Sewer Asset Inspection and Maintenance (AIM) - A Targeted Approach to System Operation & Rehabilitation


Littlejohn Engineering Associates, Inc.
1935 21st Avenue
Nashville, TN 37212

ABSTRACT

Presentation of a case study showing the lessons learned while developing a program to find, evaluate, prioritize and undertake rehabilitation projects that achieve a reduction of sanitary sewer overflows and increase hydraulic performance in a collection system. This presentation will document the development and results of a 5 year program implementing a sanitary sewer asset inspection and maintenance program for a midsize utility. Over 1.1 million feet of closed-circuit television (CCTV) inspection and 4,100 manhole inspections were performed, along with 1.1 million feet of smoke testing. The purpose of this presentation will show how data was captured electronically and integrated into the Owner’s geographic information system (GIS) and combined with other information to develop a targeted, effective rehabilitation program to reduce sanitary sewer overflows and improve hydraulic performance in the collection system. This targeted approach has allowed the utility to meet stringent regulatory requirements while remaining fiscally responsible to their rate payers.

KEYWORDS

Sewer, wastewater, asset inspection, maintenance, GIS, rehabilitation, smoke testing, manhole inspection, CCTV, CIPP, SSO, Sewer AIM, PACP, MACP, NASSCO.

INTRODUCTION

Many municipal water and wastewater providers are learning that their infrastructure, which has served them well for the past half-century or more, is rapidly deteriorating. They are looking for ways to deal with these problems with available funds. One of the most important tools that can be developed to address this situation is an asset inspection and maintenance program utilizing a geographic information system. Utilities need a way to concisely pinpoint where their worst problems are located, the extent of these problems and in what priority they need to be addressed. Additionally they need a method to accurately document and seamlessly combine disparate sources of information to assist with the decision making process. This case study will show (utilizing real world data) how this utility developed a program to find, evaluate, prioritize and then undertake rehabilitation projects that are achieving a reduction in sanitary sewer overflows and increasing the hydraulic performance of their collection system. This program allows a targeted approach to achieving these results in a financially sustainable manner.
8 KEY ELEMENTS OF SEWER AIM

1) Develop a geographic information system (GIS) of the wastewater collection and transport system, minimum elements are:
   a) Manholes – with unique identifiers/numbers (i.e. only one MH#1, 2, 3)
   b) Pipelines – flow direction drawn correctly with diameters and material if available
   c) Pump Stations & Force Mains – Size and tie in points are critical
   d) Sewer Basins sub-delineated evenly into 20,000 to 100,000 ft sewer sheds
   e) Historical SSO’s with X & Y coordinates and date of occurrence
   f) Flow monitoring data by sewer basins
   g) Work order history with who, what, when, why, how and where

2) Develop basin prioritization based on goals (i.e. reducing I/I, eliminating SSO’s or improving water quality)

3) Conduct inspection and maintenance activities in the highest priority basins, order of work is:
   a) Flow isolation – quick way to determine further delineate 20,000 to 100,000 ft basins.
   b) Manhole Inspections – verify connectivity and correct GIS
   c) Smoke Testing – Identify service lateral and private issues and sources of inflow
   d) Cleaning & closed-circuit television (CCTV) inspection of pipelines

4) Capture inspection data electronically using the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment and Certification Program (PACP), Manhole Assessment and Certification Program (MACP) and/or Lateral Assessment and Certification Program (LACP). Ensure that operators are certified and data is quality controlled.

5) Integrate inspection data with GIS and develop criteria for selecting optimum rehabilitation methods and prioritization of work.

6) Perform rehabilitation with direct inspection of work process and post rehabilitation documentation (photos, CCTV video, record drawings)

7) Integrate post rehabilitation documentation into GIS to track success and failures to modify and improve overall process.

8) Share and disseminate lessons learned to internal and external customers.

BACKGROUND

Hallsdale-Powell Utility District (HPUD) was established in 1954 to provide water and wastewater services for customers located in northwest Knox County, Tennessee. HPUD is a midsized utility district with approximately 22,000 wastewater accounts, 415 miles of gravity sewer ranging in size from 6-inches to 36-inches in diameter, 9,273 manholes, 19 lift stations with 33 miles of force main and 2 wastewater treatment plants.
In 2004 HPUD was placed under a Consent Order by the Tennessee Department of Environment and Conservation (TDEC) for sanitary sewer overflows (SSO’s) in the collection system. The main requirements of the Consent Order for the collection system were to develop a corrective action plan consisting of two phases. Phase 1 of the CAP included the development of a geographic information system (GIS) and a hydraulic model of the wastewater collection and transport system. Phase 2 consisted of the development of a Capital Improvement Plan (CIP) and timeline for implementation. In addition to the requirements of the CAP, HPUD was required to perform a Management, Operations and Maintenance (MOM) Audit. This audit included the following elements:

(1) Identification of major goals of the MOM program.

