Inspecting Twin 42” Reinforced Concrete Pipes with Pipe Penetrating Radar Supplemented by LiDAR

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ABSTRACT

In the midst of a renovation project set to convert an old field house into a recreational centre, concerns were raised about the feasibility of the project due to the structural integrity of the pipes running under the building. The project entailed converting an old Campbell soup factory into a recreational cold storage facility for the residents of Worthington, MN. The issue involved two 80+-year-old 42 inch reinforced concrete pipes with unknown conditions that lay beneath the building. Without proper inspection of the pipes, the consultants could not allow the project to continue. A condition assessment was called for, in order to continue the project but the consultants were not convinced either CCTV or LiDAR alone was the solution, so they contacted SewerVUE Technology and inquired about their patented Pipe Penetrating Radar (PPR) technology.

PPR is the in-pipe application of ground penetrating radar. GPR antennas are taken inside the pipe and are used to scan the inner wall. With this method, PPR surveys can see remaining wall thickness, rebar cover, delamination, and detect the presence of voids developing outside the pipe. PPR, supplemented by LiDAR were assets in coming up with the appropriate design approach for the project.

INTRODUCTION

The City of Worthington directed Short Elliot Hendrickson (SEH) to renovate the field house into a recreational centre. SEH contracted SewerVUE Technology to confirm through inspection if the reinforced concrete pipes had held their structural integrity to begin renovations. The City, however, had concerns and required an review of the pipe’s condition. The purpose of the inspection was to determine the life of the pipe, and detect any voids around the foundation soils surrounding the pipe.

To complete the inspection, a robot was deployed to inspect the twin pipes. The ROV deployed six sensors: closed-circuit television (CCTV), light detection and ranging (LiDAR), pipe penetrating radar (PPR), inertial measurement units (IMU), barometers, and odometers. Along each pipe’s length, PPR continuously scanned one line each at 9, 11, 12, and 2 o’clock positions.

PPR’s ability to detect voids was crucial in the rehabilitation decision-making process for the City of Worthington. This paper will discuss the results from the inspection and how PPR, supplemented by LiDAR, answered the City of Worthington’s concerns for voids.

SENSOR OVERVIEW

LiDAR is a method to measure profiles and distances above the water level. LiDAR scanners are used to gather point cloud data to generate an accurate pipe profile to detail crack depth, width, and length. Combined with sonar profiles below the flow, a 360-degree profile of inside the pipe can be generated to determine the inner diameter of the pipe, help assess wall loss, and measure ovality.

Pipe Penetrating Radar (PPR) is an electromagnetic technique that is used to accurately map reinforcement location, pipe wall thickness, and classify voids outside non-ferrous pipes. PPR is the in-pipe application of ground penetrating radar (GPR). PPR can also identify grout placement between pipe renewal systems and host pipes, liner bonding, and in-situ conditions including exterior repair clamps and soil variations for pipe-bursting replacement operations. Some circumstances that can contribute to the formation of voids are soil aeration, localized gas pockets, or unknown pipe structures.

When PPR and LiDAR are used together, the quantitative data collected from each sensor work together to offer a complete picture. By supplementing PPR data with LiDAR, models above and below the flow line can be used to develop a 3D point cloud of the pipe resulting in accurate imaging of complex structures including voids; even in challenging subsurface conditions (Figure 1).

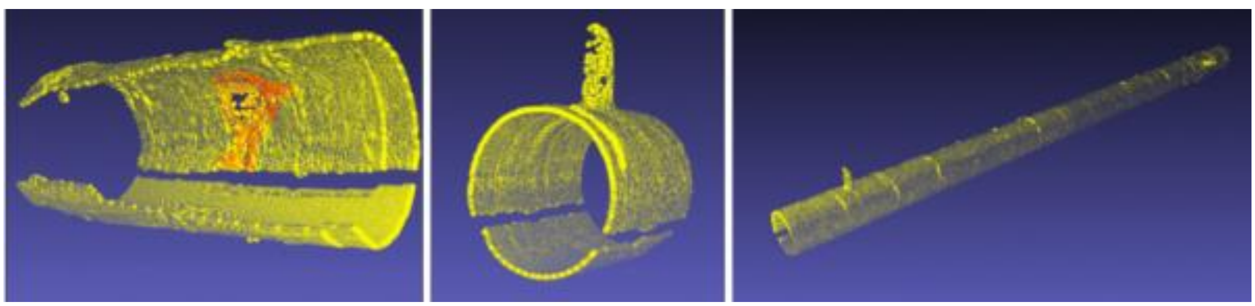

Figure 1. 3D Point Clouds: Digital doubles for accurate imaging

PPR DEPLOYMENT

Pipe Penetrating Radar is deployed via remotely operated vehicle (ROV) platforms. PPR deploys on the Robot; equipped with CCTV and LiDAR data to correlate with PPR scans. The Surveyor can be used for 525 mm through 1500 mm pipes. The ROV collects two lines of PPR data in one run. The antennas can be configured for any two clock positions between 9 o'clock and 3 o'clock. Current PPR antennae transmit at the gigahertz (GHz) frequency range. This setup results in signal penetration of up to 920 mm (3 feet).

