How to Select, Procure and Utilize Multi-Sensor Sewer Inspection Data to Make Intelligent Decisions

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Agenda

• Overview of the Multi-Sensor Technologies
  – CCTV, HD Photos, Sonar, Laser, PPR, Gas,
• When and How to select the right technology
• Interpreting complex data
• Recent case studies using Multi-Sensor Gravity Inspections
  – Florida, California, Minnesota, Pennsylvania and Ohio
  – Responder, Cleanflow and PPR
• Lessons Learned & Conclusions
Multi-Sensor Sewer Inspections
CCTV, HD Photos, Lidar, Laser Profiling, Sonar & Gas
When Do You Need Multi-Sensor Sewer Inspection?

- Large Sewers 24” to 72” & Siphons
- Concrete Pipes
  - Where and how much concrete is lost from wall or at joints
  - Identify bends
  - Exact dimensions of pipe
- Brick & Flexible Pipes
  - Ovality & Precise Dimensions of sewers
- ID holes in pipes and size of voids; above and below water
- Debris levels and locations beneath water surface without bypassing
- Non-Circular Pipes
  - Determine exact dimensions for rehab options
- Because its new and cool and the sales rep says you NEED all this data or your pipe will catastrophically fail!
Laser Profiling
Cleanflow enables the sonar and laser data to be combined allowing you to overlay potential debris and corrosion locations throughout the entire pipe.
Laser Profiling & Sonar Example: Debris, Depth, Width of holes
Laser Profiling & Concrete Pipe Wall Loss
Laser Profiling – 3D Lidar
Case Study MCD Dayton: Laser Profiling – 3D Lidar
Case Study MCD Dayton: Laser Profiling – 3D Lidar
Pipe Penetrating Radar (PPR) Case Study: Coachella Valley CA

- 30” & 36” VCP
  - 20-year old pipe
  - Walls sloughing off
  - Major Debris
  - Void Analysis before CIPP
Pipe Penetrating Radar (PPR) Case Study: Coachella Valley CA

- **SewerVue**
  - Identify and quantify voids behind the pipe wall
  - Can approximate wall thickness
Pipe Penetrating Radar (PPR)  
Case Study: Coachella Valley CA

- CCTV and PPR Performed
- ~$10 per foot
- Robot rotated sensors at 9 & 12 down; and 10 & 2 on way back
- No Significant Voids found!
Sonar Equipment & Data

Observations

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Debris Depth</td>
<td>6.26 in</td>
</tr>
<tr>
<td>Average Water Level</td>
<td>21.3 in</td>
</tr>
<tr>
<td>Debris Volume</td>
<td>230.76 cubic feet</td>
</tr>
</tbody>
</table>

DEBRIS GRAPH

Inspection Distance (ft)
CleanFlow HD Profiler
Inspection Equipment
Cleanflow HD Profiler
Data Collection

• Laser data is collected 12x / second
• Sonar collected once/second.
• HD photos several times per second
• Information is graphically presented in cross sections every 50 LF.
• Engineers can view cross sections at any point along the pipe.
CleanFlow Inspection

• Can float or use tractor
• Data collected on the unit not in the truck; Pros & Cons
• High-Definition photos stitched to simulate video
  – 18x zoom with auto focus
• **Continuous** 2D Ring laser data (much faster than Responder)
• Sonar
  – Measures water surface and level of debris below water
• Data is post-processed and you can decide after you see video
• Open source data / no software to buy
CleanFlow / HD Profiler Inspection

Debris Graph

Inspection Distance (ft)

1200mm / 48 inch Brick Pipe

CCTV
Case Study: Jacksonville FL Landing
54” DIP Downstream of Pump Station
Case Study: Jacksonville FL
Cleanflow CCTV Video (HD Photos)
CleanFlow Inspection
CleanFlow Inspection

Multi-Sensor Inspection Report

Pipe Overview

The OVERVIEW GRAPH shows available laser and/or sonar results. The horizontal axis is the distance from the starting point in FEET (also known as 'payout') up to a maximum of 500 feet per page. The vertical axis (INCHES) will extend slightly above the internal vertical height of the pipe. A solid horizontal line is drawn along the vertical height of the pipe for reference. In this example, the pipe is circular and has a 60" internal diameter, so there is a line at 60.

