring</td>
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</tbody>
</table>

**Project Total**
- $23,218,429
- $10,977,521
- $1,724,438
- $4,169,258
- $11,199,516
Conclusion:
• 14 Acoustic anomalies, 10 voids
• Corrosion severe
• Ovality less than 2%
• Deep fill - high cost of replacement
• Excellent rehab candidate
• Low flow

Rehabilitation Plan:
1. Clean and Surface Prep
2. Water Stop Collar
3. Flow By-pass and Grout Injection
4. CCCP Liner 0.6”
Conclusion:
- 14 Acoustic anomalies, 2 voids
- Through wall corrosion
- Ovality 10% localized
- Deep fill - high cost of replacement
- Excellent rehab candidate
- Wetland – saturated soil
- Environmentally sensitive

Rehabilitation Plan:
1. Clean and Surface Prep
2. By-pass and Grout Injection
3. CCCP Liner 0.7”
1. Proactive asset management is key to optimizing your assets and budget
2. Must ensure soil voids are properly identified prior to rehab
3. Rehab can provide a new design life at a fraction of the cost
4. Rehabilitation cost for 2 assets was $311k, including all bypass, permitting, electrofishing and design
5. Replacement was estimated by the client to be $1.65-$3.2m (CMP vs Concrete)

Client Savings = $1.34-$2.89m
CONTACT INFORMATION:

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(506)476-5648 (c)
(506)455-6799 (f)
Inversasystems.com
John@inversasystems.com
Conclusion:
• 17 Acoustic anomalies, 5 voids
• Corrosion severe
• Ovality less than 5%
• Deep fill - high cost of replacement
• Excellent rehab candidate

Rehabilitation Plan:
1. Clean and Surface Prep
2. Water Stop Collar and Coffer Dam
3. Semi-Structural CCCP 25mm

Return on Investment (ROI) - YP09
$644,000 - 1,357,000
Asset S849 – Overview Pipe Map

**Acoustic Anomalies** are designated as rectangles and are assigned an ID number. The X and Y position is recorded and displayed in the table for the corresponding pipe segment.

**BCT Images** are assigned an ID number and represented as red diamonds. Once an acoustic anomaly is scanned, it is verified as void or solid backfill. The X and Y position is recorded and displayed in the table for the corresponding pipe segment.

**Visual Indicators** are shown as black squares and assigned an ID number. The X and Y position is recorded and displayed in the table for the corresponding pipe segment. Photos are included in the visual assessment section.
Asset S849 – Segment Pipe Map

SEGMENT 3 - NORTH

SEGMENT 3 - SOUTH

Visual Indicators

<table>
<thead>
<tr>
<th>X1 (m)</th>
<th>Clock</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-14</td>
<td>65.1</td>
<td>3:30 Through wall corrosion with missing bolts</td>
</tr>
<tr>
<td>V-15</td>
<td>72.17</td>
<td>2:00 Through wall corrosion with water intrusion</td>
</tr>
<tr>
<td>V-16</td>
<td>82.9</td>
<td>1:30 Through wall corrosion with visible soil</td>
</tr>
<tr>
<td>V-17</td>
<td>90.86</td>
<td>2:00 Missing bolts with visible soil</td>
</tr>
<tr>
<td>V-18</td>
<td>101.71</td>
<td>2:30 Through wall corrosion causing visible void with water intrusion</td>
</tr>
<tr>
<td>V-19</td>
<td>90.7</td>
<td>12:00 Through wall corrosion with visible soil</td>
</tr>
<tr>
<td>V-20</td>
<td>90.7</td>
<td>12:00 Water intrusion with through wall corrosion and visible soil</td>
</tr>
<tr>
<td>V-21</td>
<td>76.03</td>
<td>7:00 Missing bolts and water intrusion with soil visible</td>
</tr>
</tbody>
</table>

Insight™ BCT Images

<table>
<thead>
<tr>
<th>X1 (m)</th>
<th>X2 (m)</th>
<th>Clock</th>
<th>Verdict</th>
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<tr>
<td>BCT-4</td>
<td>84.92</td>
<td>85.12</td>
<td>4:00</td>
</tr>
</tbody>
</table>
Conclusion:
- 0 Acoustic anomalies, 0 voids
- Corrosion severe throughout – through wall
- Tidal – pipe overtopped daily
- Saturated soil
- Severe water infiltration
- Environmentally sensitive area
- Extremely Deep fill - high cost of replacement
- Excellent rehab candidate

Rehabilitation Plan:
1. Dewater and Coffer Damn
2. Water By-pass
3. Clean and Surface Prep
4. Placement of Segmented Liner Panels
5. Grouting of Annular Space

ROI of Pursuing Trenchless Rehabilitation
$0-3 Million