North American Society for Trenchless Technology (NASTT)
NASTT's 2015 No-Dig Show

Denver, Colorado
March 15-19, 2015

TA-T1-01

Implementation of Acoustic Inspection Technology at the City of Augusta, GA

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1. ABSTRACT

The City of Augusta, GA manages 1,040 miles of gravity sanitary sewer mains over an area of 280 square miles. In February 2013, they began using the Sewer Line Rapid Assessment Tool (SL-RAT) to help prioritize cleaning operations. They have since added several devices and have worked toward incorporating the technology into their asset management program.

Currently, the SL-RAT is used by 2 person crews to perform acoustic inspections. The average rate of inspection is approximately 7,500 linear feet per day per crew. Inspection areas are planned out based on tax maps, and then the information obtained from the inspection is used to prioritize cleaning operations. Over 12,000 segments (3 million feet) have been inspected since the program started. Results from these acoustic inspections indicate that even a conservative cleaning policy guided by acoustic inspection would result in a substantial reduction in the amount of cleaning that needs to be performed. Based on these results, cleaning for the segments considered can be reduced anywhere from 60% to 85%.

Use of this device as a preliminary screening tool has resulted in substantial cost savings, while simultaneously reducing the amount of sanitary sewer overflows (SSO's). Financial impact of using the technology, along with an evaluation of SSO reduction will be discussed. In summary, use of this technology has shown that acoustic inspections can be performed quickly and cheaply, and are an effective tool for asset management.

2. INTRODUCTION

Municipal wastewater collection system managers face significant challenges in today's environment including 1) Managing vast networks of pipes 2) Coping with aging infrastructure 3) Complying with ever more demanding environmental regulations and customer service expectations and 4) Facing pressure to improve efficiency and to avoid rate increases. The United States has approximately 700 to 800 thousand miles of sewer lines (American Society of Civil Engineers, 2013). And, in the United States alone, capital investment needs for wastewater and storm water collection systems are estimated at $298 billion over the next 20 years (American Society of Civil Engineers, 2013). These significant demands for aging infrastructure reinvestment squeeze operating budgets. The U.S. EPA, as well as increasingly, state regulators and non-governmental organizations are forcing utilities to improve their system performance and reduce CSO's/SSO's through Consent Orders and Consent Decrees. Industry experts believe the EPA's stance "will be to maintain or increase enforcement" for the foreseeable future (WaterWorld, 2013). All of the previous trends point toward increasing costs, but the current economic and political environment makes rate increases even more unpalatable than in the past. As Bob Woodhouse of MWH Global states further in his recent Waterworld interview, "Utilities need to take a hard look at system maintenance as part of

the overall approach to reducing discharges…A comprehensive CMOM approach may help to identify cost effective solutions" (WaterWorld, 2013).

As part of a comprehensive Capacity, Management, Operations, and Maintenance (CMOM) program, implementation of Condition Based Maintenances (CBM) strategies for utility assets can provide critical new capabilities to collection systems managers. These new CBM technologies enable utilities to better utilize and prioritize their allocation of expensive and limited maintenance resources for a variety of asset classes from pumps and force mains to gravity-fed sewer lines.

Specifically, it is well known that a significant portion of cleaning resources in most wastewater utilities are wasted on unnecessary cleaning of small diameter gravity-fed lines, (those that range between 6" and 12" in diameter). This occurs because operators lack effective tools to objectively prioritize which pipes to perform CCTV inspection and cleaning activities on within their network. This misallocation of resources not only creates inefficiency, it allows for blockages to build up and ultimately result in undesirable SSO's.

To assist utilities in reducing SSO's through improved maintenance focus, a recently commercialized acoustic inspection technology enables economical pre-cleaning assessment of small diameter gravity-fed sanitary sewer lines. The product called the Sewer Line Rapid Assessment Tool, or SL-RAT® has been evaluated by the U.S. EPA which states:

> "The emergence of acoustic sewer inspection technologies, like SL-RAT, as rapid deployment, low-cost, reliable, pre-cleaning assessment tools is focusing growing attention on the potential for more cost-effective sewer cleaning programs. Through the ease of deployment, reduction of cost, increases in reliability of these inspection approaches, combined with the potential for reducing the "cleaning of clean pipes," significant cost savings are attainable. As utilities apply these new inspection technologies, they can move towards implementing sewer cleaning programs that consist of planned directed and quick response, reactive cleaning. Also, these cost savings can be realized while improving collection system performance and the protection of public health and water quality." (Pangulari, Skipper, & Donovan, 2014)

This paper focuses on the City of Augusta's experience with implementing a comprehensive pre-cleaning assessment program using this new acoustic inspection technology.

3. BACKGROUND

The City of Augusta's (City) sewer system is one of the oldest in the Southeastern United States and traces its history back to a combined system that began in the 1860's. In 1996 Augusta and Richmond County merged their wastewater collections operations and today operate as one entity. The City's utility currently manages a 1,040 mile sewer collection system that services a population of over 190,000 people spread over 280 square miles.