- **GREEN** is the HEIGHT OF BUILD-UP (debris, sediment) under the flow as measured by the SONAR.  
- **BLUE** represents the WATER LEVEL, also obtained using SONAR data.
- **BROWN** is the AVERAGE DIAMETER of each LASER cross-section. It is calculated using a best-fit methodology that also provides the center of each cross-section.
- **RED** is the MINIMUM DIAMETER of each LASER cross-section. It is the radius of the point closest to the center in each laser cross-section (multiplied by two to match scales with the other data). This value is noisy relative to the Average Diameter and single points are typically just noise; however, a cluster of points can indicate small defects that would otherwise be ' averaged out '.

At 100' intervals (and at areas of interest) a callout box displays one or more of: HDcam image, laser cross-section, and sonar cross-section. In the top-right corner, the payout is displayed along with the reason for the callout and any observational notes.

The sonar cross-section (bottom right) shows the as-built template (black) and the scanned profile (light-blue) derived by driving a path along the most intense sonar returns.

The laser cross-section (top left) shows the post-processed laser beam (in red), best-fit circle (yellow for a good result, red for a poor result), minimum radius (purple), and maximum radius (light-blue).
CleanFlow Inspection

- Average Diameter (Laser Points)
- Minimum Diameter (Laser Points)

--- Water Surface (sonar)
--- Debris Surface (sonar)

Depth (in)

Pipe Length (feet)
Case Study: WLSSD MN CCTV & Laser Profiling (Responder)

• Loss of concrete due to H2S Corrosion
• Mostly at Joints where Tee-Lock Liner peeled off
WLSSD MN: Laser Profiling

- WLSSD MN
  - Laser profiling helped quantify the depth of missing concrete at joints
  - Example Pipe Joint
    - 3.18 inches Max
    - 2.26 inches Avg.

![Graph showing depth of void with two markers indicating measurements](image)
Case Study: Harrisburg PA
CCTV, Laser & Sonar

- 13 Miles (71,000’) of Interceptors
  - ~250 pipes
  - 24” to 72”
- Redzone
  - 13.3 miles CCTV, Laser, Sonar, GIS Mapping
- Some Cleaning
- ICOM software
  - Interactive, Maps/PACP
- Video, PDF Reports ~ 200 pages per interceptor
Case Study: Harrisburg PA
PACP Maps
Case Study: Harrisburg PA
CCTV, Laser & Sonar

<table>
<thead>
<tr>
<th>PCI-74B - PCI-75</th>
<th>Length</th>
<th>343.9 ft</th>
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<tbody>
<tr>
<td>Upstream MH</td>
<td>PCI-74B</td>
<td>Dimensions</td>
</tr>
<tr>
<td>Downstream MH</td>
<td>PCI-75</td>
<td>Material</td>
</tr>
<tr>
<td>Survey Direction</td>
<td>Downstream</td>
<td>Shape</td>
</tr>
<tr>
<td>Date Installed</td>
<td></td>
<td>Date Profiled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operator</td>
</tr>
</tbody>
</table>

Observations

- Average Debris Depth: 12 in
- Average Water Level: 27 in
- Debris Volume: 895.4 cubic feet

Debris Graph

* The match to reference is the point that best indicates the shape and size of the original condition of the pipe.
Case Study: Harrisburg PA
Sonar Graphs

### Observations

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Average Debris Depth</td>
<td>12 in</td>
</tr>
<tr>
<td>Average Water Level</td>
<td>27 in</td>
</tr>
<tr>
<td>Debris Volume</td>
<td>695.4 cubic feet</td>
</tr>
</tbody>
</table>

