The Value of both Assessment and Inspection Technologies in a Basin-wide Evaluation for the City of Lancaster, SC

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ABSTRACT

In 2013 the City of Lancaster, SC, was placed under an Administrative Order on Consent (AOC) by the Environmental Protection Agency (EPA) in order to reduce and eliminate the incidence of Sanitary Sewer Overflows (SSO) within their collection and treatment system. WK Dickson was retained to aid the City in the negotiation of the AOC with the EPA and manage the implementation of the AOC. The negotiated AOC requires the establishment of a Continuing Sewer Assessment Program (CSAP) including procedural development, documentation and the analysis, rehabilitation and successful operation of three of the City’s sewer basins over the next 5-7 years. In establishing this program between October 2013 and March 2014, the project team first assessed an initial collection basin, then inspected and cleaned the basin, followed up with a full re-assessment of the basin, established a flow monitoring plan and began to process the inspection data to develop a rehabilitation plan. This process has allowed the team to compile data from different tools to determine the effective value of each to operations and maintenance processes.

Specific tools implemented in the course of this study include:

- Assessment – Sewer Line Rapid Assessment Tool (SL-RAT), smoking, dye testing
- Inspection – PACP / MACP standards – Manholes & Line cleaning followed by CCTV
- Basin-wide real time flow monitoring
- Data Collection – development of custom GIS mobile applications
- Data Storage - GIS centric asset management

This paper evaluates the SL-RAT as an assessment technology, PACP coded CCTV as an inspection technology, and the correlation of the findings of each with respect to before and after basin-wide cleaning. Additionally, the paper discusses the other technologies used to quantify and collect data into the IMS for evaluation and prioritization of rehabilitation efforts.

Other elements and work items addressed include the following:

- EPA Consent Order negotiation
- Implementation of an Information Management System (IMS)
- Mobile GIS Application Development for:
  - FOG Inspection Program
  - Sewer Overflow Response Program
  - Gravity Line Maintenance Program
  - SL-RAT assessment
- Manhole Inspections
- Continuing Sewer Assessment Planning (CSAP)

KEY WORDS

SSES, SL-RAT, CCTV, Flow Monitoring, Administrative Order on Consent, EPA, SCDHEC, MOM Programs, SORP, GLMP, CSAP, FOG, Condition Assessment, Gravity Sewer Inspection, Rehabilitation, Prioritization, Asset Management, GIS Mobile Applications
INTRODUCTION

In 2013 the EPA notified the City of Lancaster that they planned to place the City under an Administrative Order on Consent (AOC) to eliminate sanitary sewer overflows (SSOs) from their entire collection and treatment system. The City retained WK Dickson to aid and advise the City in how to best address the requirements of the impending AOC. WK Dickson worked with the City to negotiate the fine, scope, and schedule of the draft AOC to a manageable form that could be implemented in both a feasible fiscal interest of the City and the best interest of the environment, health and welfare of the public.

The objective of the study presented herein, is to focus on the efforts of the City in an initial collection basin to identify the most effective use of assessment and inspection methodologies in the implementation of the structured programs being developed as part of the AOC. While the requirements of the programs to be developed are clear according to the AOC, the specific data acquisition techniques, storage, and reporting requirements are open to interpretation for utility specific implementation. Work order flow, asset management, resource availability and response, field data acquisition, data quality control, and data storage are all considerations in the development of the required IMS developed by WK Dickson and implemented by the City.

METHODOLOGY

The methodology employed and associated technologies break down in the following general categories:

- Communication – City of Lancaster, WK Dickson, EPA, Contractors
- Basin field evaluation
  - Assessment – SL-RAT, Smoking, Dyed water flooding
  - Cleaning and Inspection – Pumper truck / jetting, PACP coded CCTV via robotic crawler and camera truck
  - Flow quantification – Real-time online flow monitors throughout basin
- Development of the IMS – GIS based server repository for all data collected by operation and maintenance staff, field applications on hand-held devices
- Rehab Evaluation - Implement software for defect code based analysis and cost estimation, prioritization using uniform application of risk - based on likelihood and consequence of failure

The focus of this paper will be on the technologies involved with the basin field evaluation; specifically the inspection and assessment technologies. As the data collected in the field was required to meet the standards of the programs being developed and implemented as part of the AOC, the paper briefly discusses the other steps, processes and technologies employed.

