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Sewer Leak Detection – Electro-Scan Adds a New Dimension

Abstract

This study shows that sewer Electro-Scanning is able to pinpoint pipe defects that are large sources of collection system infiltration. These defects were not located using other investigation methods.

The City of Redding has used flow monitoring, television inspection, joint air pressure testing and smoke testing for infiltration assessment and location for more than 20 years. Despite repairing all detected leaks, the collection system wet weather flows were consistently 300% greater than dry weather flows.

A pilot study, Electro-Scanning 7.6 km (25,000 ft) of main line sewers was instigated to pinpoint the sources of the infiltration in a sub-basin that had particularly high peak wet weather flows of 1.7 megalitre (450,000 gallons) per day.

This paper describes how the Electro-Scan data was used to select twelve locations for spot repair. Photographs of some of the defects found when the pipe was exposed are included. The locations were accurate and large defects were found and repaired. After the repairs the peak wet weather flow decreased to 0.9 megalitre (250,000 gallons) per day.

This paper also discusses how the straightforward Electro-Scan testing was integrated into the regular jet cleaning maintenance operations.

Introduction

The City of Redding wastewater collection system has the same problem as most utilities – infiltration. During periods of high rainfall, treatment plants have received flows in excess of 300% of their daily dry flows. System operating cost is considerably increased by these high volume wet weather flows. Daily treatment volumes are larger and emergency maintenance increases. Greater capital expenditure is required to increase pipe sizes and treatment plant capacity.

Leak Detection Methods Previously Used by the City of Redding

Flow Monitoring

The city has 9 permanent flow monitors located at lift stations and uses 28 portable flow monitors to cover the 610 km (380 miles) collection system. Attempts have been made to localize the sources of the inflow and infiltration by monitoring smaller and smaller collection sub basins. However due to the variability of rainfall events it takes years to obtain definitive data. Data analysis requires complex modeling and statistical analysis requiring out-of-house expertise. Obtaining data to show definitive evidence that a leak repair project in a specific sub basin has been successful is equally as complex, time consuming and expensive.

Flow monitoring is able to show the volume and general extent of infiltration but to design an infiltration mitigation project the location and nature of the pipe leaks is required.

Closed Circuit Television (CCTV) Inspection

The City of Redding has owned a CCTV unit since 1976 and has inspected most of the system at least once. These inspections have shown that the structural condition of the collection system is generally good.

CCTV cannot detect pipe joints or service connections that are suspected of being major contributors of infiltration. Except for indirect evidence of potential leaks, such as root penetration, the only time CCTV identifies a faulty joint is when water is detected flowing through the joint. This usually only happens during or shortly after a high rainfall period. This is not a time when CCTV can be used because the pipes are full.

This major shortcoming of CCTV goes a long way towards explaining why attempts to minimize infiltration fell short of expectations, and why significant payback from pipe rehabilitation through reduced operations and maintenance costs have been difficult to realize. CCTV only detects the location and nature of some pipe leaks.

CCTV is a subjective test in that its reliability depends on the experience and judgment of the operator. The review and input of CCTV information into a collection system condition analysis database is a major component of the assessment cost.

Joint Testing and Sealing

Joint testing and sealing has been used extensively in the City of Redding to identify faulty joints. This technique uses an in-pipe packer to isolate a joint and applies air pressure to test the soundness of the joint. If the air test shows that the joint leaks, chemical grout is pumped into the isolated joint and the joint is air tested again to ensure that the joint has been sealed. During this process CCTV is used to inspect the pipe, position the packer and monitor the testing and sealing of the joint. While this system can effectively identify and seal leaky joints, it has the following shortcomings:

- Joints immediately adjacent to service connections cannot be tested or sealed.
- Service connections cannot be tested.
- The severity of the defect is not quantified so joints may be sealed that are not cost effective to seal.
- The process takes considerable time. It can take a three man crew up to two days to test and seal a 150 m (500ft) section of 1940's vintage clay pipe with 2 foot joint separation.
- The in-pipe equipment barely fits into 150 mm (6 inch) pipe. Over 50% of the City of Redding's collection system is comprised of 150 mm (6 inch) pipe. Consequently the equipment becomes stuck frequently, often requiring excavation to retrieve the equipment.

This process has been used for 20 years to test and seal every accessible joint. The lengths of serviced pipe are 143 km (89 miles) of 150mm (6 inch) diameter pipe, 64 km (40 miles) of 200mm (8 inch) diameter pipe and 32 km (20 miles) of 250 mm (10 inch) and 300 mm (12 inch) diameter pipe. A considerable number of joints in these pipes were grout sealed.

