ABSTRACT

The City of Fort Worth’s wastewater collection system includes more than 255 miles of large diameter interceptor sewers 24-inches in diameter or greater. The City has recognized the need to determine the condition of these vital large diameter sewers and develop recommendations for a long term capital improvement plan. As a result of these needs, the City has initiated an Interceptor Condition Assessment Program (ICAP) for the large diameter sewer interceptor, with an initial duration of six years.

The City of Fort Worth has implemented an innovative approach to condition assessment of its large diameter sewer interceptor system. The approach uses a combination of HD CCTV, sonar and laser technology to inspect pipe segments. The combination of these three technologies provides the City with a 3 dimension model of the pipe wall and an advanced tool for making long term and short term rehabilitation decisions.

One of the primary objectives of ICAP is to assign a score to each pipe segment that represents its condition. The estimated remaining useful life of a pipe segment is based on the pipe condition score. The pipe wall thickness from the pipe specification data establishes the original inside diameter of each pipe segment. The laser profiling measures the amount of wall thickness loss. The difference between the inspected inside wall location and the original inside wall location is used to calculate the estimated wall loss. The wall loss or remaining wall thickness is used to assign pipe segment condition scores. The remaining wall thickness may vary along the length of the pipe segment depending on the rate of corrosion along the pipe segment. This paper will discuss the technology utilized by Fort Worth along with the benefits of the ICAP program. Some of the major benefits include reduced capital improvements, reduced reactive maintenance and cleaning costs, and enhanced understanding and knowledge of assets status and life cycle. The ICAP program can reduce the amount of cleaning by pinpointing areas that actually need cleaning and allows the City to inspect pipes in half the time that it would with traditional CCTV.

INTRODUCTION

The City of Fort Worth’s wastewater collection system includes more than 260 miles of large diameter sewer interceptor 24-inches in diameter and greater. The City has recognized the need to determine the condition of these vital large diameter sewer interceptors and develop recommendations for a long term capital improvement plan. As a result of these needs, the City initiated an Interceptor Condition Assessment Program (ICAP) for the large diameter sewer interceptors. This program began in October 2010 and is currently planned to have duration of six years. The ICAP project team is using results from the 2012 Wastewater Collection System Master Plan, as well as input from Field Operations group to prioritize sewer interceptors for the ICAP program.

ICAP consists of three contracts. The first is for advanced inspection of large diameter sewer interceptors, currently performed by Ace Pipe Cleaning. The contract includes inspection of the interceptors using High Definition CCTV inspection, sonar Inspection, and 3-D laser profiling technology. Contract 1 provides the ability for the City to authorize up to three annual contract options for renewal that would total up to 740,000 linear feet for inspection. Contract 2 is for cleaning of the large diameter sewer interceptors, also being performed by Ace Pipe Cleaning. Contract 2 also provides for an authorization by the City and up to 3 additional annual contract renewal options. Large diameter sewer interceptors found during the Contract 1 inspection with excessive amounts of debris will be cleaned under Contract 2. The Cleaning Contract 2 will also be implemented city-wide on an as needed basis. The third contract is
with the program management team of White Rock Consultants and Freese and Nichols, Inc. for providing engineering services and managing Contracts 1 and 2. **Figure 1** shows the lines inspected during Years 1 through 4. Inspection is complete for Years 1 through 3, resulting in nearly 50% of the City’s large interceptors with a remaining useful life score assigned. Each year includes interceptors divided into individual work orders performed over that year, with a total of typically four to five work orders per year. The large diameter pipelines were prioritized for inspection based on a risk based assessment performed during the 2012 Wastewater Master Plan.

![Figure 1](image)

**Figure 1**
ICAP Inspection Priorities, Years 1 - 4

**METHODOLOGY**

ICAP utilizes three technologies during the field condition assessment. The three technologies are High Definition TV inspection, sonar inspection, and 3-D laser inspection. The data from the sonar is combined with the data from the laser to develop a three dimensional model of the entire pipe length. Combined with the HD video, the result is a high resolution visual picture of the pipe and a three dimension model of the pipe that is used for detailed analysis of the pipe condition.

- **High Definition TV inspection** is the most advanced method for capturing video images. The images are high resolution quality and are stored in a digital format. Once the HD TV Inspection data is collected, the data can be viewed using conventional digital video viewing software.

- **Sonar inspection** is used to inspect the pipe below the water level flow line. The device sends a sonar signal and measures the time required for the signal to return. The technology then creates
an image of the pipe below the water surface and identifies accumulation of debris, deformation due to deflection in the pipe, broken pipe, or other features. Sonar is also used to determine the effectiveness of large diameter cleaning, and the Contractor is required to demonstrate the pipe was properly cleaned using sonar inspection.