(2) Identification of the person or position, employed by HPUD, responsible for implementing each of the elements of the MOM program.

(3) Establish procedures for training of appropriate personnel on a regular basis regarding elements of the MOM program.

(4) Identification of the means by which the mapping of the collection and transmission system is accomplished and maintained.
(5) Identification of the physical inspection and testing procedures.

(6) Description of preventive and routine maintenance procedures.

(7) Outline of corrective maintenance procedures.

(8) Identification of procedures for the maintenance of right-of-ways and easements for the sanitary sewer lines.

(9) Inventory management system.

(10) List of programs and procedures to identify and prioritize structural deficiencies and implementation of short-term and long-term rehabilitation actions to address identified deficiencies.

(11) List of requirements and standards for the installation of new sewers, pumps and other appurtenances and rehabilitation and repair projects.

(12) Identification of procedures and specifications for inspecting and testing the installation of new sewers, pumps, and other appurtenances and for rehabilitation and repair projects.

(13) Identification of procedures to update MOM program elements as appropriate.

(14) List of procedures to modify the written summary of the MOM program as appropriate.

After completion of the MOM self audit, HPUD was required to submit annual reports to TDEC that included the follow elements:

(a) Overview of the HPUD’s one-year and five-year capital planning process.

(b) Overview and summary of the implementation and effectiveness of the MOM program.

(c) Summary of capital improvement projects undertaken for the preceding fiscal year.

(d) Summary of capital improvement projects identified but not yet undertaken.

(e) Description of completed, ongoing and planned rehabilitation program projects for the collection system.

(f) Description of completed, ongoing and planned major pump station projects.

(g) Description of the HPUD’s community outreach efforts.

(h) Description of changes to the MOM program, including any updates to the system capacity assurance program.
In preparation of the impending Consent Order in 2004, HPUD had undertaken a temporary flow monitoring program between June and September 2003. The collection system was broken into 46 sub-basins, 50 flow monitors and three rain gauges were installed to monitor depth and velocity and capture rain events. Ten sites were selected for permanent long term monitoring.

**Figure 2 – Sewer basins and monitoring points**

The flow monitoring results indicated that HPUD’s system was subject to substantial infiltration and inflow (I/I) during wet weather events with over 68% of the 50 monitoring sites experiencing surcharge conditions during the temporary monitoring period. As HPUD had not completed the GIS prior to the completion of the temporary monitoring period, the actual quantity of pipe located in each sub-basin was not immediately available. The basins were initially ranked on the projected net rainfall derived infiltration and inflow (RDII) for 1-inch and 3-inch storm events. The highest ranked basin indicated a RDII flow of 148,000 gallons for a 1-inch storm event, while several downstream basins had negative RDII volumes indicating a loss of flow due to upstream SSO’s. After completion of the GIS in 2005, a re-evaluation of the basin rankings was performed, normalizing the RDII by the linear footage (LF) of gravity sewer in each basin to more accurately prioritize the basins by the amount of RDII in gallons/LF.
Table 1 - Normalized Net RDII Basin Rankings for 1-inch Storm Event