The utility itself has operated under numerous Consent Decrees issued by the Georgia Environmental Protection Division dating back to the late 1980s primarily related to discharge levels and the construction and operation of wastewater treatment facilities. In June 2011, Georgia EPD issued Consent Decree #EPD-WQ-5309 which required Augusta to "implement the City's Corrective Action Plans and Schedules (CAP) for the collection system" which includes "The evaluation and point repairs for the entire collection system" (Georgia Environmental Protection Division, 2011). Since entering the Consent Decree, the City has worked diligently against the CAP to meet the requirements set forth while also evaluating how new technologies and processes could improve the effectiveness of the City's collection system maintenance program.

For pipe cleaning Augusta has two city-owned combination cleaning trucks as well as access to cleaning contractors on an as-needed basis. The combination truck fleet is enhanced by seven one-person rodding units. On the inspection side, Augusta owns a Squad of four RedZone Solo cameras as well as an Envirosight ROVVER-X for inspection of large diameter lines and two PANERAMO® cameras from RapidView IBAK. As part of the overall performance improvement effort, the SL-RAT technology was reviewed through a field demonstration with the vendor in late 2012. The first SL-RAT was purchased in February 2013 for use by the Asset Management and Cleaning Departments. Two more SL-RAT units were purchased in late 2013 and early 2014. The City's

collection system maintenance organization currently operates these SL-RAT devices as a complement with their existing maintenance and inspection assets described above.

The Asset Management and Collections departments have focused over the past two years on shifting from a reactive to a proactive maintenance strategy as well as on getting storm water out of the collection system to reduce or eliminate SSO's. The SL-RAT technology has provided crucial support to these initiatives. As of August 2014, SL-RAT crews had completed an acoustic survey of the entire approximately 700 miles of small diameter gravity-fed sewer lines. Over that time, the trailing twelve month SSO rate has declined almost 33% from 4.5 SSO's per month to 3.0 SSO's per month as show in Figure 1 below. Importantly, it should also be noted that SSO spill volume has also declined significantly as well as seen in Figure 2.

