

CONDITION ASSESSMENT

Better data, better evaluations

New inspection technology using multi-sensor data can provide more accurate condition assessments. Jeff Griffiths and Jeff Graham discuss a recent US project

IN THE summer of 2008, Salt Lake City, US, initiated a master plan to study its sewer-collection system, which serves an area of roughly 180km². An important component of the plan was a condition assessment of existing large pipelines, some of which had diameters of up to 1,975mm. The goal was to identify and adopt best management practices, protect capital investments cost-effectively, prolong asset life and improve performance.

The importance of understanding the structural condition of the city sewers was realised during the earliest stages of the study, when a 1,215mm section of a reinforced-concrete main trunk line failed. Evidence appeared to indicate that hydrogen sulphide corrosion led to the failure.

The original pipe wall thickness was estimated to be 125mm; however, some sections showed thicknesses of less than 25mm at the crown, with a complete absence of steel reinforcement. This corrosion appears to be confined to the area above the normal waterline, which is consistent with failure from hydrogen sulphide corrosion.

Having prioritised the order in which sewers were to be inspected, the city authorities faced the challenge of how to collect meaningful data. While engineers were aware that some corrosion was occurring in the system, past CCTV inspections did not give adequate information on its magnitude and the impending problem.

The desire to quantify corrosion information more efficiently led the city to use the CleanFlow HD Profiler, a new inspection technology from New Zealand that incorporates high-definition (HD) imaging, laser profiling and sonar data collection.

The scenario presented above is not unique. In many cases, accessibility issues, significant debris and surcharging, coupled with the fact that it is often impractical to take large interceptors out of service, require innovative inspection technologies.

Many utility owners and engineers are challenged with making rehabilitation decisions on limited budgets. As a result, a cost-effective method of evaluating the condition of their collection systems is important. One of the most cost-effective condition-assessment technologies is the use of multiple sensors to collect meaningful data on a single inspection run.

This article will highlight the principles of one multi-sensor technology and the results from several different inspections.



Failure of 1,215mm RC main sewer

INVESTIGATIONS

Following the 1,215mm trunk-line failure mentioned above, the city began investigating available inspection technologies for condition assessment. A number of issues were considered:

- **Image quality in large-diameter pipelines**

While the city's existing CCTV inspection equipment works well for small-diameter pipelines, it has been less successful when used on large-diameter trunk lines. To be successful, the selected technology needs to have adequate lighting and an image with high enough resolution to capture the details.

- **Quantification of corrosion magnitude**

To avoid a failure similar to the one noted above, the city needed technology that could identify both the location and extent of corrosion at each section of pipe.

- **Estimate of sediment depths**

Many of the city's large-diameter trunk lines have been installed at a relatively flat grade and can incur accumulation of sediment. The city needed

technology that could identify sediment depth to provide guidance for future cleaning activities.

- **Distance between manholes**

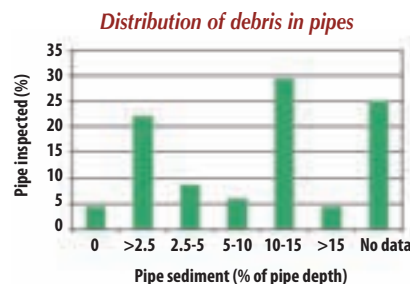
A few sections of large-diameter trunk lines were installed before the development of modern standards for manhole spacing. As a result, one of the trunk lines included a section of pipe with around 760m between manholes. Therefore, the city needed technology that could run significant distances between manholes.

Having considered these issues, the city contracted Hydromax USA (HUSA) to utilise the CleanFlow HD Profiler for condition assessment.

CLEANFLOW HD PROFILER

Using multi-sensor technology (CCTV, sonar and laser) is a better way of understanding large-diameter brick and concrete sewers. Sonar data (below the water surface) allows owners to understand how much debris is in the pipe. This is important because cleaning contractors can provide better quotes as they will not be paying for risk with unknown debris quantities. In addition, this information can help provide a better understanding of a model's results.

The laser (above the water surface) is critical because it will identify the amount of pipe wall that has corroded. Although above-waterline CCTV inspections might confirm the existence of sediment or corrosion, they cannot quantify the magnitude of either one sufficiently.



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The CleanFlow HD Profiler can collect data on sewers ranging from 600mm to 3m in diameter, and is currently configured to inspect lengths of up to 2,300m in a single deployment. It can also inspect odd-shaped sewers.

Typically, the equipment floats through sewers with the flow, but it can also be mounted on a skid or tractor. The floating apparatus enables the sonar data to be collected without disturbing the material. This allows the engineer to view how the debris is actually building up in the line. In order for both the sonar and laser to collect data, there needs to be a minimum of 300mm of flow (for the sonar), and at least 400mm between the waterline and pipe crown.