Communication

The most critical component in this project was the immediate communication between the City of Lancaster and WK Dickson. The foresight of the City Manager to ask for help in the immediate evaluation all of the City’s options and approach the EPA in a positive manner with the support of their engineer allowed the City to stay ahead of further negative enforcement action. WK Dickson was able to work with the EPA’s draft order to identify areas in most critical need, focus the scope of the Order, negotiate the schedule of the Order and advise the City on best options in reduction of the EPA fine. Additionally, WK Dickson setup meetings with funding agencies and assisted in the evaluation of potential budget impact and likely funding sources to best coincide with the strict schedule of the Order. This upfront coordination allowed the project team to collectively identify plan of action for the City and begin to work through the technical, time-based and financial hurdles presented by the Order even before the Order was finalized.

Basin field evaluation

The initial basin was evaluated in a stepwise manner to identify the best technologies for use in assessing, inspecting, collecting data and storing data in parallel with the development of the various programs required by the Order to be approved by the EPA and implemented by the City.
The programs include the Sewer Overflow Response Plan (SORP), Continuing Sewer Assessment Plan (CSAP), Fats Oils and Grease Plan (FOG), Gravity Line Maintenance Plan (GLMP), and Infrastructure Rehabilitation Plan (IRP). The tools to be implemented in the basin evaluation had to meet the requirements set forth in each of these plans, be captured in a repeatable and reliable manner and be stored in an Information Management System (IMS), also to be developed concurrently and described below. In order to get the project quickly off the ground the SL-RAT IMS application was fast tracked for basin specific implementation.

The SL-RAT application was used in conjunction with the SL-RAT initial assessment and follow-up assessment to provide before and after cleaning snapshots of the system. The SL-RAT uses acoustic technology to determine how clear a passage is through the pipe in one to three minutes. This is possible due to the similarities between how water and sound move through the pipe. The general set up of the SL-RAT device consists of a transmitter and receiver set up on two adjacent manholes. The sequence begins when the transmitter generates sound waves that travel through the pipe to the receiver. The receiver measures the amount of sound that has passed through the pipe and generates a blockage assessment level between 0 and 10 as described in Table 1.

After the transmitter has completed its sequence and the receiver displays the blockage assessment level, the field operator would input the blockage assessment level in the GIS tablet application. Additional information input into the tablet application may include date of inspection and operator name. This process was repeated for each line segment within the basin of interest, approximately 51,000 linear feet (LF).

<table>
<thead>
<tr>
<th>Blockage Assessment Level</th>
<th>Description</th>
<th>Typical Condition of Pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Good</td>
<td>No significant obstructions within the pipe</td>
</tr>
<tr>
<td>7-9</td>
<td>Good</td>
<td>Minor Impediments within the pipe such as joint offsets, partial sags, protruding laterals, debris, minor grease, and/or minor root fibers.</td>
</tr>
<tr>
<td>4-6</td>
<td>Fair</td>
<td>Impediments within the pipe such as joint offsets, partial sags, protruding laterals, debris, grease, and/or root fibers. Single or multiple occurrences.</td>
</tr>
<tr>
<td>1-3</td>
<td>Poor</td>
<td>Significant impediments within the pipe such as multiple joint offsets, near full pipe sag, multiple protruding laterals, significant debris, significant grease, significant root fibers and/or root balls. Single or multiple occurrences.</td>
</tr>
<tr>
<td>0</td>
<td>Blocked</td>
<td>Full pipe sag; single or multiple obstructions within the pipe reaching or nearly reaching the flow.</td>
</tr>
</tbody>
</table>

Once the initial SL-RAT assessment was complete, the entire basin was cleaned, documented with CCTV, and all defects were coded according to National Association of Sewer Service Companies (NASSCO) standards. The follow-up SL-RAT assessment was then performed. The results of these assessments and inspections as well as their relative correlations are presented below in the Results section.
To measure the reduction in wet weather I/I a baseline measurement of wet weather I/I was established using 14 temporary velocity area flow monitors installed in the basin. The information collected from these flow monitors may also be analyzed to identify problem areas.

**Development of the IMS**

The AOC required the development and implementation of an Information Management System (IMS) to serve as the repository for all data collected from the programs being developed and implemented (SORP, CSAP, FOG, GLMP, IRP). In order to standardize and control the flow data, the various processes involved with the wastewater collection and treatment system (WCTS) were considered. These processes included the work order system, the asset registry and inventory (GIS), data storage and existing programs and procedures.

