A New Entrant in Sewer Economics: How a Regional Sewer District Saved Scheduled Rehabilitation Budget

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ABSTRACT

Facing compliance with a 2007 EPA consent decree to address combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs), Kentucky’s Sanitation District 1 (SD1) turned to micro-monitoring. The micro-monitoring program can quickly identify sewer pipes high I&I or, more importantly, zero I&I pipes. The micro-monitors are deployed for one or two storm events. The result is targeted areas.

The first round of micro-monitoring revealed that 50% of the tested reaches had very low I&I, eliminating them from further investigation. SD1 saved about $240,000 in budgeted costs: a 5:1 return on the micro-monitoring investment. SD1 narrowed in on just 12 homes where gutters or driveway drains contributed the majority of I&I for the entire basin.

As a result of this success, SD1 followed up with four (4) more basins in the Spring of 2012. The success in each of these basins has changed SD1’s fundamental approach to I&I investigation.

KEYWORDS

SSES, I&I, Micro-monitoring, Smoke testing, Dye testing, Flow monitoring

INTRODUCTION

In the United States, more than a million miles of sanitary sewer collection system pipes carry almost 50 trillion-plus gallons of raw sewage daily (Costa, 2012). But deficiencies in aging wastewater infrastructure release billions of gallons of untreated sewage into the rivers and oceans each year. The U.S. Environmental Protection Agency (USEPA) has estimated that collectively wastewater systems responsible for the discharge of untreated sewage must spend upwards of $400 billion over the next two decades on sewer investigation and rehabilitation (USEPA, 2012). Many communities throughout the country have been subject to various regulatory actions and are taking action to reduce unwanted inflow and infiltration (I&I) into the sanitary sewer collection system.
Kentucky’s Sanitation District 1 (SD1) covers 220 square miles and 30 municipalities, and manages the largest water quality improvement program in northern Kentucky. Facing compliance with a 2007 EPA consent decree to address combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs), part of the improvement program involves the reduction of I&I through manhole, pipeline, and lateral rehabilitation. SD1 identified the priority basins in which to begin the work after a system wide flow monitoring project involving over 245 flow monitors. Priority basins have high I&I, typically with R Factors greater than 0.10 (McGillis et al 2013). Before pursuing areas for proactive renewal, it was important to classify assets and separate assets requiring a corrective action into different rehabilitation categories. SD1 determined the five general classifications to be the following:

1. Critical/Structural – Cracking, Collapses, Emergency Repairs
2. Maintenance – Roots, Grease, etc.
3. Hydraulic Limitations – Upsizing of the System
4. Functional Improvements – Improved Alignments and Location
5. I&I Rehabilitation

The first four categories above were identified and prioritized using a condition assessment report, historical behavioral data of the system, regional flow monitoring data, overflow locations, etc. I&I Rehabilitation was identified for the planning basin as a whole using this information but the area requiring rehabilitation was not narrowed down. Thus it was not possible to determine what type of rehabilitation would most effectively eliminating inflow and infiltration. Additional information about the development of the Asset Management Program is available in McGillis et al (2013).

In each of the Priority basins Asset Management with CCTV and manhole inspections demonstrated where rehabilitation was necessary. Those areas targeted would receive complete rehabilitation. The complete rehabilitation approach, which had achieved success in Nashville, TN and King County, WA, would preserve the asset and eliminate the I&I in identified basins. Though expensive, this proven approach can achieve necessary reductions in I&I.

Studies have shown that source removal is more cost effective than using a “convey and treat” method. I&I source removal can eliminate overflows rather than moving them downstream in the system. It also removes the I&I over time so future conveyance, O&M, and treatment expenditures are reduced. Moreover, I&I source removal is highly encouraged by regulators across the board (McGillis, 2013).

Over the past 40 years, the wastewater industry has seen advancement in technology and collection system engineering which have increased system efficiencies, reduced costs, and produced cutting edge rehabilitation. The invasive and expensive investigations conducted to perform condition assessment of the sewer system are known as Sanitary Sewer Evaluation Surveys (SSES). Some of the conventional SSES techniques are flow monitoring, smoke testing,
dye water testing, and CCTV inspection. However, with improvements in flow monitoring, traditional SSES activities have taken a smaller role in quantifying I&I. (Stevens, 2012).