<table>
<thead>
<tr>
<th>Sub-Basin</th>
<th>Actual System Footage (LF)</th>
<th>Calculated Projected Net RDII (MG)</th>
<th>Calculated Normalized Net RDII (gal/LF)</th>
<th>Basin Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP 5D</td>
<td>6,837</td>
<td>0.059</td>
<td>8.62</td>
<td>1</td>
</tr>
<tr>
<td>HP 8B</td>
<td>10,459</td>
<td>0.054</td>
<td>5.13</td>
<td>2</td>
</tr>
<tr>
<td>HP 5E</td>
<td>11,933</td>
<td>0.055</td>
<td>4.60</td>
<td>3</td>
</tr>
<tr>
<td>HP 8E</td>
<td>13,781</td>
<td>0.063</td>
<td>4.57</td>
<td>4</td>
</tr>
<tr>
<td>HP 0A</td>
<td>13,956</td>
<td>0.062</td>
<td>4.47</td>
<td>5</td>
</tr>
<tr>
<td>HP07</td>
<td>36,461</td>
<td>0.148</td>
<td>4.07</td>
<td>6</td>
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<tr>
<td>HP 8A</td>
<td>14,972</td>
<td>0.055</td>
<td>3.66</td>
<td>7</td>
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<tr>
<td>HP 3A</td>
<td>1,339</td>
<td>0.005</td>
<td>3.38</td>
<td>8</td>
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<tr>
<td>HP 6A-1/6A-2</td>
<td>32,544</td>
<td>0.085</td>
<td>2.60</td>
<td>9</td>
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<tr>
<td>HP 7E</td>
<td>29,098</td>
<td>0.065</td>
<td>2.24</td>
<td>10</td>
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<tr>
<td>HP 5A</td>
<td>28,203</td>
<td>0.060</td>
<td>2.13</td>
<td>11</td>
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<tr>
<td>HP 5B</td>
<td>24,080</td>
<td>0.047</td>
<td>1.94</td>
<td>12</td>
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<tr>
<td>HP 1A</td>
<td>50,591</td>
<td>0.098</td>
<td>1.93</td>
<td>13</td>
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<tr>
<td>HP 4B</td>
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<td>0.090</td>
<td>1.92</td>
<td>14</td>
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<tr>
<td>HP 5C</td>
<td>9,087</td>
<td>0.015</td>
<td>1.68</td>
<td>15</td>
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<tr>
<td>HP 1B</td>
<td>42,475</td>
<td>0.071</td>
<td>1.67</td>
<td>16</td>
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<td>23,006</td>
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<td>81,432</td>
<td>0.119</td>
<td>1.47</td>
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<td>HP 2A</td>
<td>86,341</td>
<td>0.126</td>
<td>1.46</td>
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<td>HP 09</td>
<td>75,043</td>
<td>0.105</td>
<td>1.40</td>
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<td>HP 5F</td>
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<td>0.072</td>
<td>1.28</td>
<td>23</td>
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<tr>
<td>HP 9B</td>
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<td>0.056</td>
<td>1.23</td>
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<tr>
<td>HP 3B</td>
<td>26,504</td>
<td>0.032</td>
<td>1.22</td>
<td>25</td>
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<tr>
<td>HP 9A</td>
<td>31,261</td>
<td>0.031</td>
<td>0.99</td>
<td>26</td>
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<tr>
<td>HP 08</td>
<td>55,875</td>
<td>0.049</td>
<td>0.89</td>
<td>27</td>
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<tr>
<td>HP 7D</td>
<td>7,874</td>
<td>0.007</td>
<td>0.86</td>
<td>28</td>
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<tr>
<td>HP 8C</td>
<td>21,896</td>
<td>0.019</td>
<td>0.85</td>
<td>29</td>
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<tr>
<td>HP 1D</td>
<td>18,090</td>
<td>0.015</td>
<td>0.81</td>
<td>30</td>
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<tr>
<td>HP 9C</td>
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<td>0.030</td>
<td>0.76</td>
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<tr>
<td>HP 3D</td>
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<td>0.74</td>
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<tr>
<td>HP 2B</td>
<td>72,956</td>
<td>0.047</td>
<td>0.64</td>
<td>33</td>
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<tr>
<td>HP 3E</td>
<td>40,154</td>
<td>0.023</td>
<td>0.58</td>
<td>34</td>
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<tr>
<td>HP 03</td>
<td>120,092</td>
<td>0.067</td>
<td>0.56</td>
<td>35</td>
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<tr>
<td>HP 7F</td>
<td>54,990</td>
<td>0.031</td>
<td>0.56</td>
<td>36</td>
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<tr>
<td>HP 04</td>
<td>112,023</td>
<td>0.060</td>
<td>0.54</td>
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<td>HP 1G</td>
<td>76,258</td>
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<td>HP 1F</td>
<td>44,505</td>
<td>0.019</td>
<td>0.42</td>
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<td>HP 7A</td>
<td>31,200</td>
<td>0.013</td>
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<td>HP 4A</td>
<td>17,910</td>
<td>0.005</td>
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<td>41</td>
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<tr>
<td>HP 3C</td>
<td>33,923</td>
<td>0.010</td>
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<td>42</td>
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<tr>
<td>HP 7BC</td>
<td>22,913</td>
<td>0.003</td>
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<td>43</td>
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<td>HP 06</td>
<td>68,452</td>
<td>0.008</td>
<td>0.12</td>
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<tr>
<td>HP 02</td>
<td>18,172</td>
<td>-0.064</td>
<td>-3.51</td>
<td>45</td>
</tr>
<tr>
<td>HP 01</td>
<td>142,039</td>
<td>-0.596</td>
<td>-4.20</td>
<td>46</td>
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</tbody>
</table>
With the completion of their GIS, HPUD was able to begin integrating their historical SSO information with their temporary flow monitoring program to begin prioritizing basins that would require further investigation.