After reviewing the existing state of the WCTS processes and in consideration of the programs and procedures required by the AOC, it was determined that the best path forward would be asset management via a GIS centric platform with field data to be collected via mobile applications. The value presented by the mobile GIS applications includes:

- Real time field based data entry
- Searchable uniform data entry
- Asset based work records and history tied to GIS database
- Standardized approach for each program
- Utility / regulation specific interface

Each IMS application includes the GIS sanitary sewer system map and relevant related assets and attributes including roads, parcels, other utilities, previous SSO locations, FOG device location, etc. Once an asset from the sanitary sewer system is selected in the application the data collected from the inspection may be input. The data collected is used a record attached to the asset which may be used for future reporting and evaluation or to measure the effectiveness of rehabilitation and replacement projects. The initial IMS application, SL-RAT, was fast-tracked to begin the initial assessment on the first basin while other programs and the IMS was being developed. This application was used in the field evaluation as discussed above and presented in the results section below.

**Rehab Evaluation**

Once the basin has been assessed, inspected and the data collected and stored in the IMS, the evaluation of the data to produce an rehabilitation plan may be performed. This evaluation includes the development of a flow chart to determine actions to be taken based on defects found within a given pipe segment. Costs associated with each action are determined and correlated to the actions to be performed. The basin is then processed according to this evaluation paradigm, the assets are scored based on condition, repair recommendation made and associated costs are generated. Once these results are produced, a risk prioritization procedure is applied to determine which rehabilitation projects should be carried out first. This prioritization process is developed based on the basin characteristics, surrounding features, past history and any other specific consideration that may be of import to the concerned parties. The risk is then determined based on the confluence of likelihood and consequence of the failure of each asset and weighted according the actual condition of the asset. Given the prioritized list, a rehabilitation plan is then developed.

**RESULTS**

**IMS Applications**

The IMS applications are being developed to collect data from manhole inspections, smoke testing, dye testing, corrosion defect assessments, pump station assessments, and SL-RAT inspections. The SL-RAT application has been successfully implemented in the initial basin to capture field data and record it.
in the IMS. The remaining applications remain under development and will be implemented in conjunction with the specific programs as approved by the EPA.

SL-RAT

The initial assessment results, shown in Figure 1, indicate that 65% of the lines were rated between “Fair” and “Good”. Alternately, the other 35% of the lines were found to be “Poor” or “Blocked”. On a normal basis, the lines that were determined to be “Fair” or “Good” may have been left alone and all the focus would have gone into the “Poor” and “Blocked” Lines. For the purpose of this study all lines were cleaned and underwent CCTV inspections. Figure 2 displays the color coded map of the initial SL-RAT results.

![Figure 1. Results of initial SL-RAT assessment](image1)

Following the cleaning and CCTV inspection of all the pipes, follow up SL-RAT inspections were made, the results are displayed in Figure 3. The amount of “Good” ratings increased by over 22% compared to the initial assessment. Similarly, the number of “Fair” results increased by over 12% compared to the initial assessment. Alternatively, the amount of “Blocked” and “Poor” results decreased from the initial assessment by 40% and 35%, respectively. Figure 4 displays the color coded map of the SL-RAT results after cleaning and CCTV inspections.

![Figure 3. Results of post cleaning SL-RAT assessment](image2)
Figure 2
Before Cleaning
SL-RAT Values

Legend
- Not Completed
- Blocked
- Poor
- Fair
- Good
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Figure 4
After Cleaning
SL-RAT Values

Legend
- Not Completed
- Blocked
- Poor
- Fair
- Good
Additional analysis was done to verify the accuracy of the SL-RAT assessments. Table 2 displays the results of the comparison between the initial assessment and post cleaning assessment. It can be seen in this table that 97% of pipe segments had SL-RAT scores that either stayed the same, were ± 1 (Infosense’s reasonable margin of error) or increased after pipe cleaning.

<table>
<thead>
<tr>
<th>Table 2. Comparison of Pre and Post Cleaning SL-RAT Results</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Number of lines that stayed the same</td>
</tr>
<tr>
<td>Number of lines that were ± 1 of original test</td>
</tr>
<tr>
<td>Number of lines that increased more than 1</td>
</tr>
<tr>
<td>Number of lines that decreased more than 1</td>
</tr>
</tbody>
</table>

CCTV Inspections

The entire basin was cleaned and CCTV inspections were performed on all the lines in accordance with NASSCO’s PACP standards. PACP is a standard coding system for pipe defects, each defect can be scored as a structural or an operation and maintenance defect. Table 3 presents the summary scores for pipe defects detected in the CCTV inspections.

<table>
<thead>
<tr>
<th>Table 3. Defect Score Distribution</th>
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<tbody>
<tr>
<td>Score</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1 / 0 / Other</td>
</tr>
</tbody>
</table>

Using the results of defect coded CCTV, evaluation of the pipeline segments within the basin were carried out and the resulting summary of recommendations is presented in Table 4.