*The match to reference is the point that best indicates the shape and size of the original condition of the pipe.*
# Case Study: Harrisburg PA

## Sonar Graphs

### CRW Harrisburg PA

**Sonar and Laser Profile Results Summary of Conveyance Interceptors and Cleaning Recommendations**

Redzone Robotics Exports from ICOM3

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<thead>
<tr>
<th></th>
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<tr>
<td>PCI-85 - PCI-86</td>
<td>PCI</td>
<td>599</td>
<td>PCI-85</td>
<td>PCI-86</td>
<td>72</td>
<td>18.5</td>
<td>26%</td>
<td>2568</td>
<td>Yes</td>
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<td>PCI-83 - PCI-84</td>
<td>PCI</td>
<td>448</td>
<td>PCI-83</td>
<td>PCI-84</td>
<td>72</td>
<td>13.68</td>
<td>27%</td>
<td>1702</td>
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<td>PCI-84 - PCI-85</td>
<td>PCI</td>
<td>523</td>
<td>PCI-84</td>
<td>PCI-85</td>
<td>72</td>
<td>14.31</td>
<td>20%</td>
<td>1452</td>
<td>Yes</td>
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<td>PCI-89 - PCI-89A</td>
<td>PCI</td>
<td>514</td>
<td>PCI-89</td>
<td>PCI-89A</td>
<td>72</td>
<td>12.02</td>
<td>17%</td>
<td>1233</td>
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<tr>
<td>PCI-87 - PCI-88</td>
<td>PCI</td>
<td>407</td>
<td>PCI-87</td>
<td>PCI-88</td>
<td>72</td>
<td>10.38</td>
<td>14%</td>
<td>1185</td>
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<td>PCI-RI-04 - PCI-RI-05</td>
<td>PCIRI</td>
<td>242</td>
<td>PCI-RI-4</td>
<td>PCI-RI-5</td>
<td>48.05</td>
<td>31.16</td>
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<td>PCI-RI-35B</td>
<td>PCI-RI-36</td>
<td>60.17</td>
<td>8.87</td>
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<td>SCI-23 - SCI-24</td>
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<td>302</td>
<td>SCI-23</td>
<td>SCI-24</td>
<td>32</td>
<td>3</td>
<td>9%</td>
<td>33</td>
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<tr>
<td>FSI-32B - FSI-33</td>
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<td>38</td>
<td>FSI-32B</td>
<td>FSI-33</td>
<td>36</td>
<td>7.69</td>
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<td>SCI-09A - SCI-10</td>
<td>SCI</td>
<td>446</td>
<td>SCI-09A</td>
<td>SCI-10</td>
<td>32</td>
<td>3.22</td>
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<tr>
<td>SCI-03 - SCI-04</td>
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<td>228</td>
<td>SCI-03</td>
<td>SCI-04</td>
<td>32</td>
<td>3.1</td>
<td>10%</td>
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<tr>
<td>SCI-24 - SCI-25</td>
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<td>388</td>
<td>SCI-24</td>
<td>SCI-25</td>
<td>48.09</td>
<td>17.72</td>
<td>37%</td>
<td>22</td>
<td>Yes</td>
</tr>
<tr>
<td>SCI-22 - SCI-23</td>
<td>SCI</td>
<td>228</td>
<td>SCI-22</td>
<td>SCI-23</td>
<td>32</td>
<td>3.75</td>
<td>12%</td>
<td>18</td>
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<tr>
<td>SCI-04 - SCI-05</td>
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<td>193</td>
<td>SCI-04</td>
<td>SCI-05</td>
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<td>3.45</td>
<td>11%</td>
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<td>PCI-RI-09 - PCI-RI-10</td>
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<td>257</td>
<td>PCI-RI-9</td>
<td>PCI-RI-10</td>
<td>48.09</td>
<td>7.25</td>
<td>15%</td>
<td>14</td>
<td>Yes</td>
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<td>PCI-RI-10 - PCI-RI-11</td>
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<td>389</td>
<td>PCI-RI-10</td>
<td>PCI-RI-11</td>
<td>48.09</td>
<td>14.41</td>
<td>30%</td>
<td>12</td>
<td>Yes</td>
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</tbody>
</table>
Case Study: Harrisburg PA Cleaning Recommendations