- **3-D laser inspection** uses laser technology to create a three dimensional model of the pipe wall above the water flow line. Similar to the sonar technology used below the water flow line, the laser sends a rotating beam of light around the pipe surface and measures the amount of time required for the light to bounce back. Using thousands of data slices along the length of the pipe, a three dimensional model of the pipe wall is created. For ICAP, the most important defect identified and quantified is hydrogen sulfide corrosion and resulting wall thickness loss in concrete sewer lines. However, other defects are also found, including deformation of rigid pipes, deflection of plastic pipes, tuberculation of metal pipes, debris and holes.

Certain data were needed prior to the inspection being conducted. At a minimum, the pipe age, material, wall thickness, placement of steel cages, along with the sources used to identify these values, were documented. The estimated original pipe wall thickness is used initially by the Contractor for processing the laser profile data. Although pipe age and material were typically identified in the GIS, the remaining data needed had to be obtained from project files. The project team identified seven potential sources to capture this information. Each of the sources was evaluated and ranked based on the reliability and availability of documents specific to the pipe. Research for the pipe wall thickness was conducted using the highest ranking source document available for each pipe segment. Potential sources included field verification, construction files, project manager files and pipe manufacturer/industry standards at the time of construction.

The pipe wall thickness from the pipe specification data establishes the original inside diameter of each pipe segment. The laser profiling measures the amount of wall thickness loss. The difference between the inspected inside wall location and the original inside wall location is used to calculate the inspected wall loss. The inspected wall loss or remaining wall thickness is used to assign pipe segment condition scores. The remaining wall thickness may vary along the length of the pipe segment depending on the rate of corrosion along the pipe segment. Developing the condition score of a pipe segment based on such a varying parameter would be difficult and time consuming. The ICAP project team chose to use the thinnest point of remaining wall thickness to determine the condition score of each pipe segment. The condition scoring system used by the ICAP project team for reinforced concrete pipe segments is shown below. The condition scoring system allows the ICAP project team to quantify the remaining wall thickness and apply a condition score to each concrete pipe segment in the ICAP program. An example of this scoring system applied to two pipe sizes and specifications is shown in **Figure 2**.

- **Score 1**: Material loss of 0 to 0.5 inches from original inside wall.
- **Score 2**: Material loss of 0.5 inches to interior face of first row of reinforcement steel.
- **Score 3**: Material loss from interior face of first row of reinforcement steel to half the distance to interior face of the second row of reinforcement steel.
- **Score 4**: Material loss from half the distance to the interior face of the second row of reinforcement steel to the interior face of the second row of reinforcement steel.
- **Score 5**: Interior face of second row of reinforcement steel to outer pipe wall surface.

On **Figure 2**, the inner wall starts at the 0.00" mark, and the outer wall is at the far right. In the first pipe specification shown, 39" Class III, Wall B, the pipe wall thickness is 4.25", with steel reinforcement located at 1.0" and 3.25". In the second example, the 39" Class III, Wall B with Wall A Steel, also has a wall thickness of 4.25"; however, the steel is located at 2.25" and 3".
RESULTS

Pipe Cleaning Savings

Under the ICAP Contract 1 for inspections, Ace Pipe Cleaning inspected 190,391 linear feet of large diameter sewer interceptors. Using the sonar inspection data, the FWWD is able to strategically clean only the portions of the interceptors that require cleaning. In the past, the FWWD would clean the entire interceptor due to the lack of available HD TV, sonar and laser data. The required amount of interceptor cleaning for Year 2 was 51,148 linear feet at a cost of $556,738, which was covered under Contract 2 of ICAP. The average pipe diameter cleaned for Year 2 was 34.77-inches, slightly higher than the Year 1 average pipe diameter cleaned of 33.06-inches.

Pipe Inspection Results

An example of the variation of condition scoring along an interceptor is illustrated in Figure 3. For this particular work order, approximately 15% the length of the pipe received a score of 4 or 5. Rather than replacing the entire interceptor, the City is able to rehabilitate or replace just those segments receiving a score of 4 or 5. Before conducting this inspection and tying it to the City’s GIS, the City staff did not have the ability to easily graphically communicate the current condition of its sewer assets to the City Manager’s office or to the City Council.