**SD1’s COMPREHENSIVE REHABILITATION PROGRAM**

SD1 started comprehensive rehabilitation to achieve I&I reduction in 5 sub-drainage basins experiencing basement backups. These are upstream of overflows and experience high wet weather peak flows. The project area was first assessed to confirm if the sewer system was designed appropriately to handle the necessary sanitary dry weather flows. Then, the conventional flow monitoring data was analyzed to assess each drainage basin. The comprehensive rehabilitation approach included rehabilitating and replacing all of the SD1 Assets in the sub-basins which included pipelines and manholes and initially replacing all of the laterals 11 feet minimum from the main and to install a cleanout (McGillis, 2013).

By 2008 a huge portion of the system had already reached the end of its useful design life and required some form of renewal over a short period of time. The comprehensive approach accelerated the amount of pipe being renewed. However, without a complete understanding of the entire system, particularly the location of the I/I sources, there were lost opportunity costs. When making the decision to perform rehabilitation in structurally sound pipes to achieve I&I reduction, there were budgets which could have been allocated to address other critical parts of the sewer system.

SSES work which requires internal and external testing of all plumbing connections and testing for foundation or window well drains can cost in the range of $800 to $1200 per house (McGillis et al 2013). SD1’s initial goal was to perform investigations in every single house-hold in an I&I basin; which ranged between 150 to 500 homes in each basin. Even before actual ground work commenced, a lot of time and money need to be spent for public meetings, letters to home owners, coordination with home owners, etc. SD1’s initial cost estimate for the comprehensive rehab in the five priority drainage areas was totaling more than $14 million dollars.

**MICRO-MONITORING: A NEW SSES TOOL**

Micro-monitoring focuses on small pipe segments to isolate I&I sources. The micro-monitoring program quickly identifies sewer pipes with high I&I or, more importantly, pipes with no I&I. To achieve this goal the micro-monitors are deployed in individual pipe reaches for one or two storm events. The result is targeted areas instead of system-wide solutions. If a sewer line does not show any I&I response to a storm event during the monitoring period, it is immediately removed from the investigation and rehabilitation program. The SSES investigations are focused on other segments which show a response with high I&I to further locate the ultimate source
The micromonitor uses an adapted version of a standard flow monitor. The flow monitoring sensor is installed in front of a fiber-glass weir insert. At low subcritical flows, the micro-monitor acts as a weir with a primary rating curve. At higher supercritical flows, it offers no obstruction, and the sensor calculates the flow directly using continuity equation (Flow = Area x Velocity). Figure 1 shows a micro-monitor set-up in a test flume.

**DA 215: PILOT REHABILITATION PROJECT**

The comprehensive rehabilitation approach for DA 215 began in late 2010. This drainage area was located upstream of 2 active SSOs and a pump station. To meet the Consent Decree, SD1 had to upgrade the pump station and upsize the sewer system before 2015. Before designing the upgrade for the pump station and the conveyance system, SD1 performed an assessment to pursue private source I&I removal. Presuming that DA215 was going to be selected as a “pure” comprehensive I&I projects, the condition assessments of all of the assets were complete and a corrective action for rehabilitation was given for all assets in the priority basin.

Most of the pipe CIPP lining, and most of the manhole rehabilitation was completed by October 2011. Only the rehabilitation of approximately 129 laterals still remained. With budgeted costs of about $4,500 per lateral, the rehabilitation costs in this basin was anticipated to be about $580,500 (Barton and McGillis, 2013). At this point in the comprehensive rehabilitation program, SD1 learned of micro-monitoring as a tool to focus investigations and rehabilitation.
In the end of 2011 two rounds of micro-monitoring collected sewer flow data in fourteen (14) various segments of the basin and revealed that 55% of the tested reaches had very low I&I, eliminating them from further investigation and rehab. Figures 2 and 3 present data from two different monitoring locations in the drainage area showing clear response to the rainfall event. Figure 4 shows the monitoring network in DA 215 and the areas with I&I. By eliminating these areas from the scheduled rehabilitation, SD1 saved about $240,000 in budgeted costs: a 5:1 return on the $45,000 investment in micro-monitoring. As the micro-monitoring program in this pilot basin proceeded, the team was able to narrow in on just 12 homes where gutters or driveway drains were connected to the sanitary sewer lines, which contribute the major source of I&I for the entire basin.
Figure 2: Comparison of two micro-monitoring sites in Round 1

Figure 3: Comparison of two micro-monitoring sites in Round 2
After all work was completed in DA 215, over a million dollars was spent, about $900,000 less than the initial cost estimates. This number could have been lower if micro-monitoring was conducted prior to the early rehab work in the project area. Hence by the end of 2011 SD1 decided to direct the sewer rehab program using the results from micro-monitoring data in each priority basin.