Smoke Testing

Smoke testing has been used extensively on sections of the collection system that show dramatic increases in flow over very short periods of time during rain storm events. Smoke testing is carried out by isolating a manhole to manhole section of pipe and blowing smoke into the pipe. Observers then inspect the area in the region of the test section for the appearance of smoke coming from cracks in the ground, roof drains, clean outs etc

The type of flow sources usually located were inflows from roof drains, open clean-outs or leaky manholes covers that would become submerged during peak wet weather conditions. While smoke testing has located some sources of wet weather flows, repairing the defects has had little effect on the wet weather flow volume.

Summary of Past Efforts to Reduce Wet Weather Sewer Flows

The City understands that reducing infiltration could significantly reduce operation and maintenance costs. However, despite over 20 years of flow monitoring, CCTV inspection, joint air pressure testing and smoke testing to locate and repair pipe defects, peak wet weather flows continue to stress both the collection system and the treatment facilities. Apparently a considerable number of pipe defects have not been located. The pipe defect investigation methods used to date have been unable to identify the sources of leaks with sufficient reliability and accuracy for the design and implementation of an effective pipe rehabilitation program to mitigate infiltration.

Sewer Electro-Scan

The City of Redding determined that more accurate and reliable information was required about the location, nature and size of potentially leaky pipe defects. With this objective in mind an electro-scan pilot study was undertaken.

Technology

Sewer electro scanning locates pipe defects by measuring the electrical resistance of the pipe wall. Most sewer pipe materials such as clay, plastic, concrete, reinforced concrete and brick are electrical insulators thus having high resistance to electrical current. A defect in the pipe that leaks water will also leak electrical current, whether or not water infiltration is occurring at the time of the test.

A fixed electric voltage is applied between an electrode in the pipe, called a sonde, and an electrode on the surface, which is usually a metal stake driven into the ground. A simplified electrical circuit for this procedure is shown in Figure 1. The water in the pipe is at a level that ensures that the pipe is full at the sonde location. The electrical resistance of the current path between the sonde and the surface electrode is very low except for through the pipe wall. The high electrical resistance of the pipe wall prevents electrical current from flowing between the two electrodes unless there is a defect in the pipe, such as a crack, defective joint or faulty service connection.

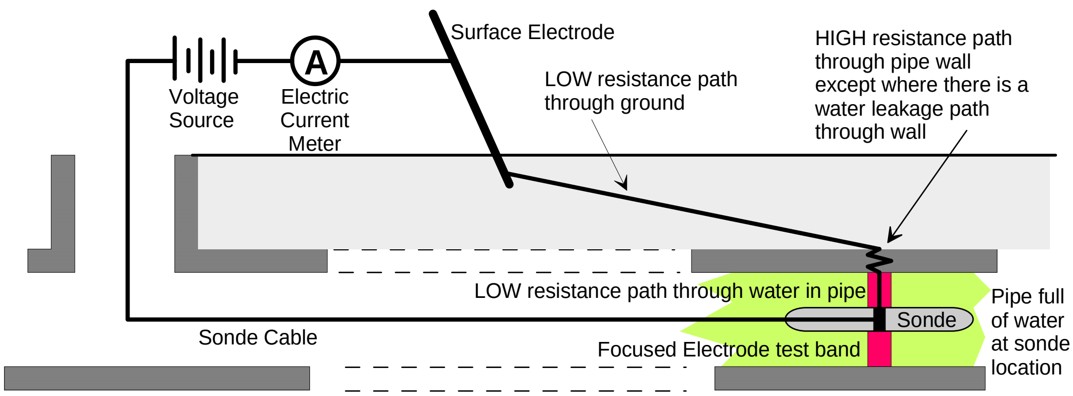


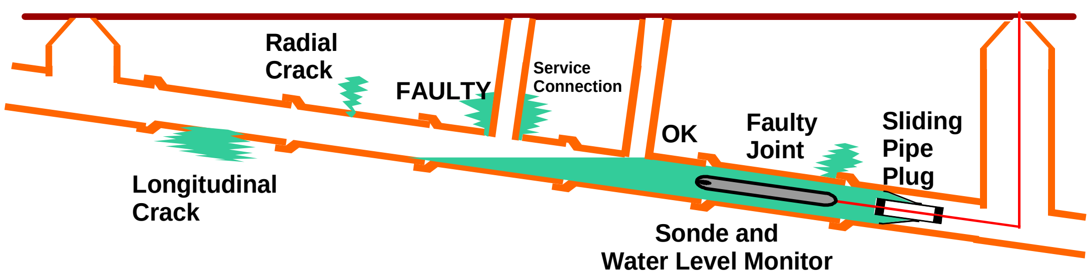
Figure 1. Electro-Scan Electrical Schematic

Electro-Scanning is carried out by pulling the sonde through the pipe at a speed of 10 m/minute (30 ft/minute) and measuring the variation of electric current flowing between the sonde and the fixed electrode on the surface. When the sonde is close to a pipe defect the electric current increases because the defect decreases the electrical resistance of the pipe wall. The sonde is designed to measure only that electric current which flows through a circular test band around the pipe wall. The test band is about 30 mm (1 inch) wide and located at the middle of the sonde.