WORTHINGTON, MINNESOTA

The City of Worthington, Minnesota directed Short Elliot Hendrickson (SEH) to convert an old Campbell Soup cold storage field house into an all-purpose recreational center. The building was located in an open field near Okabena Lake and the Union Pacific Railroad.

The job was presumed to be a conventional building renovation; however, upon closer inspection, a few challenges emerged. The renovation plan had the City questioning the condition of the pipes passing beneath the field house. The building was structured on top of two reinforced concrete storm sewer pipes that were installed in the 1930s. The pipes control the elevation of the water surface on Okabena Lake. The City also had concerns regarding the proximity of the active Union Pacific Railroad located next to the field house and the implications of the pipe's structural integrity concerning the railroad (Figure 2).

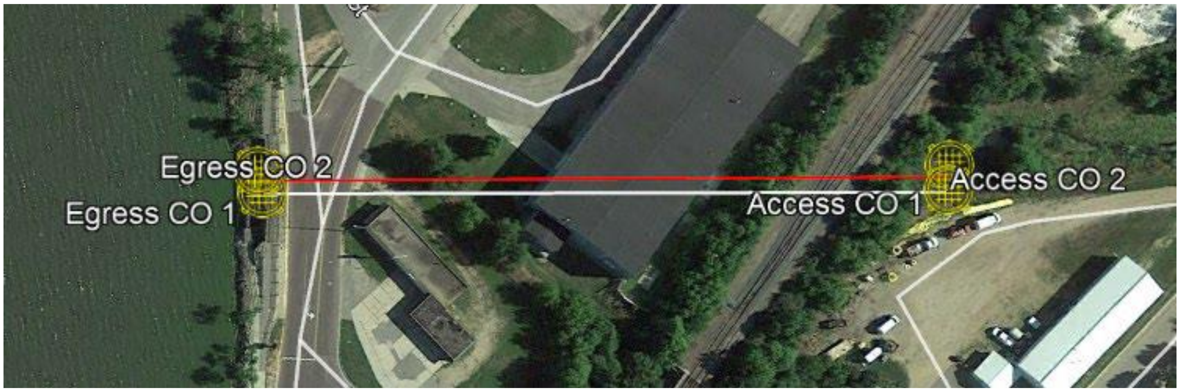

Figure 2. Aerial view of the Field house

Due to concerns about the condition of the pipes, Worthington was unable to determine if they could continue with the project. The consequences of commencing the project without proper inspection of the pipes could lead to infrastructure damage and huge financial losses. To assist in making the proper rehabilitation decision, Worthington hired Short Elliott Hendrickson Inc. (SEH). SEH was not convinced that traditional LiDAR and CCTV would provide enough data to detect voids, nor would the data be able to determine wall thickness so, SEH directed SewerVUE and inquired about Pipe Penetrating Radar (PPR).

The scope of the project was to provide an advanced condition assessment inspection consisting of pipe penetrating radar (PPR), LiDAR, and CCTV to determine the feasibility of building the facility. A robot was used for the inspection (Figure 3). LiDAR with the help of CCTV would be able to determine if the pipe had lost any interior pipe wall. In addition, Pipe Penetrating Radar would gather detailed data and determine the exterior condition outside the pipe.

