New Developments in Multi-sensor Condition Assessment Technologies for Large Diameter Pipe Infrastructure

Csaba Ékes, PhD, PGeo.

SewerVUE Technology Corp. - 7993 Enterprise Street - Burnaby, BC, Canada - V5A 1V5
Tel: 1-888-973-9378 - email: info@sewervue.com

Abstract

SewerVUE Technology uses CCTV, LiDAR, and Pipe Penetrating Radar (PPR) technology to gather quantitative data for underground pipe condition assessment. This MPIS system can be deployed on either a remotely-operated vehicle (ROV), or a float. In either case, the system produces an accurate 3D reconstruction of the pipe. To measure profiles and distances above the pipe flow line, the MPIS uses a time-of-flight LiDAR that is accurate to within 1.6 mm. Below the flow line, a pipe profiling sonar is used.

This MPIS technology was employed for a project in Melbourne, Australia. The project saw the survey of 3521 m of pipe. This included 572 m of 600 mm (24 inches) reinforced concrete pipe (RCP), 1297 m of 750 mm (30 inches) RCP, 1165 m of 950 mm (37.5 inches) RCP, and 487 m of 1050 mm (42 inches) brick lined pipe. Through the use of radar, LiDAR, and CCTV, SewerVUE was able to assess the condition of these pipes and quantify deformations. This application of multi-sensor technology allowed the client to make informed decisions about the timing of future repairs.

The same multi-sensor technology was used in a project at the Henderson-Urad site, located near Empire, Colorado. The project aimed to inspect two sections of pipe: 1606 meters of 600 mm (24 inches) diameter RCP, and 457 m of 1350 mm (54 inches) high density polyethylene pipe (HDPE). The Surveyor remote operated vehicle was used to inspect the 600 mm pipe. Due to high flows, the 1350 mm (54 inches) HDPE pipeline was inspected using the MPIS float. In the 600 mm (24 inches) pipe, the LiDAR results showed small elongation of the pipe diameter, approximately 3 to 4 percent of the nominal diameter, along the horizontal axis of the pipe. The CCTV inspection showed the pipe to be in good overall shape, the only exception being occasional roots intruding at joints, as well as some structural defects scattered along the pipe. In the 1350 mm (54 inches) plant fill pipeline, the inspection revealed no reportable defects. Both pipes appeared to be in good shape which provided peace of mind for the client.

The advanced pipe condition technologies outlined here are highly useful for generating detailed, accurate data that can provide the basis for utility owners to make informed decisions about cost allocation and timing of rehabilitation. Multi-Sensor technology is both cost-effective and non-destructive, making it an excellent choice to help better understand the remaining life of pipes.

Introduction

It is of great interest to municipalities and contractors to keep costs as low as possible. Efficient asset management is a key part of this. When it comes to water and wastewater infrastructure, developing effective asset management plans can be difficult. Conventional pipeline condition assessment methods do not necessarily fulfill the need adequately. This is where modern multi-sensor inspection (MSI) techniques become very valuable. By collecting comprehensive, quantitative data from pipelines, utility owners can develop predictive models of the remaining useful life of their assets. With these models, pipes can be replaced before they fail, without the wasted cost of replacing them too early. By avoiding the costs incurred by catastrophic failures, as well as the inefficiency of replacing pipes that are still useful, budgets can be stretched much further.

To gather the comprehensive data required to build a useful predictive model, information from more than one type of survey method may be needed. This paper presents two case studies where multi-sensor inspection methods were used to collect quantitative pipeline condition data. The methods used in these case studies include LiDAR, sonar, Pipe Penetrating Radar (PPR), and CCTV. This paper will also look at how these technologies are deployed using two different platforms: a tracked ROV, and a float.