**Figure 3 – Integration of Flow Monitoring with SSO History**

As shown in Figure 3, eight of the top ten basins with the highest normalized RDII rankings occurred in the middle of the collection system. This area also had a high concentration of SSO’s between 2003 and 2006. HPUD referred to this problematic area as their system’s “gut punch”. A review of the alignment along the 30-inch diameter interceptor in this area also indicated several potential grade and alignment issues causing severe hydraulic restrictions. Because of these issues and the fact that a routine cleaning and inspection program had not been implemented in previous years, HPUD began a pilot program to clean and inspect the interceptor in this area in early 2006. Given that this initial pilot area consisted of over 57,210 LF of 8-inch to 30-inch diameter pipeline, HPUD elected to bring in a subcontractor to perform this work. The initial pilot work included the implementation of a totally integrated sonar CCTV inspection technique (TISCIT), whereby a standard CCTV inspection camera system is combined with a sonar system allowing the inspection of partially or fully surcharged pipelines. This inspection method was performed on the 24-inch and 30-inch diameter pipelines, while standard CCTV inspection was performed on 18-inch and below pipelines.

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In addition to capturing CCTV images of the pipelines, HPUD required the subcontractors performing this work to utilize NASSCO’s PACP certified operators and software to capture defect information digitally and provide it in a Microsoft Access database format. Defects and observations were classified as either linear or point defects. Linear defects began at one location within the pipeline and continued for a specific distance. Point defects typically occurred in only a single location. Specific information required to be delivered in the database for every inspection included the upstream and downstream manhole identification of the pipeline being inspected, the direction of survey, the location of the observed defect from the starting point, the description and two digit code for the defect, the grade of the defect and hyperlinks to the snapshot and video files. This information was then integrated into the GIS, allowing it to be overlaid with other data to provide a comprehensive view of the collection system’s performance.
Due to the success in discovering several substantial sources of infiltration, as well as the locations of severe hydraulic restrictions due to the deposition of sediment, HPUD elected to
extend the program an additional 40,000 upstream of the pilot area along the interceptor.

**Figure 7 – Addendum to Initial Pilot Project**

In addition to capturing the specific location of key defects and hydraulic bottlenecks within the collection system, cleaning of the pipelines was performed using a hydraulic jetter. Substantial quantities of material were removed during this work, resulting in the immediate relief of several chronic SSO’s upstream of the work areas. It was realized during this initial pilot project that common engineering practice calls for sanitary sewer conveyances to be constructed on minimum slopes in order that scouring velocities will be maintained, thereby reducing the need for routine cleaning during the lifetime of the pipeline. However, in the majority of interceptor installations, it may take 5 to 10 years for enough flow to be added to reach these scouring velocities in these larger lines. In the interim, deposits in the form of grease and sediment tend to accumulate in the pipelines and manholes as the sanitary sewer flow reaches its attenuation point. In the case of smaller trunk lines (8-inch diameter) scouring velocities may never be reached. Therefore performing preventative maintenance cleaning activities on these pipelines was critical to ensuring that future flows could be carried. HPUD did not have a routine preventative maintenance program in past years; therefore it was reasonable to assume that an aggressive program, initially targeting problem areas, would serve to drastically reduce the occurrence and severity of SSO’s. By cleaning the pipelines and removing obstructions such as
sediment, grease and roots, the system would begin performing as it was originally designed to perform. If this maintenance work was combined with inspection activities, data could be obtained to further calibrate a hydraulic model and allow very accurate simulations to be conducted. In turn, the results of these simulations could be used to determine whether specific reaches of pipelines need to be upgraded to serve future customers. Additionally sources of I/I could be discovered and rehabilitated, further increasing the quantity of available capacity in the collection system and reducing the occurrence of SSO’s.