SD1 continued micro-monitoring in four additional priority drainage areas. The average length of pipe upstream of the micro-monitors is less than 1,000 linear ft; this is much smaller than the upstream area in conventional flow monitoring programs. Micro-monitoring improved the effectiveness and efficiency of identifying private and public source I&I. Table 1 shows a summary of the micro-monitoring program in the first 5 drainage areas.
Table 1 Summary of SD1s micro-monitoring program

<table>
<thead>
<tr>
<th>Priority DA's</th>
<th>DA Area (Acres)</th>
<th>Approx. Length of Sanitary Sewer (ft.)</th>
<th>No. of Micromonitors</th>
<th>Date of Installation</th>
<th>Date of Removal</th>
<th>Total Duration (Days)</th>
</tr>
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<tbody>
<tr>
<td>215</td>
<td>120</td>
<td>14000</td>
<td>15</td>
<td>11/27/2011</td>
<td>1/29/2012</td>
<td>63</td>
</tr>
<tr>
<td>49</td>
<td>150</td>
<td>23500</td>
<td>31</td>
<td>2/3/2012</td>
<td>6/13/2021</td>
<td>131</td>
</tr>
<tr>
<td>208</td>
<td>200</td>
<td>17000</td>
<td>27</td>
<td>4/17/2012</td>
<td>8/13/2012</td>
<td>118</td>
</tr>
<tr>
<td>209</td>
<td>94</td>
<td>33500</td>
<td>16</td>
<td>6/1/2012</td>
<td>8/7/2012</td>
<td>67</td>
</tr>
<tr>
<td>193</td>
<td>300</td>
<td>28000</td>
<td>19</td>
<td>4/25/2012</td>
<td>6/26/2012</td>
<td>62</td>
</tr>
</tbody>
</table>

Dye-testing results
SD1 perform dye testing of all downspouts, area drains and catch-basins in areas shown to have high I/I rates by the micro-monitoring data. Figure 5 below shows the results of micro-monitoring for Drainage Area 193 one of the four drainage areas completed in 2012. When the original flow monitoring was performed downstream of this drainage area the entire basin was ranked as priority. However, the finer resolution provided by the micro-monitoring program show that the vast majority if the I&I is coming from a limited area. SD1 performed dye testing to determine the sources of the I&I. All of the area with high medium I&I rates was tested. A selection of the low I&I areas were also tested. Figure 6 shows the results of the dye testing. The numbers are the results of the micro-monitoring peak flow rates for the areas which were dye tested. Clearly the micro-monitoring and the dye testing show a strong correlation. Although each source does not make the same I&I contribution, a plot of the initial micro-monitoring peak rates per foot of pipe plotted against the number of sources per foot of pipe clearly demonstrates the correlation of the micromonitoring results and number of sources located by dye testing. Figure 7 shows this graph. To summarize it simply, where the micro-monitoring shows no I&I, there are no sources connected, where the micro-monitoring shows high I&I, there are lots of sources connected.
Figure 5: Grouped Results from 25 Micro-monitors for DA 193
Figure 6: Peak Micro-monitoring flow rates per linear foot of pipe and dots showing dye test results for DA 193
Micro-monitoring reveals an additional bonus not demonstrated by regional flow monitoring. Looking back at Figure 5, it is obvious that the I&I results from 25 micro-monitors are grouped into areas with high, medium and low I&I rates. This is not seen at the regional flow monitoring level as the results are averaged together. It appears curious that the High I&I area ends right on the boundary of the drainage area, and begs the question, “What is the I&I rate just over the border?” A review of the subdivision mapping demonstrates that the entire Low I&I area in green in Figure 6 was built by a single builder. Everywhere the micro-monitoring poked around in that subdivision, there was no I&I. Conversely, when reviewing the subdivision boundaries of the High I&I area, the subdivision was built by a group of builders. The boundary of the subdivision built by these builders is shown in Figure 8 and extends across the drainage basin boundary. This strongly suggests that I&I investigation should not be by drainage basin, but by subdivision and micro-monitoring makes this possible. This will be the subject of a future paper after more facts and data are collected.
Figure 8: SSES boundaries should be by Subdivision. The area of the subdivision outside of Drainage Area 193 should also be included in the SSES.