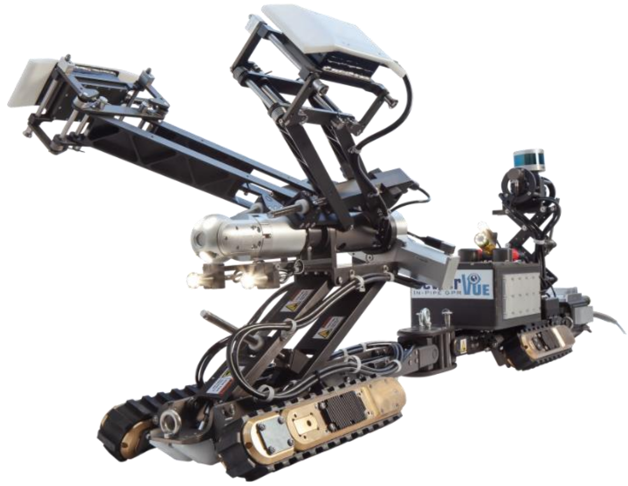

Figure 3. The SewerVUE Surveyor

While inspecting the 42” reinforced concrete pipes, the PPR inspection determined the concrete pipe wall was 4.5 inches (Figure 4). The city was notified otherwise, leaving a contradiction between the PPR data results and the manufacture’s provided information. SewerVUE responded with supplementary LiDAR which confirmed data that the pipe wall was indeed 4.5 inches. The LiDAR and PPR results were consistent, providing the client with evidence and confidence in the data.

RESULTS

The two 523-foot-long 42-inch diameter reinforced concrete combined storm and sewer pipes were inspected with pipe penetrating radar for a total length of 1002 feet. The Surveyor provided an ideal stable platform to operate the LiDAR’s since the quality of the antenna-pipe wall contact is critical to the success of PPR investigations. The 9, 10, 11, and 12 o’clock positions were investigated.

Figure 4. Surveyor deployment in the RC pipe

A 20 foot long 48-inch cured in place pipe (CIPP) lined corrugated metal pipe (CMP) segment is present at access CO 1 and CO 2 (Figure 5). The Surveyor was successfully deployed; data collection started at the point where the 42" RCP pipes started and drove past each CMP segment.

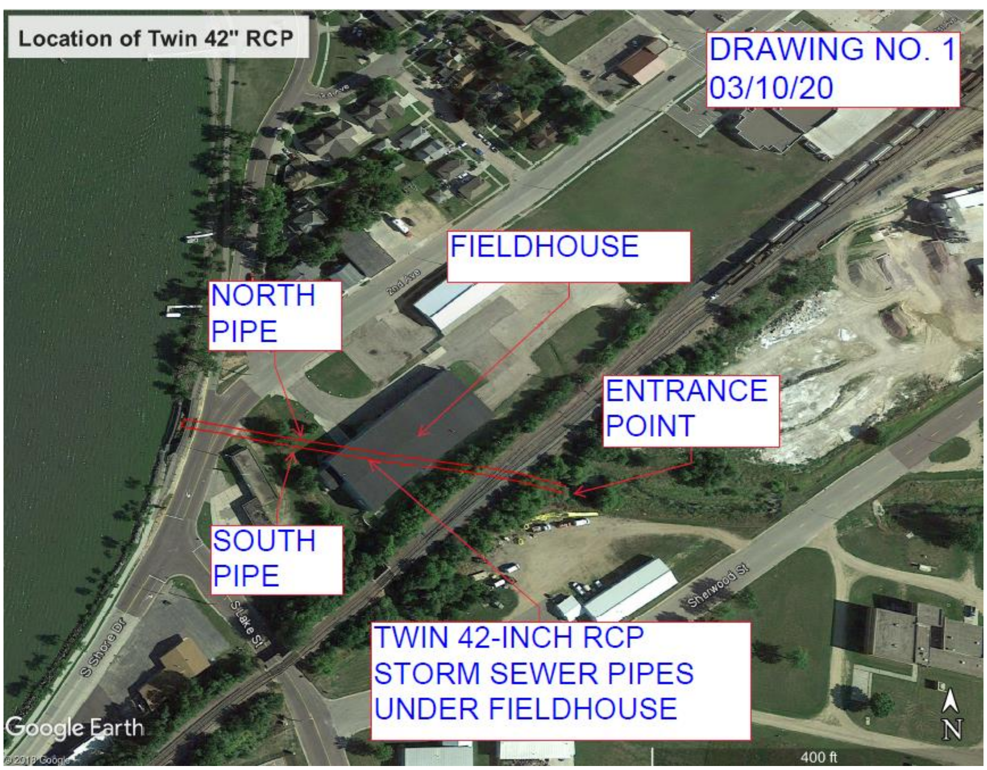

Figure 5. Field house overview

Proprietary software was used to apply different corrections, filter, and gain functions to the PPR data. This processing enhances anomalies and allows for a clearer interpretation of the results. The results of the PPR data are then presented as two-dimensional depth slices (Figure 6).