METHODOLOGY

A key lesson learned during the initial pilot program was that attacking problem areas from a sub-basin approach and working from the top of the system downstream provided the best results. Working from the top of the sub-basin down to the main interceptor or trunk-line allowed debris and sediment to be removed. If work commenced from the bottom up, there was a tendency for accumulated debris to be washed into cleaned areas almost immediately after space was made in the downstream pipelines. Additionally it was determined that CCTV or TISCIT inspections alone did not provide a complete picture of problems within the collection system. Manhole inspections and smoke testing were combined with the cleaning and CCTV inspections to fill in missing sources of I/I that were not being captured via CCTV. An added benefit of these additional evaluations was that problems with connectivity and missing pipelines and manholes within the GIS could be discovered and addressed prior to mobilizing CCTV contractors. By correcting issues with the GIS and providing more accurate maps, as well as finding and raising buried manholes allowed the CCTV crews to work much more efficiently resulting in substantially reduced unit prices. Smoke testing identified numerous private service lateral problems (e.g. missing clean-out caps) as well indicating sources of infiltration that were missed when CCTV inspections were performed during dry periods.

The initial goal of implementing this inspection and maintenance program as a component of the corrective action plan was to complete 10% of the system (219,150 ft & 928 manholes) per calendar year. Work would begin in the sub-basins with the highest normalized RDII rankings that also contributed flow to greatest number of downstream SSO’s. By prioritizing the sub-basins in this manner, HPUD was assured of beginning this program in the areas that might have the largest sources of I/I and provide the greatest return on their investigation expenses.

Due to the sheer volume of work involved, HPUD contracted with consultants to manage the work, perform quality control checks and integrate the results into the GIS. Additionally the consultants assisted HPUD with selecting and prioritizing the rehabilitation projects resulting from the inspection work. Initially this work was accomplished by hand and entailed reviewing each individual CCTV video and the accompanying manhole and/or smoke testing inspection to determine the optimum rehabilitation method. Because this information was all contained in databases and tied to the GIS, the task of performing the initial rehabilitation selections could be automated utilizing customized database queries.
RESULTS

The results of the last five years of the program are shown in Table 2. As of December 31, 2010 HPUD has CCTV inspected over 50% of their pipelines and manholes. Over 37% of the manholes inspected to date have documented defects. This represents a total of 17% of the manholes in the system. Serious defects within the pipelines, which is defined as those having a PACP score of 3 or greater, occurred at a rate of 6.5 defects per 1,000 feet of pipe.

Figure 8 – CCTV Inspections completed between 2006 and 2010

A review of the smoke testing data indicated that defects occurred at a rate of 1.18 defect per 1,000 ft inspected. The breakdown of locations of positive smoke events by year performed are shown in Figure 9. The data is summarized for all years in Figure 10. It is important to note that over 58% of the smoke defects found occurred in either service laterals, clean-outs or were the result of inappropriately abandoned service laterals. The majority of the remaining smoke defects (32.4%) were related to manholes.
### Table 2 – Summary of Asset Inspection and Maintenance Work 2005 thru 2010

<table>
<thead>
<tr>
<th>Program/Performance Measures</th>
<th>Program Start Date</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infrastructure From GIS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Gravity Lines (feet)</td>
<td>2,072,040</td>
<td>2,180,640</td>
<td>2,180,640</td>
<td>2,232,203</td>
<td>2,229,440</td>
<td>Includes 37,944 ft abandoned gravity line</td>
</tr>
<tr>
<td># Forcemain (feet)</td>
<td>86,657</td>
<td>110,880</td>
<td>110,880</td>
<td>185,036</td>
<td>186,866</td>
<td>Includes 11,886 ft abandoned force main</td>
</tr>
<tr>
<td># Connections</td>
<td>21,000</td>
<td>21,028</td>
<td>21,028</td>
<td>22,224</td>
<td>21,981</td>
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</table>

<table>
<thead>
<tr>
<th>Monitoring Period from January 1st to December 31st</th>
</tr>
</thead>
</table>

#### Manhole Inspection 8/15/2005

<table>
<thead>
<tr>
<th># Manholes in System</th>
<th>8,500</th>
<th>8,898</th>
<th>9,130</th>
<th>9,228</th>
<th>9,275</th>
<th></th>
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</thead>
<tbody>
<tr>
<td># Manholes Inspected during the Calendar Year</td>
<td>485</td>
<td>1,086</td>
<td>1,546</td>
<td>897</td>
<td>316</td>
<td>866</td>
</tr>
<tr>
<td># Manholes with Defects</td>
<td>169</td>
<td>142</td>
<td>666</td>
<td>548</td>
<td>93</td>
<td>324</td>
</tr>
</tbody>
</table>