Figure 4 shows the resulting condition scores for the approximately 380,000 linear feet of large diameter sewer interceptor inspected during Years 1 and 2. Only 15% of the sewer interceptors in Years 1 and 2 were assigned a condition score of 4 or 5, which would result in a capital improvement project. For interceptors with a condition score of 5, the ICAP project team was able to identify several major point repairs that were addressed through emergency projects. These repairs allowed the City to avoid major pipe failures and significant costs and regulatory impacts of those failures.

Some of resulting 4’s and 5’s were areas where major debris had accumulated and resulted in a buildup of hydrogen sulfide. One example is in the City’s Little Fossil Basin where large boulders from construction debris caused a major blockage in the interceptor, reducing the flow and resulting in significant hydrogen sulfide levels. Through inspection, the ICAP team identified the obstruction and removed it, which freed up additional capacity in the system and greatly decreased the chemical costs because it was no longer required at this location. Another example is adjacent to a car junkyard. The ICAP project team pulled car parts from the sewer manhole, also capturing lost capacity in the interceptor.
Figure 3
Pipe Condition Scoring for Individual Work Order
DISCUSSION

Once the ICAP project team assigned a score to each pipe segment for the work orders in Contract 1, the condition scores were used to prioritize the replacement and rehabilitation recommendations. The pipe segments that received a condition score of 1, 2 or 3 were considered to be in fair to very good condition and did not require any immediate improvements over the next 20 years. Pipe segments that were assigned a condition score of 4 have an estimated RUL of 3 to 10 years. Pipe segments that were assigned a condition score of 5 have an estimated RUL of 0 to 2 years. The ICAP project team recommended that pipe segments with a condition score of a 4 or 5 be replaced or rehabilitated in the short term to avoid costly emergency repair work, disruption in service and potential environmental damage.

From the condition scoring results, it was obvious that pipe age and material are not always a good indicator of condition. Although the data in Figure 5 shows a high percentage of the 4’s and 5’s being 50 to 60 year old pipe, there was also a significant amount of that same pipe with scores of 1 through 3, and pipe from the 1980’s with scores of 4 and 5. An additional item noted is that pipes with potentially high corrosion rates are resulting in a shorter service life. Although the scoring system indicates a maximum service life of 50 years for sewer lines in Fort Worth’s
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At the end of the project, one of the most important items is how this information is stored and tracked. The ICAP inspection data (sonar, laser, & HD video) are stored in Inspect IT software. The software integrates the HDTV, 3D laser and sonar data, along with the hydraulic model results into one software package. This allows for quick access to previous inspections and for the condition data of an asset to be viewed. Future inspection efforts can be focused on specific pipe segments instead of entire interceptors, thereby reducing future inspection costs.

CONCLUSIONS

The benefits of ICAP can be summarized into three areas:

- **Reduced Capital Improvements**
  The Capital Improvement Plan was estimated to be reduced as a result of the ICAP program by two primary means. The first was the ability to restore capacity through focused detailed cleaning and removal of large debris in multiple interceptors. It is recommended that the City’s Infoworks CS hydraulic model be reanalyzed in these locations where significant debris was identified and removed from the sewer interceptors to determine if CIP improvements can be deferred or downsized in the future. The second was the replacement of portions of sewer interceptor instead of the entire interceptor.

- **Enhanced Understanding and Knowledge of Asset Status and Life Cycle**
  The ICAP field assessment findings linked backed to the City’s CMMMS program, and GIS provided enhanced asset understanding to enable the City to prioritize replacement project more effectively. ICAP field assessment findings provided the needed information to Engineering during
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development reviews and annual budget planning on business case justification for renewal/replacement projects.

- **Reduced Reactive Maintenance and Cleaning Costs**
  Prior to the creation of the ICAP program, the FWWD utilized the industry standards of “clean to inspect” to determine pipe condition and restore capacity. Cleaning under ICAP Year 2 using the “clean to inspect” method was projected to cost $1.97 million. Utilizing the sonar data developed from the ICAP results, the FWWD was able to “inspect to clean” resulting in significant cost savings. Year 2 cleaning cost utilizing the “inspect to clean” method totaled $346,740 which represents an approximate savings of $1.63 million over the traditional “clean to inspect” method. It is estimated that the ICAP methodology of “inspect to clean” will result in a savings of $15.2 million in cleaning cost over the six year program. A summary of the total cleaning costs, project to date, is shown in Figure 6.

  The ICAP results also enabled the City, through the use of Maximo and I.T. Pipes, to significantly increase the ratio of preventive maintenance vs. reactive maintenance. Remaining pipe wall thickness can now be monitored, allowing the City to get the most value out of its assets before replacing them.

  ![](Figure_6.png)

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