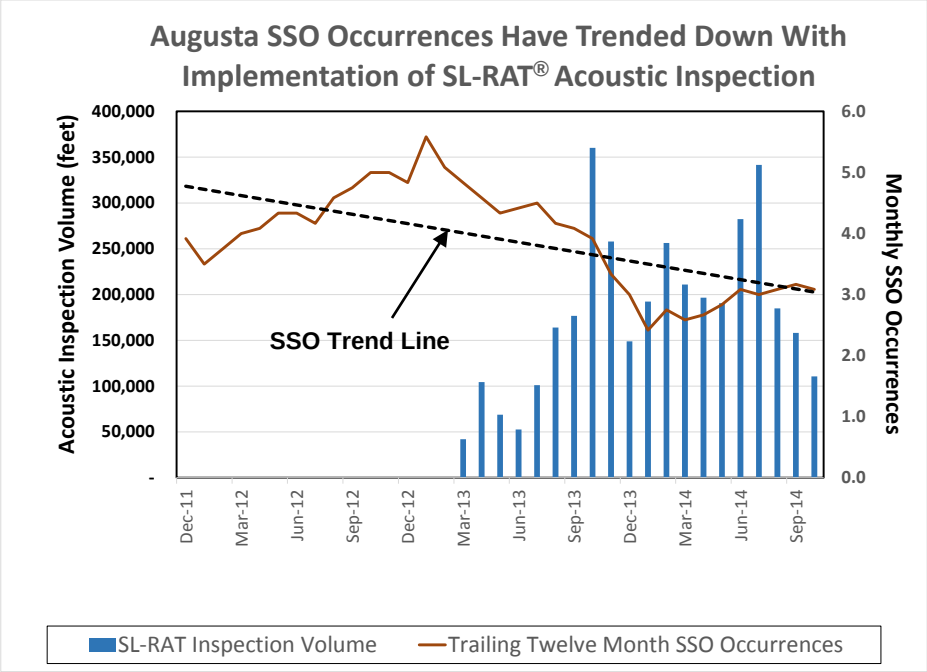


Figure 1 – Augusta Monthly SSO Trend Plotted with Acoustic Inspection Volume

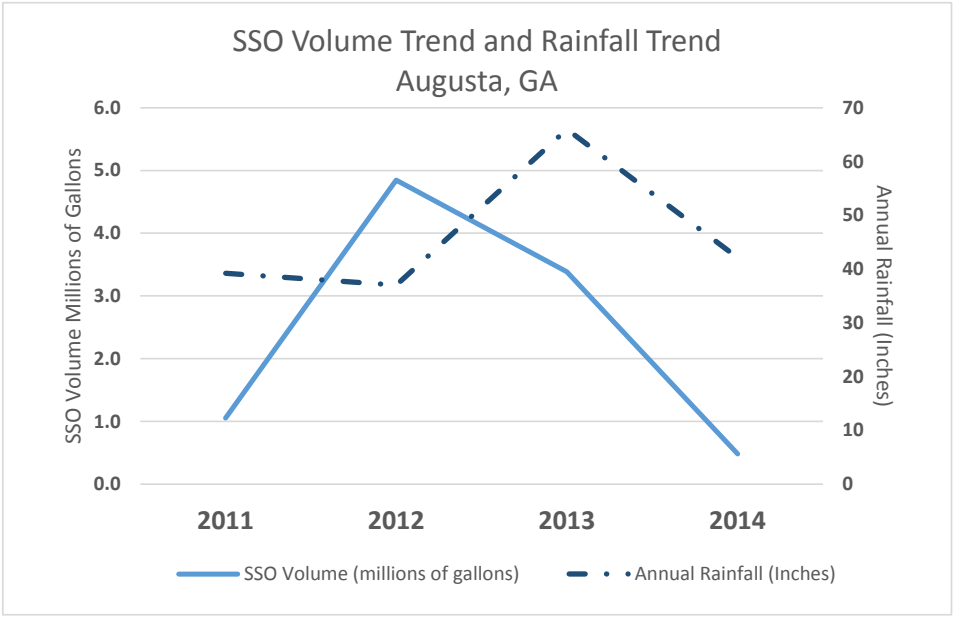


Figure 2 – Augusta SSO Volume Trend and Rainfall Trend

4. OVERVIEW OF THE ACOUSTIC INSPECTION TECHNOLOGY

The Sewer Line Rapid Assessment Tool, or SL-RAT®, provides blockage assessments on gravity sewer lines in less than 3 minutes. The acoustic score for the segment ranges from 0 to 10 (0 – blocked, 10 – fully open pipe), and is typically used to help prioritize cleaning and CCTV inspection resources. The Sewer Line Rapid Assessment Tool (SL-RAT) exploits the similarities and difference between water and sound transmission through a sewer line segment in order to diagnose the extent of the pipe's blockage. This novel and patented methodology is based on measuring the signal received through an active acoustic transmission between manholes. Figure 3 depicts the general configuration of the SL-RAT device. The acoustic transmitter generates sound waves just below the entrance to the manhole which naturally couple into connecting sewer line segments, whether the depth of the manhole is 3 feet or greater than 30 feet. The sound wave propagates in the air gap above the wastewater flow from the speaker in the Transmitter to the receiving microphone in the Receiver located at the adjacent manhole. Segment lengths exceeding 800 feet have been successfully evaluated. The acoustic receiver measures the acoustic plane wave from the transmitted signal in order to evaluate the condition of an entire segment and provides an onsite aggregate assessment of blockage condition. An important practical aspect of the SL-RAT is that both the speaker and the microphone are placed just within the opening of the manhole and never come in contact with the wastewater flow and therefore, the operators have no requirement for confined space entry.

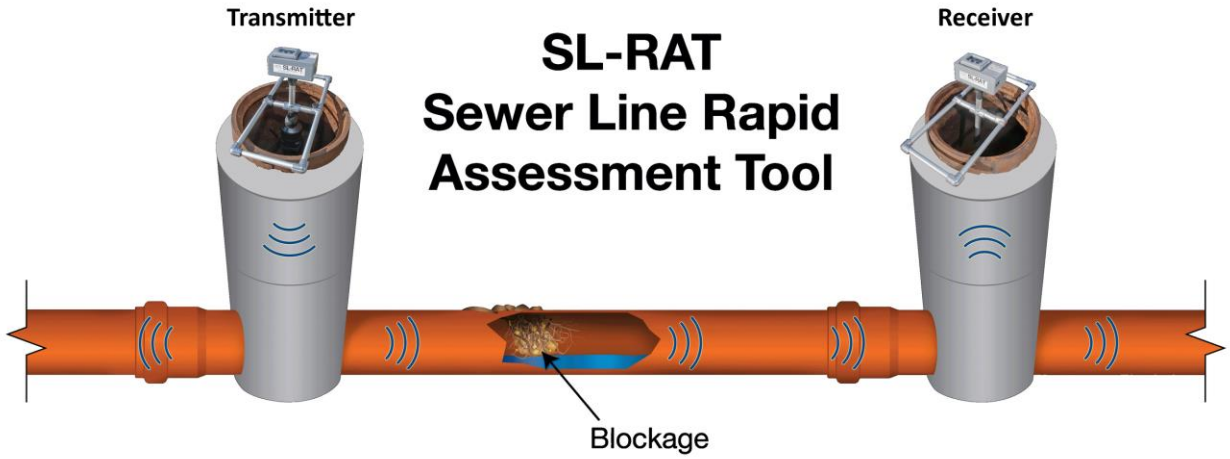


Figure 3. Operation of the Acoustic Inspection System

A pipe segment is a natural acoustic waveguide (Philip & Ingard, 1968). Commonly encountered sanitary sewer defects, such as roots, grease, pipe sags and pipe breakages naturally absorb or reflect acoustic energy. These defects change a segment's acoustic properties and produce a measurable impact on the received signal at the microphone, i.e., the segment's acoustic fingerprint (SAF). Each segment has an individual SAF representative of its current state. The SAF changes over time as the condition of the segment varies. The SL-RAT uses the SAF to determine the SL-RAT Blockage Assessment, i.e., an estimate of the aggregate blockage within the pipe segment between the acoustic transmitter and acoustic receiver. The aggregate blockage assessment is provided to the operator at the end of each test on the scale from 0-10 with "0" indicating complete blockage and "10" indicating a fully unblocked segment. Based on budgetary and risk management constraints, the blockage assessment information enables the collection system operator to better prioritize subsequent cleaning or CCTV inspection activities.