Light Detection and Ranging, or LiDAR, is a relatively new technique for pipeline condition assessment. LiDAR profiling can collect very precise measurements of a number of parameters, including ovality, deformations, lateral size, offset joins, and flow level. The technology works by projecting a laser and measuring the time it takes for the laser to reflect off a target and return to the point of projection. A highly accurate measurement of distance can be determined from the "time-of-flight," or the length of time that elapses between emission of the light signal and that signal reaching its target. (Salik & Conow, 2012) LiDAR pipe scanning technology collects 2-D cross sections of the pipe wall continuously. (Figure 1) A high-resolution 3-D model of the pipe can be created by compiling these cross sections. Outputs from LiDAR surveys can vary quite widely even when the same profiler is used. Engineers and utility owners must take care to assess the accuracy and calibration of the systems, as well as the repeatability of the results. (Travis & Shelton, 2012)

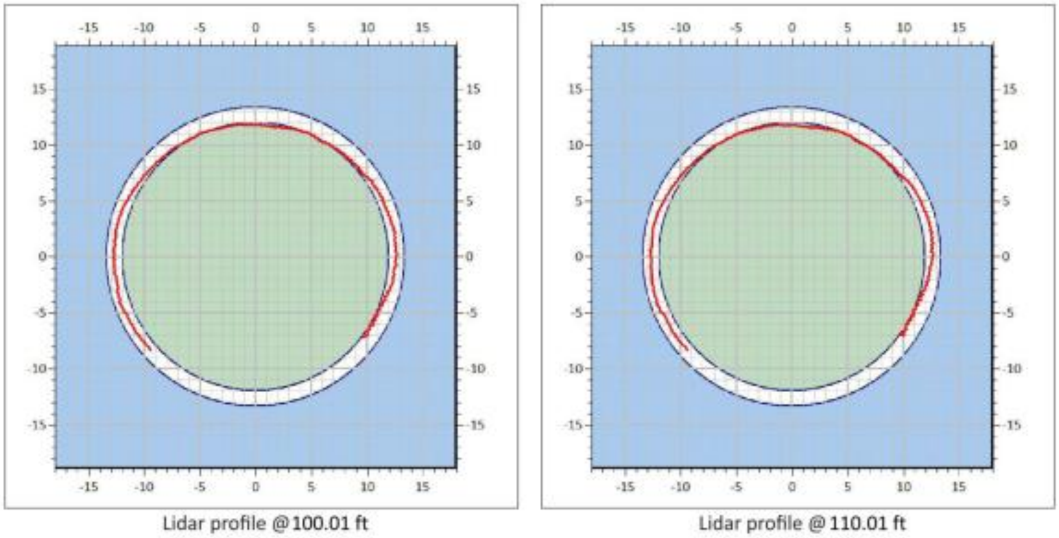

Figure 1 - Example of LiDAR cross-sections from a delivered report

Pipe Penetrating Radar is the in-pipe application of ground penetrating radar (GPR). PPR can be used to survey pipes made of non-ferrous materials (concrete, RCP, AC, PVC, HDPE, etc.). A PPR survey will determine the remaining pipe wall thickness along a scanned line at the chosen clock position. PPR also reveals information about the area beyond the pipe wall, including the presence of voids. The technology works by sending electromagnetic pulses through the pipe wall and into the soil beyond. (Ékes & Neducza, 2012) These electromagnetic waves are reflected and refracted by changes in material properties, for example the difference between the pipe wall and an air or water-filled void beyond it. A sensor on the survey equipment records these reflected EM waves. This data can be used to create a 2-D image showing the pipe wall thickness and the presence of voids in the fill material on the outside of the pipe.

In the two case studies presented here, these sensors were deployed using two different platforms: a tracked ROV (Surveyor) and a float (MPIS). The ROV collected CCTV, LiDAR, and PPR data, while the float collected LiDAR, sonar, and CCTV data. By using these different methods together on unmanned vehicles, a comprehensive set of data can be collected while avoiding any of the dangers and pitfalls of man entry operations.

Case 1: Melbourne, Australia

A number of different lines of reinforced concrete pipe (RCP) were surveyed in Melbourne, Australia as part of a single condition assessment project. The client needed quantitative data about their pipes, and so commissioned this multi-sensor inspection from SewerVUE Technology Corp. All the inspections were done using a tracked ROV, the 4th

Generation Surveyor. (Figure 2) The ROV was equipped with two PPR antennas, a LiDAR sensor, and a CCTV camera.