- ~ 50 to 60% required cleaning
- ~ $30 to $50 per LF
- ~ $1.1 Million
- Plans & Specs being produced
Case Study: Harrisburg PA
CCTV, Laser & Sonar

Pipe is Buckled & Flow is 30% Restricted
Case Study: Harrisburg PA
Concrete Loss and PACP Defects

- SRV Surface Reinforcement Visible
  - Problem ??
- Laser Data Defines Extent of Concrete Loss by relative comparison of entire pipe
### Case Study: Harrisburg PA Laser Data – Concrete Loss

<table>
<thead>
<tr>
<th>Distance</th>
<th>Observation</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.9 ft</td>
<td>Beginning of Inspection</td>
<td>PCI-76</td>
</tr>
<tr>
<td>5.9</td>
<td>General Observation</td>
<td>Measurement outside reference to 0.7&quot;, Debris to 20.4&quot;</td>
</tr>
<tr>
<td>5.9</td>
<td>General Observation</td>
<td>Measurement outside reference to 0.9&quot;, Debris to 20.9&quot;</td>
</tr>
<tr>
<td>7.6</td>
<td>Maximum Debris</td>
<td>To 24.2&quot;</td>
</tr>
<tr>
<td>50</td>
<td>General Observation</td>
<td>Measurement outside reference to 1.5&quot;, Debris to 23.4&quot;</td>
</tr>
<tr>
<td>91.3</td>
<td>Maximum Measurement outside reference</td>
<td>To 2.7&quot;</td>
</tr>
<tr>
<td>99.9</td>
<td>General Observation</td>
<td>Measurement outside reference to 2.2&quot;, Debris to 22.5&quot;</td>
</tr>
<tr>
<td>150</td>
<td>General Observation</td>
<td>Measurement outside reference to 1.9&quot;, Debris to 23.1&quot;</td>
</tr>
<tr>
<td>200</td>
<td>General Observation</td>
<td>Measurement outside reference to 1.8&quot;, Debris to 21.8&quot;</td>
</tr>
<tr>
<td>250</td>
<td>General Observation</td>
<td>Measurement outside reference to 1.9&quot;, Debris to 22.1&quot;</td>
</tr>
<tr>
<td>299.8</td>
<td>General Observation</td>
<td>Measurement outside reference to 2.0&quot;, Debris to 22.0&quot;</td>
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<tr>
<td>350</td>
<td>General Observation</td>
<td>Measurement outside reference to 1.1&quot;, Debris to 20.7&quot;</td>
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<tr>
<td>399.8</td>
<td>General Observation</td>
<td>Measurement outside reference to 0.9&quot;, Debris to 22.1&quot;</td>
</tr>
<tr>
<td>449.8</td>
<td>General Observation</td>
<td>Measurement outside reference to 1.1&quot;</td>
</tr>
</tbody>
</table>
Case Study: Harrisburg PA
Laser – Pipe Dimensions & Concrete Loss

Observation Report

2.5ft General Observation - Measurement outside reference to 1.6", Debris to 11.7"  
2.5ft General Observation - Measurement outside reference to 1.6", Debris to 11.7"  
21.6ft Maximum measurement outside reference - To 1.3"

28.3ft Maximum Debris - To 12.8"  
49.9ft General Observation - Measurement outside reference to 1.2", Debris to 12.8"  
100ft General Observation - Measurement outside reference to 1.9", Debris to 11.9"
Case Study: Harrisburg PA
CCTV & Laser - Ovality