The pipe remains in service when conducting an inspection with the SL-RAT and the transmitter and receiver are in most cases interchangeable between upstream and downstream locations. The operator enters an estimate of the pipe length in the SL-RAT within 100 feet when making a measurement as the length of the pipe can affect the strength of the acoustic signal. The receiver will suggest a pipe length when GPS is available. And, if a mistake is made in the pipe length estimation process, the data can be re-evaluated/re-scored after the data is downloaded from the device within an accompanying cloud-based service called the Sewer Line Data OrGanizer, or SL-DOG™.

Using the SL-RAT's scale of 0-10, the Augusta team has chosen to initiate maintenance or further inspection activity for pipe segments that receive an acoustic score of "3" or below. This is typical of most municipal customers that have implemented the SL-RAT as part of their collection system maintenance program.

5. IMPLEMENTATION DETAILS

Initially the SL-RAT was used in Augusta on an ad hoc basis to pre-assess basins prior to cleaning. In the first week of use, a 36,000 foot basin was evaluated acoustically to test the device's efficacy in targeting cleaning activity. The basin had previously been added to the cleaning schedule because of neighborhood complaints about slow flow and because of prior service issues in the area. The City had planned to use a contractor to clean the entire basin at a cost of approximately $40,000. A two person SL-RAT team was able to inspect the entire basin acoustically in under a week, and found that only approximately 3,500 feet of pipe needed to be cleaned. This initial effort essentially paid for the investment in the first SL-RAT.

With this success under their belt, the Asset Management team began deploying the SL-RAT on a project-specific basis in concert with the Cleaning Team. Continued successes led them to develop a vision for screening the entire ~700 miles of small diameter gravity-fed lines with the SL-RAT on an annual basis and to tie the acoustic inspection program in with their existing manhole inspection program.

A second SL-RAT was added in August 2013 to assist with screening the entire system. The Asset Management team began using tax maps to plot out inspection areas and to drive competition between the two crews. The crews averaged approximately 7,500 feet per day each. Because some manholes were difficult to access and/or to locate, a third unit was added in February 2014. The team uses this third unit to "mop up" behind the two screening crews. The third unit also assists with post cleaning quality assurance and functions as a spare.

The field crews have found the SL-RAT work attractive because it is cleaner and easier than other activities such as jetting, rodding, excavation, etc. The management team has found the ease of use, speed, durability, and real-time data provided by the SL-RAT allows them to prioritize the pipes that need the most attention and avoid "cleaning clean pipe".

6. LESSONS FROM IMPLEMENTATION

The City of Augusta's Asset Management team has found the SL-RAT to be simple, reliable, and easy to use. These features were key to developing buy-in from the field crews as well as for generating quality data. The Asset Management Team also learned that because the SL-RAT requires each inspection to occur between adjacent manholes for reliable results, it forced the discipline of visiting and/or locating every manhole in the system. GIS data errors are flagged as they are discovered and missing or remote manholes are located and evaluated systematically. Unknown manholes have even been located on occasion because they typically lower the acoustic score and can trigger a CCTV inspection or identify GIS errors where pipes show connections that do not exist. Consequently, Augusta has substantially improved the accuracy of their collection system GIS data over the past eighteen months while developing a tighter partnership with the GIS department that gets most issues identified corrected within 2-3 business days.

With three crews in the field almost daily, the Asset Management team receives test results for approximately 100 segments or 200 manholes each day. They have learned from experience to keep up with the data - DAILY! Backlogs can get overwhelming quickly. Assuming 20% of lines score under a 3 on the acoustic scale, this means the team is initiating follow on cleaning or inspection activity for roughly 20 pipe segments per day. This does not include scheduling missing manholes for location, setting up traffic control were needed, correcting GIS errors, etc. To accomplish all of these tasks requires teamwork and inter-departmental coordination to achieve full potential – cleaning crews, GIS, inspection crews – must all work together.

7. MANAGING THE PROCESS AND THE DATA

The City of Augusta manages the SL-RAT program using the process flow shown below in Figure 4.

Step 1: Augusta has chosen to acoustically screen their entire system on a regular basis and has found that significant efficiencies are obtainable by focusing the SL-RAT crews geographically in one area at a time. The Asset Management team found that providing the crews with paper copies of each tax map area with parcel numbers, manhole ID's, pipe lengths and pipe locations worked best. Crews are able to plan out their inspection routes, keep track of where they have been and where they need to go as well as make notes about GIS corrections needed, special situations, etc.

Step 2: Crews conduct inspections using the SL-RAT. The SL-RAT components are recharged daily to ensure the batteries are full for the next day's activity.