<table>
<thead>
<tr>
<th>Table 4. Rehabilitation Recommendations</th>
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</thead>
<tbody>
<tr>
<td>Recommendations</td>
</tr>
<tr>
<td>No Action</td>
</tr>
<tr>
<td>Full Lining</td>
</tr>
<tr>
<td>Point Repairs</td>
</tr>
<tr>
<td>Point Repair and Full Lining</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>
DISCUSSION

GIS Mobile Applications and the IMS
Using the IMS as the platform for data collection became a critical part of the response to the AOC. Once data was input into the IMS application it could be analyzed and GIS maps produced for visualization of specific issues. Additionally, reports can be generated based on the history of the assets for many different purposes. Some of these purposes may include: report of which pipes have a history of blockage, report of which FOG permitees have had violations over a given period or are up for inspection, report of which assets are in danger of failure due to corrosion and when were they last inspected, etc. The data accumulated in the IMS can be used for many purposes.

SL-RAT Assessments & CCTV Inspections
The comparison of the pre and post cleaning SL-RAT results indicate that the overall assessment of the pipe segments by using SL-RAT inspection is accurate. A general margin of error has been established by the manufacturer (InfoSense) as being ± 1. Therefore all lines with a change in SL-RAT value of 1 should not be considered and greater importance should be given to pipe segments that increased or decreased by more than one SL-RAT value. Generally speaking most pipe segments will have a clearer pathway after a thorough cleaning, which is supported by the fact that 26% of the pipe segment’s SL-RAT values increased by two or more after cleaning. The four pipe segments that decreased in SL-RAT value by two or more may be attributed to the fact that some pipes may have a decreased pathway due to changing sanitary sewer conditions like the accumulation of roots, grease, or debris in the pipe segments.

The CCTV inspections were used to locate specific defects as well as to compare to the results of the SL-RAT assessments. There does not seem to be a direct correlation between the severity of specific defects as scored by the PACP and the SL-RAT values. The current flaw in comparing CCTV defect scores to SL-RAT values is that the CCTV defect scores consider the likelihood and severity of a failure, as well as the position of the defect (top or bottom of the pipe), and the percentage of pipe that the defect is blocking.

A general comparison of the range of SL-RAT results from the post-cleaning assessment and the incidence of mid to major defects in pipe segments did produce significant results, with most defects being found in the mid-range of SL-RAT assessment (4-8). The SL-RAT scores indicating near or complete blockage (1-3) showed a lower incidence of defects. This may be explained by sags or high water levels, but not blockages. Pipes in this range with defects causing blockages have likely been detected and repaired, moving them out of this low assessment range. The SL-RAT scores indicating clear pipes (9-10) also have a low incidence of defects as would be expected.

CONCLUSIONS

Break your system EVALUATION into component parts, two of which are ASSESSMENT and INSPECTION. Research and identify the tools that will make your life easy, but don’t confuse what they are for. SL-RAT is a useful technology to ASSESS the system in a relatively fast fashion as compared to CCTV inspection. However, the results obtained are only representative of a snapshot of that very instant, telling you how open the pipe is to receive flow right then. CCTV is a useful technology for INSPECTION of the system but is relatively more time consuming than SL-RAT assessment. The results obtained detail the specific location and apparent extent of defects within the pipeline to a much greater level. Operationally, both technologies are valuable. Staff resources are limited, evaluation of a large system may include a complete ASSESSMENT to help drill down where known flow constraints are likely to cause problems. INSPECTION may be used as a follow-up in these areas for specifics as to what needs to be fixed. However, INSPECTION should continue to be a primary objective throughout the system on a regular basis to ensure that assets are properly maintained.

Relatively speaking, sewer systems are old, while easy access to computers, big data and spacial information systems is new. Every day operation of a WCTS produces, or at least exposes the WCTS staff to large amounts of data on the old systems. Efficient use of technology to record, store and access
this data in the execution of daily tasks is essential to the needed rejuvenation of the old systems in a fiscally responsible manner. The technologies and implementations presented above demonstrate one approach tailored to the specific needs of an individual utility. Work order systems, asset management programs, field applications, assessment technologies and inspection tools will continue to develop. Utilities should begin to identify where they are today, figure out where their system condition will dictate they are in 5, 10, 20, 50 or 100 years from now, and begin to gather the data necessary to plan for the fiscal eventuality. No asset is designed to last forever, even if you bury it, especially your head.

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