Figure 2 - The SewerVUE Surveyor at a deployment site in Melbourne

The first section this survey looked at was of the Mordialloc Main Sewer. This line was RCP with a diameter of 750 mm (30 inches). A 1297 m section was surveyed using a single deployment point near the middle of the section in question. LiDAR results from this section showed small but consistent deformation along the pipe's crown. The CCTV footage collected from this pipe showed a high degree of surface damage on the inner wall of the pipe. This damage appeared to be consistent with chemical attack. Two significant points of structural damage were noted, including a small hole and circumferential fracturing located 33.4 m and 41.5 m downstream from the deployment point, respectively. The PPR data collected from the Mordialloc Main showed rebar cover that ranged from 35 mm to 60 mm deep. No significant voids or other anomalies were detected outside the wall of this pipe.

The Hobsons Bay Main comprised the second part of the survey. The Hobsons Bay Main is a 600 mm (24 inches) RCP sewer main. 572 m of this main was included in the scope of the survey. Starting from the access point and moving upstream, the LiDAR data from the survey showed the section between the deployment point and the next manhole to have increased wall loss compared to sections further upstream. This section was found to have significant sedimentation in it, and CCTV footage once again showed surface damage that appeared to be the result of chemical attack. PPR data showed rebar cover to be at least 15 mm throughout the length of the survey. (Figure 3)

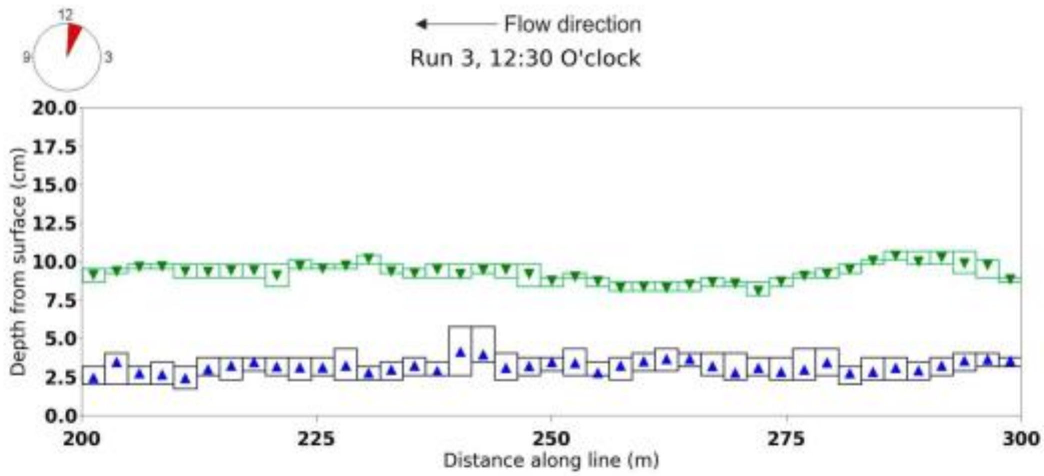

Figure 3 - Example PPR data from Hobson's Bay Main. Green triangles represent the average wall thickness of each 2.44 m section. Blue triangles represent average rebar cover.

Third in the project was a survey of the Caulfield Intercepting Sewer, a 950 mm (37.5 inches) RCP line. An 1195 m section was surveyed using a single access point near the middle of the section. The sewer was found to be in generally good condition. Visuals collected by the CCTV camera showed only a few small defects mainly consisting of mild surface damage and localized staining along the crown of the pipe. LiDAR data showed minimal deformation of the pipe. However, it showed one section of pipe to be 1100 mm (43.3 inches) in diameter rather than the 950 mm (37.5 inches) that comprised the majority of the survey. From the PPR data, a large variance in rebar depth was observed throughout the survey. Rebar was not detected close to the wall surface, with the exception of one location near the access point.

The fourth and final line to be surveyed as part of this project was the Maribyrnong Main Sewer. This was a 760 mm (30 inches) diameter RCP line, and it was inspected from two different locations. This line was difficult to inspect due to significant sedimentation, and widespread attached deposits on the pipe walls. These deposits prevented the CCTV cameras from seeing the pipe walls in many areas. In areas that were free from deposits, significant surface damage was visible, and in some areas reinforcement could be seen. CCTV footage also revealed a hole in the pipe wall near one of the access points, as well as an intruding sealing ring. Due to the significant incrustation along the walls, LiDAR data collected from this line was not particularly insightful. The information collected by the PPR scanners showed little rebar cover along most of the inspected length. The section surveyed from the second access point showed improved rebar cover, but otherwise was in similar condition to the first section.