**Cost Savings**

Table 2 shows a comparison between the total estimated capital cost of each priority drainage basin and the capital savings after the micro-monitoring program was implemented. The total estimated capital costs for the five drainage basins in FY2012 was about $15 million dollars and the capital savings was about $5.2 million dollars. For a micro-monitoring program that cost under $0.15 million dollars, this is a payback of over 34 times. This was achieved by eliminating sections of the project area that had no I&I and hence needed no repairs or rehabilitation. There is no guarantee that $5.2 million would have been the actual cost of the additional work if micro-monitoring had not been performed; it may have been more it may have been less. But either way, the savings are still substantial. SD1 is now able to spend this saved money for useful projects in other areas.
<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>C-Code</th>
<th>Drainage Area (DA) Basin Number</th>
<th>DA Sewer Length (FT)</th>
<th>City</th>
<th>Corrective Action Basin Cost</th>
<th>MH Count</th>
<th>Marshole Cost</th>
<th>Lateral Count</th>
<th>Total SSES Investigations Performed</th>
<th>Total Lateral Rehab Cost (Assume $4500 Per Lateral)</th>
<th>SDI Project Management and SSES Labor Cost</th>
<th>Total FY 12 Actual Capital Cost</th>
<th>Total FY 12 Estimated Capital Cost</th>
<th>Total Capital Cost Savings</th>
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<tbody>
<tr>
<td>2012</td>
<td>C620-27</td>
<td>49</td>
<td>23,689.00</td>
<td>Newport</td>
<td>$1,728,667.00</td>
<td>135</td>
<td>$133,491.00</td>
<td>447</td>
<td>210</td>
<td>$170,661.00</td>
<td>$2,030,729.00</td>
<td>$3,854,861.50</td>
<td>$1,924,132.50</td>
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<tr>
<td>2012</td>
<td>C623-15</td>
<td>103</td>
<td>30,440.00</td>
<td>Southgate</td>
<td>$313,011.00</td>
<td>169</td>
<td>$175,020.00</td>
<td>348</td>
<td>114</td>
<td>$137,129.00</td>
<td>$625,160.00</td>
<td>$3,266,599.12</td>
<td>$2,641,439.12</td>
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<td>2012</td>
<td>C611-15</td>
<td>208</td>
<td>33,875.00</td>
<td>Elsmere</td>
<td>$1,321,810.00</td>
<td>179</td>
<td>$143,200.00</td>
<td>612</td>
<td>To Be Determined</td>
<td>$2,754,000.00</td>
<td>$409,390.10</td>
<td>$4,628,400.10</td>
<td>N/A</td>
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<tr>
<td>2012</td>
<td>C611-21</td>
<td>209</td>
<td>15,354.00</td>
<td>Elsmere</td>
<td>$705,690.00</td>
<td>69</td>
<td>$55,200.00</td>
<td>114</td>
<td>To Be Determined</td>
<td>$513,000.00</td>
<td>$81,138.90</td>
<td>$1,355,028.90</td>
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<tr>
<td>2012</td>
<td>C633-01</td>
<td>215</td>
<td>14,104.00</td>
<td>Crestview</td>
<td>$373,464.00</td>
<td>83</td>
<td>$82,320.00</td>
<td>252</td>
<td>104</td>
<td>$565,939.00</td>
<td>$95,903.00</td>
<td>$1,117,626.00</td>
<td>$1,916,269.62</td>
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</table>

*Actual numbers listed in Red. N/A indicates no lateral rehab has been performed until inflow removal complete.*
CONCLUSIONS
As a result of this micro-monitoring success, SD1 has changed its fundamental approach to I&I investigation and micro-monitoring. Micro-monitoring helps SD1 program managers rapidly move through a sewered area, collecting flow monitoring data from one or two storm events to focus the search for I&I. Each spike of I&I is tracked upstream until isolated. The rapid investigation and analysis is a hallmark of micromonitoring programs. Decisions are made and sources are located in days and weeks, not years, a fact called the ‘Most Valuable Part of the Micro-monitoring Program’ (Barton and Kamalesh, 2012).

For municipalities looking for means to stretch budgets further, obtain usable data faster, and limit inconvenience to property owners during field investigations, the micro-monitoring program successfully employed by SD1 in Kentucky provides a valuable and demonstrated approach.

REFERENCES