#### CCTV Inspection (Contractor & Internal) 8/20/2005

| # Feet Inspected by CCTV this Calendar Year | 230,290 | 71,917 | 217,440 | 399,068 | 185,004 | 220,744 | 10.07% | 1,103,719 | 50.36% |
| # Feet Cleaned for Inspection | 112,319 | 43,443 | 177,787 | 185,446 | 80,750  | 119,949 | 5.47% | 599,744 | 27.37% |
| # Feet Cleaned for Routine or Scheduled Maintenance | 12,000 | 6,875 | 50,489 | 40,852 | 27,554 | 110,216 | 5.03% |
| # Defects Identified by CCTV Inspection | 2,589 | 391 | 835 | 2,433 | 475 | 1,345 | 0.06% | 6,723 | 0.31% |
| # Defects Catalogued or Recorded into Database | 2,589 | 391 | 835 | 2,433 | 475 | 1,345 | 0.06% | 6,723 | 0.31% |

#### Smoke Testing (Contractor & Internal) 2/15/2006

| # Feet Smoke Tested this Year | 306,934 | 206,203 | 230,103 | 290,989 | 69,456 | 220,737 | 10.07% | 1,103,685 | 50.36% |
| # Defects Found this Year | 385 | 350 | 266 | 363 | 36 | 280 | 1.18% | 1,400 | 1.27% |

#### Gravity Line Rehabilitation (Contractor & Internal) 2/15/2006

| # Feet Gravity Lines Rehabilitated | 7,918 | 30,247 | 121,592 | 53,252 | 2.43% | 159,757 | 7.29% |
| # Feet Replaced | 6,900 | 2,700 | 1,527 | 3,709 | 0.17% | 11,127 | 0.51% |
| # Feet Cured in Place | 7,918 | 30,247 | 117,905 | 52,023 | 2.37% | 156,070 | 7.12% |
| # Manholes Rehabilitated | 52 | 281 | 757 | 363 | 3.92% | 1,090 | 11.75% |
| # Manholes Replaced | 33 | 13 | 1 | 16 | 0.17% | 47 | 0.51% |

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Figure 9 – Comparison of Smoke Testing Defects by Year

FY 2006-07 Smoke Testing Results

FY 2007-08 Smoke Testing Results

FY 2008 Smoke Testing Results

FY 2008-09 Smoke Testing Results

FY 2009-10 Smoke Testing Results

FY 2010 Smoke Testing Results

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Another distinguishing characteristic of the smoke testing results was the downward trend of observed defects as inspections were performed in basins that ranked lower on the RDII comparison.

**Figure 10 – Location of Positive Smoke Testing Results 2006 -2010**

**Figure 11 – Comparison of Observed Defects by Year & Basin Inspected**
Rather than wait until the conclusion of the investigations, HPUD decided to begin rehabilitation efforts in 2008 on some of the worst problems discovered. Since beginning the rehabilitation of the system, over 159,757 linear feet (7.3% of the total system) of pipelines have been rehabilitated. Over 97% of the pipeline rehabilitation was accomplished using trenchless methods such as cured-in-place pipe (CIPP).

**Figure 12 – Rehabilitation and Replacement Work 2006 to 2011**

DISCUSSION

The maintenance efforts and rehabilitation projects have had a dramatic effect on the flows observed within the system. The most significant effect has been a reduction in the low flow readings at the Beaver Creek Wastewater Treatment Plant. Despite 2009 being one of the wettest years on record, the lowest observed flows were 741,000 gallons below the lowest observed flow in the driest year, 2007. Additionally, 2010 saw a decrease of 874,000 gallons below the 2009 level.
Table 3 – Observed Flows within the Collection System 2006 to 2010