The system collects data continuously as it floats through the sewer. Above the waterline, an HD camera takes pictures six times per second. A typical inspection will see an image taken every 12-25mm of pipe length, with images having around three times the clarity of a traditional CCTV camera. Frequency is based on the float moving through the pipe at a rate of 4.5-9m/min.

Pipe illumination is provided by a strobe, which is important as the light source never gets hot, thereby decreasing the likelihood of steam generation during the inspection. After the inspection has been completed, the images are 'stitched' together to create a video file. This file enables the pipe to be PACP-coded (Pipeline Assessment and Certification Program) and imported into a municipality's CCTV database.

The National Association of Sewer Service Companies (NASSCO) is committed to setting industry standards for the assessment and rehabilitation of underground pipelines, which has resulted in the PACP standard.

During the entire inspection, a 2D laser ring comprising 180 points is projected on to the inner wall of the pipe. Four HD cameras take pictures of the laser every 6-12mm. Image frequency is based on the rate that the float



Location of pipe failure

amount of debris and corrosion. This deliverable enables the engineer or owner to have data from all three sensors incorporated in one location, thus helping to make the data easy to understand. In addition to the cross-sections and flats, internal and external 3D views are provided.

RESULTS

The use of HD Profiler inspection technology allowed the city to collect a significant amount of data that had not been available

previously via standard CCTV inspection. Two of the more useful data categories newly available to the city were quantifiable measurements of sediment and corrosion.

1. Pipe sediment

This is the average sediment depth measured by sonar at each pipeline segment. Because several segments had too little flow to allow for accurate sonar data collection, no sediment data was available for these sections. The inadequate flow in these areas did not provide the sonar equipment with sufficient clearance between the water surface and the bottom of the pipe.

For areas where data was collected, it can be seen that most of the pipeline segments have sediment depths of less than 10% of the total pipe diameter, meeting the city's current minimum cleaning goal.

It should be remembered that the pipelines selected for inspection are primarily large diameter and near the treatment plant. Because of their relatively flat slope and location at the bottom of the system, it is believed that these pipelines are more prone to sediment accumulation than most other pipes in the system. Due to their size and flow rates, they are also the most costly and difficult pipes in the system to clean. Using the data available from the inspection, the city will be able to focus its cleaning efforts only on those pipelines that exceed its goal. →

moves through the pipe. The rapid frequency of collected images ensures that any deflection and corrosion, or missing materials, are accurately documented. Sonar signals are also collected every second, which corresponds to data collection at a rate of 150-300mm/sec.

With the voluminous amount of collected data, it is vital to present the findings in a meaningful way and simplify the evaluation process. Typical deliverables include a comprehensive multi-sensor report, a four-in-one combined video file and a PACP exchange database.

Upon request, a special viewer is available that allows engineers and owners to pan, tilt and zoom post-processed videos. This capability can be particularly beneficial to the engineer making the rehabilitation decisions.

The report contains tabular information, highlighting debris levels and corrosion throughout the pipe, total debris in the sewer, a coloured 'flat' of the pipe being inspected, and cross-sections every 15m and at places of interest. The flat is a colour-coded, 'unwrapped' view of the pipe from manhole to manhole. The top and bottom of the flat represent the data collected below the waterline, while the middle portion provides the data collected by the laser.

Within the flat, various colours identify the amount of corrosion and debris, as well as the location. Each cross-section identifies the

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→ 2. Corrosion

Corrosion measurements – as estimated from laser profiling – are based on the maximum corrosion measured at individual cross-sections taken in each pipeline at intervals of about 15m.

The majority of pipeline segments had relatively little observed corrosion – less than might be typically expected, given the average age of the pipelines and their location at the bottom of the system. However, a small number of segments have corrosion, which suggests the need for immediate action. There was also a significant amount of pipe with enough corrosion to suggest that measures should be implemented to protect against further corrosion.

Corrosion quantification has been a very useful tool to the city in terms of prioritising repair and rehabilitation projects on its major trunk lines. While consisting of a relatively small portion of the total pipe inspected, a few areas of severe corrosion were identified that will be replaced or rehabilitated immediately.

This pipeline was located at the transition of a long, flat run of pipe with a short, steep section; the hydraulic turbulence that occurred here appears to have released high levels of hydrogen sulfide. This turbulence may also be increasing humidity in the pipeline, producing optimum conditions for the formation of sulphuric acid and corrosion.

While a few dramatic instances of corrosion were identified, as described, these occurrences were rare and would have been identified as problems through typical CCTV inspection.

Of greater use to the city was the quantification of more modest amounts of corrosion. In these instances, CCTV inspection would have noted some corrosion, but the extent would have been difficult to quantify.