Step 3: Each morning before the crews go out, the SL-RAT's are downloaded. The receiver, or RX, component stores up to 199 measurements that can be downloaded via a USB cable to a PC. Each SL-RAT measurement receives a unique time-stamped measurement ID that includes map-grade GPS coordinates for both the TX and RX to assist in data registration as well as provide information about the quality of the test results. An example of the data output available in the SL-DOG cloud application is shown below in Figure-6.

Step 4: After downloading the results are checked against the crew's notes, correlated with manhole ID's and pipe segments, and evaluated to ensure the tests were performed correctly – i.e. pipe lengths were entered accurately, the transmitter, or TX, was started prior to the receiver, etc.

Step 5: The inspection results and notes are translated to ESRI's ArcView software.

Step 6: Follow up actions are initiated via work order and/or by communication with the appropriate department

Step 7: Work orders are closed out as issues are resolved

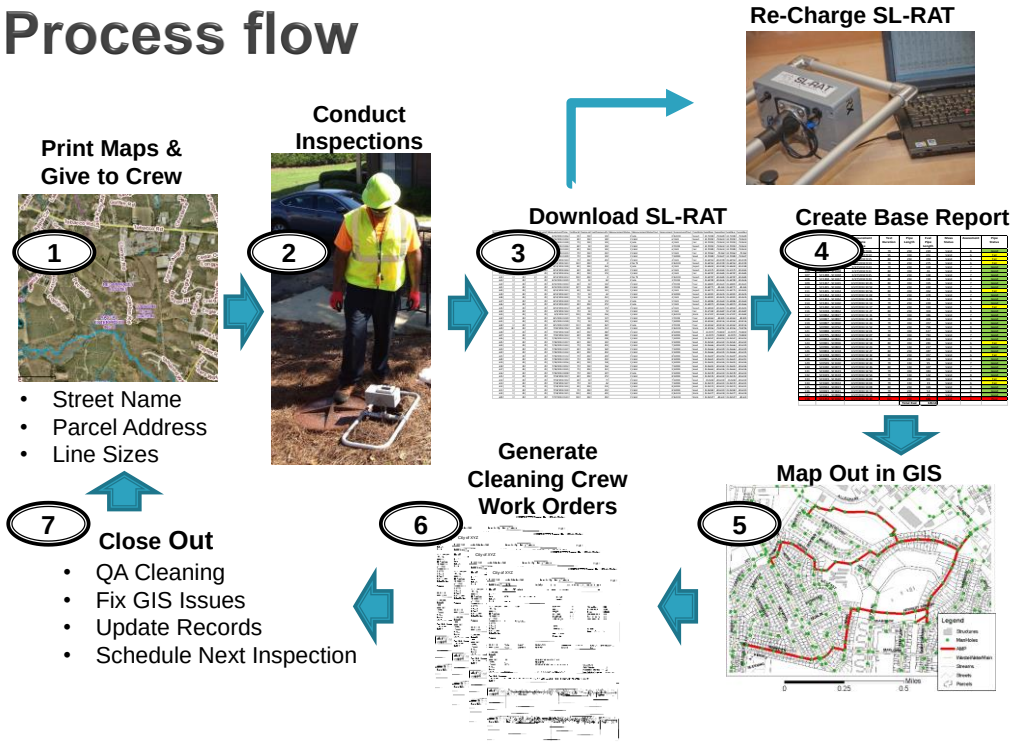
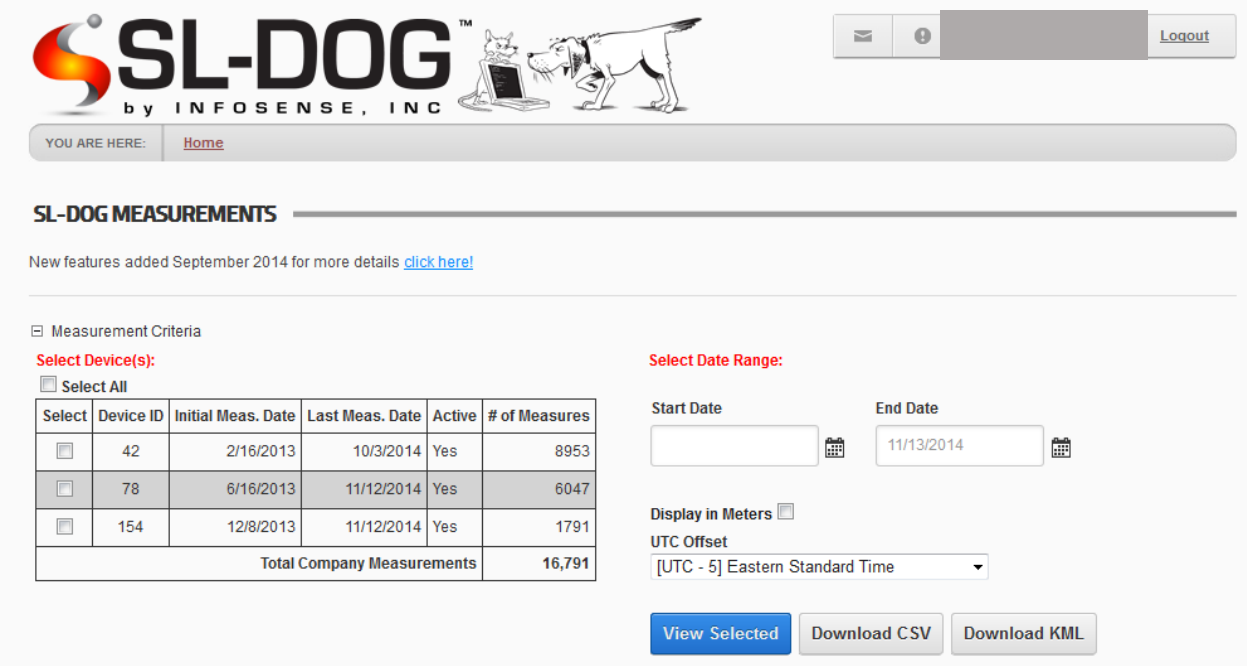