Figure 27. Examples of Structural Deterioration in the Asylum Run Interceptor.
Case Study: Harrisburg PA Rehab Recommendations
Case Study: Harrisburg PA Rehab Recommendations

- Rehabilitation
  - 40% Sewers need rehab; ~ $8 Million over 5 – 10 Years

### Interceptor Sewer Rehabilitation & Replacement Recommendations

<table>
<thead>
<tr>
<th>Name</th>
<th>Interceptor ID</th>
<th>Rehabilitation Range of Interceptor</th>
<th>Pipe Size (in)</th>
<th>Number of Pipes</th>
<th>Approx Ft.</th>
<th>Rehab Priority</th>
<th>Rehab Timeframe (yrs)</th>
<th>$ Cost per Foot</th>
<th>Total Cost Estimate $</th>
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</thead>
<tbody>
<tr>
<td>Paxton Creek Int. Rehab</td>
<td>PCI</td>
<td>PCI 20 to 20 B; 21-28; 71-72A; 73-89A</td>
<td>48&quot;H x 59W</td>
<td>30</td>
<td>8,735</td>
<td>1</td>
<td>2 to 5</td>
<td>$400</td>
<td>$3,493,880</td>
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<tr>
<td>Paxton Creek Int. Replace</td>
<td>PCI</td>
<td>PCI 72A-PCI-73</td>
<td>48&quot;H x 59W</td>
<td>1</td>
<td>92</td>
<td>1</td>
<td>3 to 5</td>
<td>$1,087</td>
<td>$100,000</td>
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<tr>
<td>Front Street (ph 1)</td>
<td>FSI</td>
<td>FSI 9 to 10</td>
<td>30&quot; Circular</td>
<td>5</td>
<td>5,070</td>
<td>2</td>
<td>2 to 3</td>
<td>$250</td>
<td>$1,267,575</td>
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<tr>
<td>Front Street (ph 2)</td>
<td>FSI</td>
<td>FSI: 10-17; 21-22A; 29-33</td>
<td>30&quot; to 40&quot; NC</td>
<td>35</td>
<td>5,100</td>
<td>3</td>
<td>5 to 7</td>
<td>$300</td>
<td>$1,530,030</td>
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<tr>
<td>Spring Creek Interceptor</td>
<td>SCI</td>
<td>SCI 22 to 43 C or &quot;44&quot;</td>
<td>24&quot;- 36&quot; C &amp; NC</td>
<td>20</td>
<td>5,117</td>
<td>4</td>
<td>7 to 10</td>
<td>$250</td>
<td>$1,279,250</td>
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<td>Asylum Run Interceptor</td>
<td>ARI</td>
<td>ARI 1 to 6-1</td>
<td>24&quot;</td>
<td>6</td>
<td>2,504</td>
<td>2</td>
<td>2 to 3</td>
<td>$200</td>
<td>$500,880</td>
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<tr>
<td><strong>Totals</strong></td>
<td></td>
<td></td>
<td></td>
<td>97</td>
<td>24,114</td>
<td></td>
<td></td>
<td></td>
<td><strong>$8,171,615</strong></td>
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</tbody>
</table>
Conclusions and Lessons Learned

1. Don’t use MSI unless you know you need this information to make prioritized intelligent decisions;
   - CCTV with PACP is often enough
2. Review CCTV before Contractor processes MSI data (sep. line items)
3. Make sure you locate & have MH / Pipe IDs in GIS before you start
4. Correlate the sewers with heavy debris with average daily velocities
5. Understand the limitations of the equipment, data and contractor
6. The user of the data (Engineer) should hold the contract with contractor for better control over final data
7. Make sure you get what you paid for before you pay the final invoice
8. Have a experienced engineer review, interpret and use the information to make prioritized recommendations
9. Get out of your chair and GO OUTSIDE !
Questions ???

For More Information

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