<table>
<thead>
<tr>
<th>Flow Measurement</th>
<th>Program Start Date</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Flow Observed During Monitoring Period (gpd)</td>
<td>8/20/2004</td>
<td>12,686,000</td>
<td>11,687,000</td>
<td>13,061,000</td>
<td>17,850,000</td>
<td>19,443,000</td>
</tr>
<tr>
<td>Average Flow Observed during Monitoring Period (gpd)</td>
<td></td>
<td>6,293,000</td>
<td>5,216,000</td>
<td>5,934,000</td>
<td>7,791,000</td>
<td>6,209,000</td>
</tr>
<tr>
<td>Low Flow Observed during Monitoring Period (gpd)</td>
<td></td>
<td>2,193,000</td>
<td>2,451,000</td>
<td>2,177,000</td>
<td>1,710,000</td>
<td>836,000</td>
</tr>
</tbody>
</table>

Table 4 – Annual Precipitation Comparisons

<table>
<thead>
<tr>
<th>Month</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>3.36</td>
<td>3.59</td>
<td>2.24</td>
<td>2.82</td>
<td>4.06</td>
<td>4.89</td>
</tr>
<tr>
<td>February</td>
<td>2.72</td>
<td>1.7</td>
<td>0.83</td>
<td>3.46</td>
<td>2.6</td>
<td>2.61</td>
</tr>
<tr>
<td>March</td>
<td>2.52</td>
<td>2.53</td>
<td>2.36</td>
<td>3.19</td>
<td>3.6</td>
<td>2.4</td>
</tr>
<tr>
<td>April</td>
<td>4.11</td>
<td>6.89</td>
<td>3.27</td>
<td>3.18</td>
<td>2.65</td>
<td>2.52</td>
</tr>
<tr>
<td>May</td>
<td>0.92</td>
<td>2.49</td>
<td>1.11</td>
<td>2.17</td>
<td>5.02</td>
<td>3.99</td>
</tr>
<tr>
<td>June</td>
<td>1.71</td>
<td>1.11</td>
<td>2.84</td>
<td>0.56</td>
<td>3.67</td>
<td>2.84</td>
</tr>
<tr>
<td>July</td>
<td>7.07</td>
<td>3.3</td>
<td>3.66</td>
<td>2.6</td>
<td>5.61</td>
<td>4.65</td>
</tr>
<tr>
<td>August</td>
<td>1.08</td>
<td>3.42</td>
<td>0.67</td>
<td>1.66</td>
<td>4.49</td>
<td>2.05</td>
</tr>
<tr>
<td>September</td>
<td>1.2</td>
<td>5.53</td>
<td>2.37</td>
<td>0.64</td>
<td>4.34</td>
<td>4.99</td>
</tr>
<tr>
<td>October</td>
<td>0.64</td>
<td>4.29</td>
<td>1.46</td>
<td>1.54</td>
<td>4.53</td>
<td>3.15</td>
</tr>
<tr>
<td>November</td>
<td>2.86</td>
<td>2.8</td>
<td>3.24</td>
<td>3.38</td>
<td>2.4</td>
<td>6.02</td>
</tr>
<tr>
<td>December</td>
<td>2.72</td>
<td>1.66</td>
<td>2.5</td>
<td>5.83</td>
<td>6.23</td>
<td>1.23</td>
</tr>
<tr>
<td>Total</td>
<td>30.91</td>
<td>39.31</td>
<td>26.55</td>
<td>31.03</td>
<td>49.2</td>
<td>41.34</td>
</tr>
</tbody>
</table>

Average Daily plant flows are also averaging 2 million gallons lower in 2010 versus 2009. This indicates that the improvements in the collection system have resulted in the reduction of I/I. Maximum flows through the plant are significantly lower for 2010 compared to 2009 as shown in Figure 14.
Figure 13 – Average Daily WWTP Flows

![Average Daily WWTP Flow (2005 through 2010)](image)

Figure 14 – Maximum Daily WWTP Flows

![Maximum Daily WWTP Flow (2005 through 2010)](image)

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A review of the historical SSO records between 2005 and 2010 indicate that the number of chronic SSO’s (i.e. occurring 5 or more times during a 12-month period) have been reduced. Furthermore, the chronic SSO’s are being systematically moved down stream as maintenance and rehabilitation has been concentrated in the upper reaches of the system as indicated in Figure 15.

**Figure 15 – Historical Comparison of Chronic SSO’s**

![Map showing Movement of Chronic SSO’s downstream](image)

**CONCLUSIONS**

Given that less than 8% of the total system pipelines have been replaced or rehabilitated and less than 12% of manholes have been rehabilitated to date, HPUD’s current approach to systematically inspecting, prioritizing and rehabilitating areas of the collection system using the techniques of the Sewer AIM program are having the desired effect of improving system hydraulics and reducing and eliminating SSO’s.