Figure 4 – Process for Conducting Acoustic Inspections

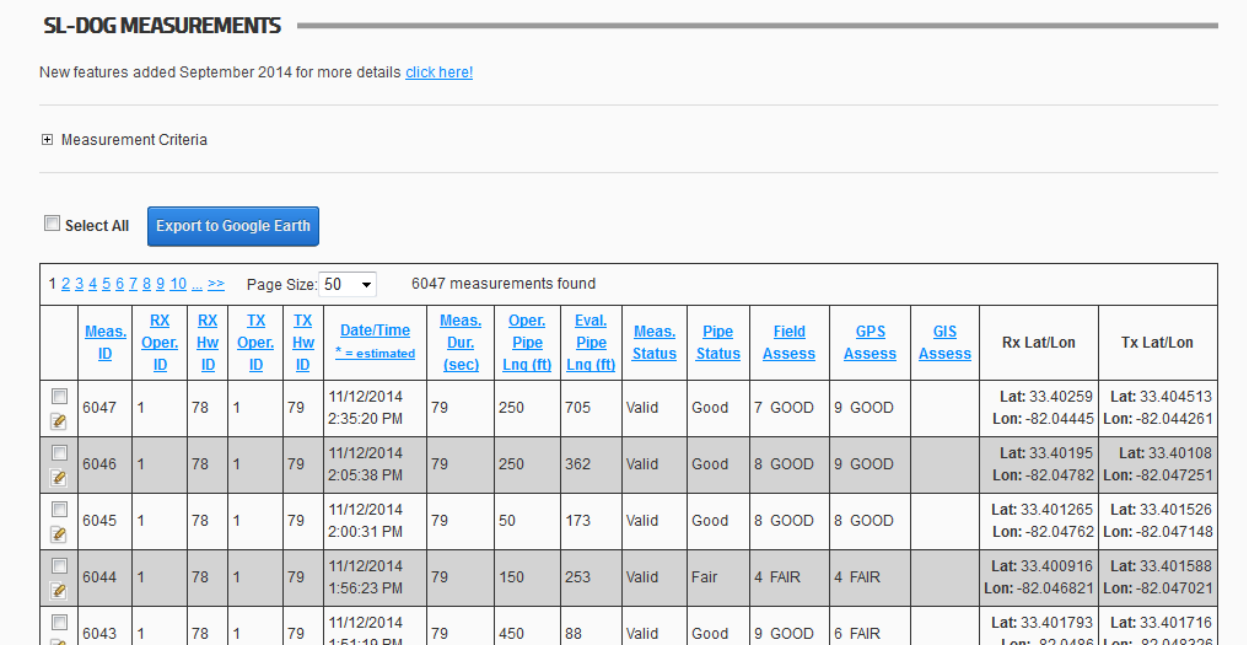
The Sewer Line Data OrGanizer or SL-DOG™ web portal at www.sl-dog.com can also be used by management and scheduling staff to check for measurement validity, view measurement data graphically in Google Earth, as well as

to manage crew productivity and to review result data. Several representative screen shots of the SL-DOG software and its features are shown below in Figures 5, 6, and 7.



Select	Device ID	Initial Meas. Date	Last Meas. Date	Active	# of Measures
	42	2/16/2013	10/3/2014	Yes	8953
	78	6/16/2013	11/12/2014	Yes	6047
	154	12/8/2013	11/12/2014	Yes	1791
			Total Company Measurements		16,791