Case 2: Urad-Henderson Mine Site, Colorado

The Urad-Henderson Mine Site is located west of Denver, Colorado. The client had two pipes that needed to be inspected: The Upper Woods Creek Bypass, and a large plant fill pipeline. The objective was to locate and identify defects within each pipeline. This would be accomplished through the use of multi-sensor inspection technology, including CCTV, LiDAR, PPR, and sonar. The two lines to be inspected were very different in nature, and so two different deployment platforms had to be used. The Upper Woods Creek Bypass was inspected using the Surveyor, while the plant fill pipeline was inspected using the SewerVUE MPIS float system. (Figure 4)

Figure 4 - The SewerVUE MPIS Float

The Upper Woods Creek Bypass is constructed from RCP, and measures 600 mm (24 inches) in diameter. The bypass is 1605.7 m (5268 ft.) in length, and was inspected using the Surveyor, a tracked ROV mounted with LiDAR, CCTV, and PPR equipment. Despite the length of the pipe, the inspection could be done from just one access point near the middle of the line. CCTV visuals collected from the pipe showed it to be in generally good condition. The only noted defects were a number of roots intruding at joints, and some scattered structural defects. (Figure 5) Though not officially coded as a defect, efflorescence was present along a significant portion of the pipeline. Efflorescence is the term for salt deposits on the surface of a porous material that become visible after the evaporation of the water. On its own, this does not pose a significant problem. However, as the concentration increases over time, the osmotic pressure on the pipe wall also increases, which can result in damage to the concrete.

Figure 5 - CCTV image showing a significant intruding root

LiDAR data from the Upper Woods Creek Bypass showed small elongation of diameter along the horizontal axis of the pipe. This was determined to be approximately 3 to 4 percent of the nominal pipe diameter. The PPR survey did not reveal anything problematic. No significant void-related anomalies could be seen outside the pipe wall. Rebar cover throughout the survey showed variations in depth, but was always found to be above the ASTM standard of 19 mm (0.75 inches).

The next part of the project was to survey a large-diameter plant fill pipeline. This pipeline was constructed from high-density polyethylene (HDPE) and had a diameter of 1350 mm (54 inches). The inspection covered the entire 457.2 m (1500 ft.) length of the pipeline. This pipeline had a very high level of flow in some sections, including the stretch between 400 and 600 ft. where the flow level was estimated to be 90%. Changes in flow level could be seen in the LiDAR data. The CCTV inspection did not detect any visible defects throughout the survey. Sonar data detected very little sedimentation, and no obstructions across the length of the survey. This pipeline, much like the Upper Woods Creek Bypass, was seen to be in good overall shape. For future inspections, it may be advisable to try and limit the amount of flow, but for the time being there were no problematic defects detected.

Summary and Conclusion

In both case studies presented here, multi-sensor inspection technology was used to collect quantitative data about the conditions of the inspected pipelines. In the case of Melbourne pipes, the client received information showing which sections of the inspected pipes needed further attention, and which lines could potentially have maintenance deferred to a later time. The information also provided a baseline against which future tests could be measured, for the creation of an accurate model of the pipes' useful life. The inspections in Colorado gave the client peace of mind that their pipes did not require immediate attention, as well as providing that same useful baseline information.

The combination of CCTV, PPR, sonar, and LiDAR deployed on two different platforms provides an efficient solution to condition assessment. With limited budgets, utility owners can employ this approach to collect quantitative data about the condition of their assets. With this information, they can design predictive models that help them better allocate rehabilitation funds. Multi-sensor inspections are an effective, safe solution to pipe condition assessment.

References

Ékes, C. & Neducza, B., 2012. *Combined application of Pipe Penetrating Radar and LIDAR for large.* Nashville, TN, North American Society for Trenchless Technology (NASTT).

Salik, J. & Conow, O., 2012. Pipe Inspections: Robotic Laser Profiling Demystified. *Precast Solutions Magazine*, Fall, pp. 22-25.

Travis, J. P. & Shelton, J., 2012. *Laser Profiling - A Case Study in Field Accurracy.* Nashville, TN, North American Society for Trenchless Technology (NASTT).