Without detailed corrosion measurements, it would have been difficult to decide on the type of action necessary for each segment and prioritise the actions.

Based on the inspection results, the city has identified a number of specific actions that it will pursue over the next few years:

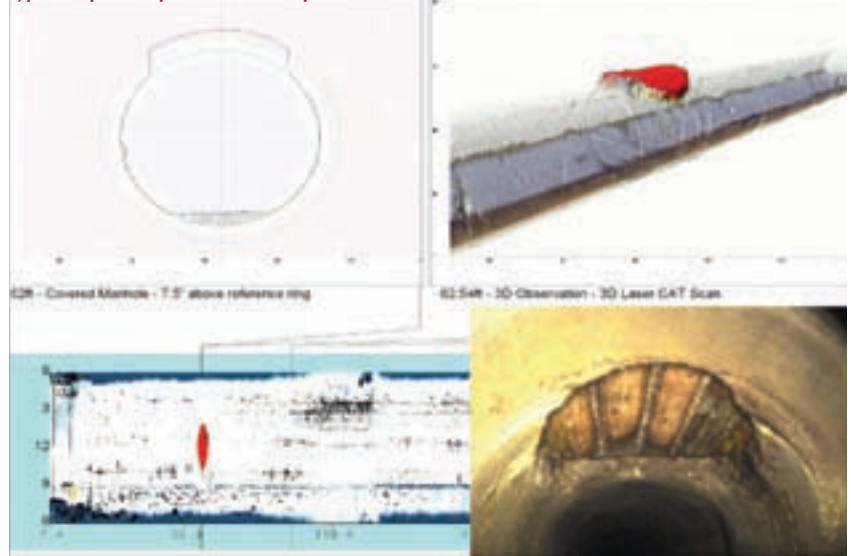
- **Seeing the unknown**

Combining above- and below-water inspection technologies, it is now possible to see the entire pipe cross-section. In several instances, sonar identified major structural flaws and significant offset joints. In brick sewers, the laser data identified the number of brick courses missing from the crown of the pipe. In other cases, the laser data quantifies deflection (ovality), enabling life-cycle analysis with successive inspections.

- **Pipe rehabilitation and replacement**

Using the inspection results, a group of the city's pipelines have been identified for rehabilitation

Typical report output, based on inspection data



or replacement. The worst sections inspected have been identified for immediate rehabilitation, while those in a slightly better condition will be rehabilitated within the next few years.

While comprising only a small percentage of the total system, the inspection provided several benefits relative to identifying pipelines for rehabilitation or replacement:

- **Understanding severity**

The pipes identified for immediate rehabilitation are those deemed to represent immediate concern and require rapid attention. Without the inspection, these pipelines would have been identified as problems, but the importance of quickly attending to the problems may not have been as apparent.

- **Efficient use of funding.**

Understanding which pipes need rehabilitation is as important as understanding which pipes do not need it. Based on the inspection, the city concluded confidently that the majority of pipes inspected are in good condition and do not need immediate attention. This minimises rehabilitation costs.

- **Prioritisation of rehabilitation**

Condition severity varies within the list of pipelines identified for rehabilitation. Some are in need of immediate attention, while others may still be serviceable for a period of time. Having detailed data from the inspection allowed the city to prioritise its rehabilitation projects.

- **Pipeline monitoring**

All pipelines not identified for rehabilitation will continue to be monitored. Those showing some signs of corrosion will be monitored more frequently than those that do not exhibit any. The benefit of the inspection for this group of pipes is that it provides a baseline for all future

inspections. As pipelines are inspected in the future, the corrosion measured can be compared to that measured during this initial inspection, which will allow calculation of the ongoing corrosion rate. This will provide a better understanding of where corrosion is most severe and allow an estimation of the remaining service life for each pipeline.

- **Additional inspection**

Based on the results of this initial inspection, the city plans to finish inspecting all remaining sections of major trunk lines. This will allow it to improve its knowledge of the condition of its large-diameter pipelines.

- **Pipeline cleaning**

Using the available inspection data, the city has identified a number of large-diameter pipelines for cleaning. The ability of the inspection to measure pipeline sediment will allow the city to focus its cleaning efforts on those pipelines with sediment exceeding its allowable limits.

CONCLUSIONS

Although many lengths of different pipe sizes and materials are televised each year, larger interceptors that carry significant flow are often ignored for a variety of reasons. Access, safety, illumination, cost, lack of redundancy, clarity of information, and the difficulty and cost of dewatering are some of the reasons preventing inspection of these important system components.

Not only are inspection technologies becoming more available, but the combined processing of multi-sensor data also allows for more accurate condition assessments, which, only a few years ago, were impractical. The real power of collecting multi-sensor data is the ability to process it into a single, comprehensive and easily interpreted condition assessment.