Figure 5 – Device Management Summary Screen



	Meas. ID	RX Oper. ID	RX Hw ID	TX Oper. ID	TX Hw ID	Date/Time * = estimated	Meas. Dur. (sec)	Oper. Pipe Lng (ft)	Eval. Pipe Lng (ft)	Meas. Status	Pipe Status	Field Assess	GPS Assess	GIS Assess	Rx Lat/Lon	Tx Lat/Lon
	6047	1	78	1	79	11/12/2014 2:35:20 PM	79	250	705	Valid	Good	7 GOOD	9 GOOD		Lat: 33.40259 Lon: -82.04445	Lat: 33.404513 Lon: -82.044261
	6046	1	78	1	79	11/12/2014 2:05:38 PM	79	250	362	Valid	Good	8 GOOD	9 GOOD		Lat: 33.40195 Lon: -82.04782	Lat: 33.40108 Lon: -82.047251
	6045	1	78	1	79	11/12/2014 2:00:31 PM	79	50	173	Valid	Good	8 GOOD	8 GOOD		Lat: 33.401265 Lon: -82.04762	Lat: 33.401526 Lon: -82.047148
	6044	1	78	1	79	11/12/2014 1:56:23 PM	79	150	253	Valid	Fair	4 FAIR	4 FAIR		Lat: 33.400916 Lon: -82.046821	Lat: 33.401588 Lon: -82.047021
	6043	1	78	1	79	11/12/2014 1:51:19 PM	79	450	88	Valid	Good	9 GOOD	6 FAIR		Lat: 33.401793 Lon: -82.0486	Lat: 33.401716 Lon: -82.048326

Figure 6 – SL-DOG Data Summary Display

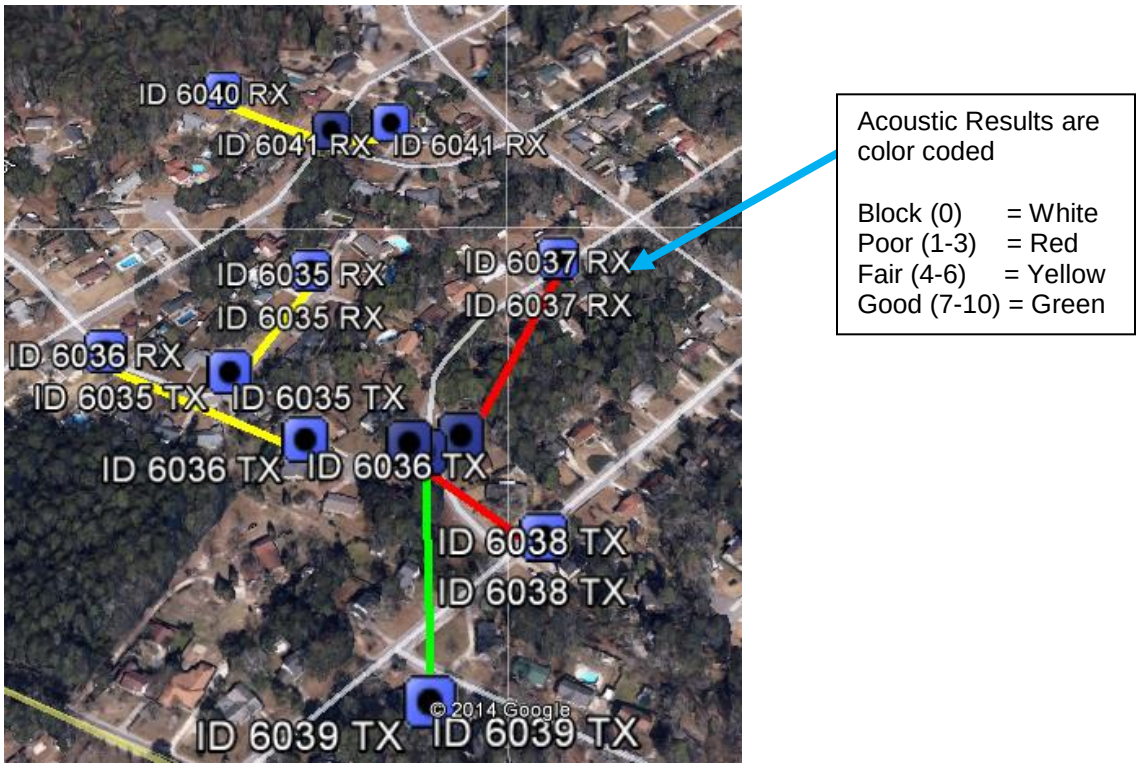


Figure 7 - Visualization of SL-RAT Measurement Data in Google Earth

9. RESULTS AND BENEFITS

The three SL-RAT field crews have inspected almost 16,000 segments totaling over 3.6 million feet of pipe in eighteen months. This accounts for almost 100% of the City of Augusta's system that is gravity-fed and below 15 inches in diameter as shown in Table 1 below by SL-RAT device ID.

Table 1 – Inspection Statistics by Device ID

SL-RAT ID	Estimated Feet of Pipe Inspected*	# of Segments Inspected
42	1,999,495	8,560
78	1,242,151	5,657
154	392,642	1,625
Totals	**3,634,288**	15,842

This information about pipe blockage condition, GIS error correction, and manhole condition has been provided in near-real time and for a cost on the order of $350,000 to $500,000. To have conducted a similarly sized inspection campaign using CCTV could easily take several years and cost several million dollars. That being said, the SL-RAT's inspection resolution does not approach that of CCTV and therefore should be considered a complementary pre-inspection and prioritization tool rather than an outright alternative to CCTV.