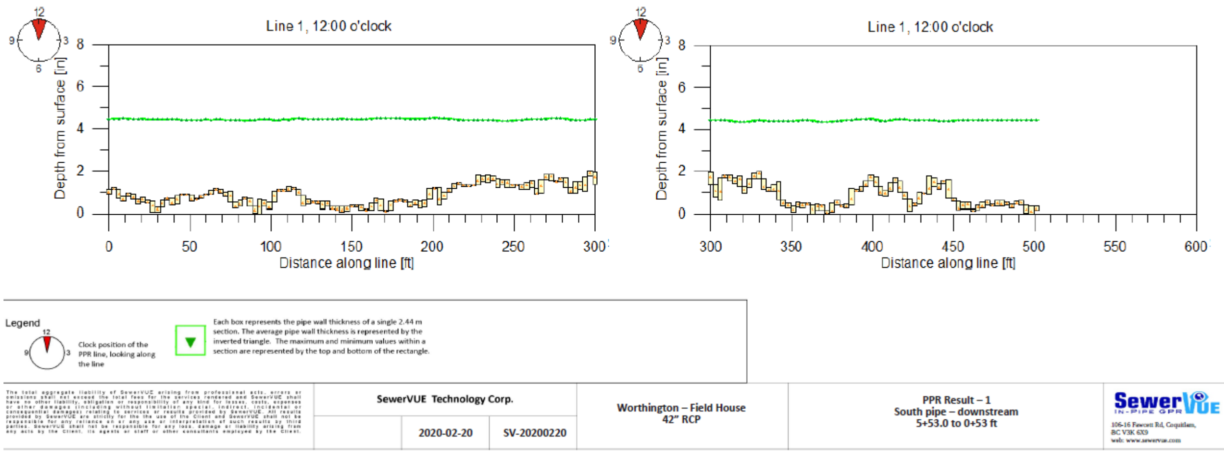

Figure 6. PPR summary graphs for the south pipe showing pipe wall thickness (green line) and rebar cover (lower "line") for each 2.44 m pipe section. Where rebar cover approaches 0 it means less than minimal rebar cover.

According to Short Elliot Hendrickson engineers, both RCPs had undergone differential settlement however the results of the inspection concluded that the North pipe exhibited 2.4 times more anomalies than the South pipe, highlighting voids outside its upper pipe walls. Both pipes' LiDAR cross-sections show signs the pipe being slightly out of round. Possibly causes of this were manufacturing defect or due to loading over time.

The size of the voids was estimated based on multiple line scans along the obvert of the pipe, and overlaying their depth based on position and stationing.

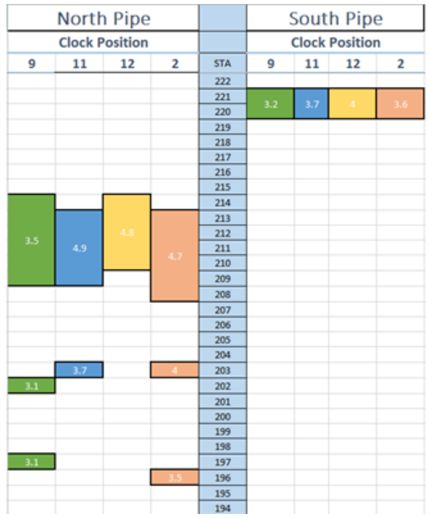

Figure 7. Pipe Penetrating Radar detected voids based on depth and positioning.

The pipe penetrating radar results showed detected several segments where the reinforcement was less than half an inch from the inner pipe wall. This is typically indicative of a pipe that has had its wall thickness diminished over time. However, video evidence showed little evidence of spalling, and the LiDAR results measured the internal diameter to be as expected. The pipe penetrating radar data corroborated this by measuring a typical pipe wall thickness of 4.5 inches. After additional research and discussion with pipe manufacturers, the positioning of the reinforcement was determined to be typical within the construction methods of this class of pipe during the era in which they were manufactured. The evidence seems to suggest that the minimal reinforcement cover was a result of construction and not corrosion. With PPR and LiDAR data the need for rehabilitation was clear. The City of Worthington will commence the renovation of the recreational center accordingly and the Union Pacific Railroad will be able to continue operation after pipe rehabilitation maintenance.

CONCLUSION

Pipe penetrating Radar is a non-destructive, quantitative condition assessment technology. The benefits allow for the accurate detection of voids, cracks and cavities. Supplemented with data from other survey methods such as LiDAR and CCTV, PPR can be used to generate comprehensive data about the conditions of the pipe.

In the case of inspecting the RC pipes in Worthington, MN PPR and LiDAR were complementary to each other. The data from both sensors form the basis for accurate predictive models that allow utility owners to make efficient asset management plans. After the inspection, the City of Worthington was able to address their concerns and continued to tackle asset management decisions to build a structurally strong and safe recreational center for its residents.