Ultimately, the SL-RAT inspection campaign has provided a high level snapshot of Augusta's system condition as shown in the Figure 8 histogram. These results allowed the collection system management to focus their limited resources away from the 9,863 "GOOD" segments that scored as largely unblocked and allocate their resources more effectively toward the 2,748 segments that scored "POOR". This has contributed to Augusta's significant improvement in SSO performance and to their efforts to move from a reactive to a proactive maintenance strategy.

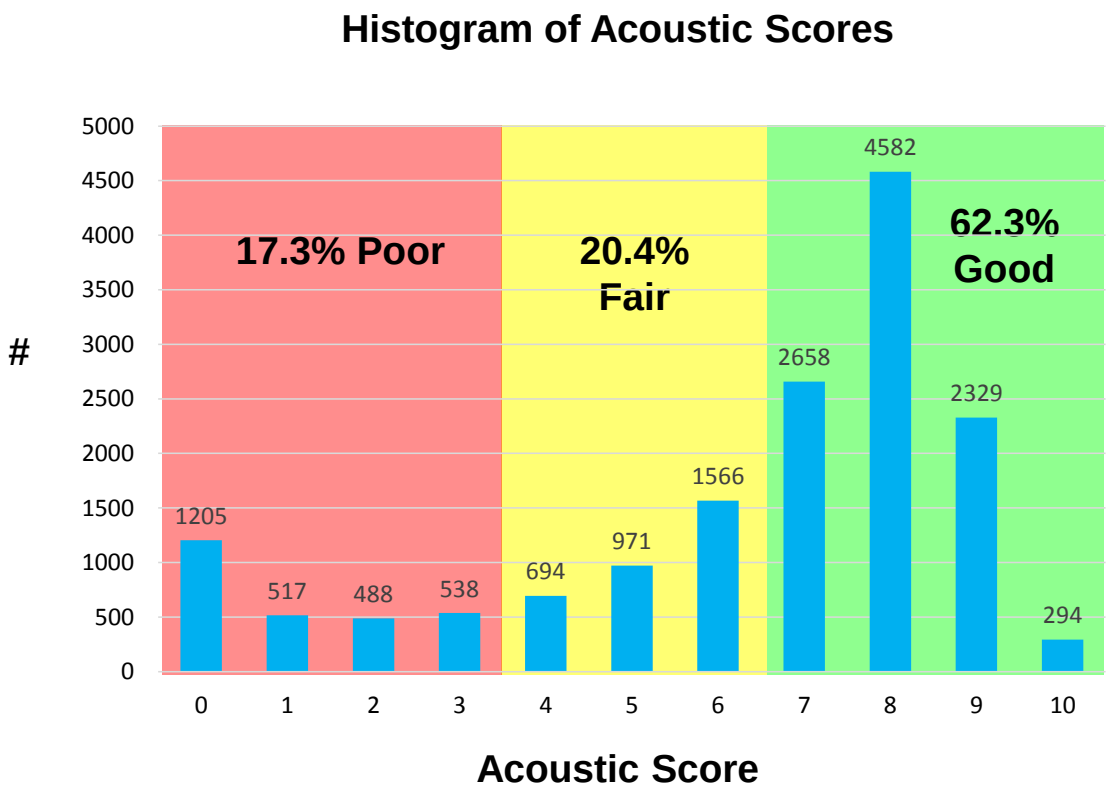


Figure 8 – Distribution of Acoustic Inspection Results for 688 miles of Sewer Line

10. NEXT STEPS

Augusta plans to continue improving their SSO performance and to expand their existing collection system maintenance capabilities over the next several years. These improvement efforts include purchases of new equipment, implementation of new software tools, and further exploitation of the condition assessment information provided by the SL-RAT technology.

The City plans to purchase several additional push cameras in 2015 to augment their existing camera fleet as well as several more combination cleaning trucks to increase their pipe cleaning capacity. This increased camera and cleaning capacity will improve reaction times and further enhance the move from reactive to proactive maintenance.

After 2016, a major implementation of Cityworks® GIS-centric asset management software will be complete with essentially all information about the City's system under one platform. At that time, the ability to use historical trending of SL-RAT data as part of an integrated Condition Based Maintenance program will become practical. As these changes are absorbed, it is even envisioned that more SL-RAT's may be purchased to reduce the acoustic screening interval of the small diameter gravity-fed system to something closer to a six month frequency from the current goal of acoustically inspecting each segment once per year.

11. CONCLUSION

As noted in Figures 1 and 2 previously, the City of Augusta has significantly reduced both the SSO rate and their SSO volume over the past two years. Many factors contribute to this improvement including efforts to reduce I&I, improve pump station reliability, and better pipe cleaning effectiveness among others.

The SL-RAT has provided critical near real-time condition assessment information to focus cleaning efforts in a practical and economical way. This new capability has enabled Augusta to focus their cleaning efforts and more

quickly realize desired system improvements. This has allowed the move from a reactive collection system maintenance strategy to a proactive collection system maintenance strategy centered on condition assessment.

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