Field Operation

To Electro-Scan a pipe the sonde is placed in the pipe through a manhole located at the start of the pipe section to be tested, and the pipe is partly filled with enough water to fill the pipe at the sonde location. The surface electrode is placed in the ground. The test location details are entered into the computer and the sonde winch turned on. The sonde current is displayed in real-time on the computer screen. When the sonde reaches the manhole at the end of the test section the winch is turned off, the computer file saved and the sonde retrieved from the pipe.

Man entry into manholes is not required. Other than ensuring that the system is operational, the field operator is not required to carry out any interpretation of the data or



adjust the test procedure.

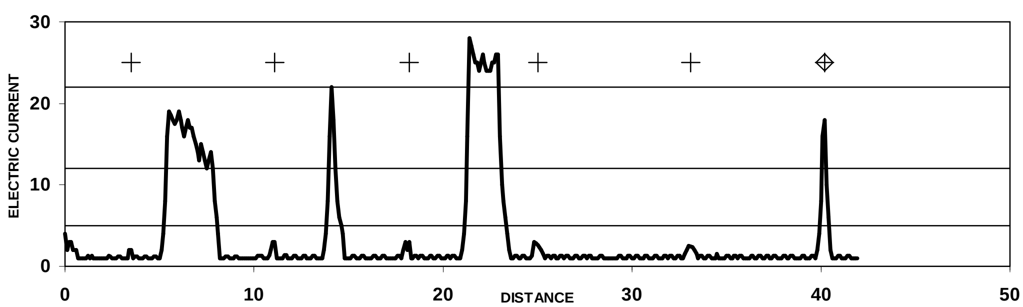


Figure 2. Electro-Scan Testing and Current Trace

Outputs

As the sonde is pulled through the pipe the electric current flow and the position of the sonde in the pipe are recorded and displayed in real time as a "current trace" on a notebook computer (See Figure 2). When the middle of the sonde comes within 20 to 30 mm of a defect in the pipe wall the electric current through the pipe wall increases, attaining a maximum value when the center of the sonde is radially aligned with the defect. All the data collected is digital and stored in a database format that can be readily accessed by, or transferred to, other collection system management software programs.

Analysis

Analysis of the current trace is carried out by setting a sonde current "threshold" level, picking anomalies where the current trace is above the threshold level, grading the anomalies as large, medium or small, entering the pipe joint interval, measuring the length of the anomalies and calculating the total length of the anomalies. Other than selecting the threshold and grade levels and entering the pipe joint interval, all other functions are performed in a few seconds by a computer program.

The threshold levels are established from comparison studies between electro-scan data and joint pressure tests. The threshold levels are selected to provide discrimination between defects that are considered to be very small and therefore very small leak sources and defects that are considered to be larger or more significant.

Regions on the current trace where the sonde electrode current levels are above the threshold level are called "anomalies". The threshold level is shown as the lowest horizontal line on the current trace (See Figure 2).

The location and length of an anomaly indicates the location and longitudinal length of a defect along the pipe. The maximum current level of the anomaly is a measure of the amount of current flow through the defect and is related to the size of the defect. The anomalies are graded as large, medium or small according to the maximum value of the sonde current level of the anomaly. The large-medium and medium-small current level boundaries are shown as horizontal lines on the current trace (See Figure 2). The threshold level and the boundaries between large, medium and small can be refined with the use of selective joint air pressure testing.

Anomalies that occur at regular intervals are usually due to joint defects. To assist with the identification of these anomalies points shown as "+" on the current trace are marked at the joint interval. Anomalies that occur at these intervals are considered to be associated with a joint defect and are marked with a "◇" plotted over the "+" (See Figure 2). Other anomalies are usually due to faulty service connections and structural defects.

Pipe Defect Frequency Comparison

An Electro-Scan Histogram shows the frequency and type of current trace anomalies for a selected group of pipe sections (See Figure 3). The total length of the anomalies for each manhole-to-manhole pipe section is expressed as a percentage of the pipe section length. The relative length, grade and type of defects for each pipe section are readily apparent. The chart can be used as a tool to prioritize repair programs. The defect type provides a guide for the design of the most beneficial rehabilitation method.

City of Redding Electro-Scan Pilot Study

Pilot Study Area

Most of the 150 mm (6 inch) and 200 mm (8 inch) sewer pipe tested was in a collection basin that would overflow during the worst of wet weather /storm conditions. This area was the city's worst infiltration sub-basin. Every pipe in the basin had been flow monitored, CCTV inspected and smoke tested. Every accessible pipe joint had been joint pressure tested and sealed. The reduction of wet weather flows from these efforts was negligible.

7.6 km (25,000 ft) of pipe was electro-scanned over a period of seven days using a FELL-41™ system

Integration of Sewer Electro-Scanning with Operations and Maintenance

The electro-scanning was integrated with the City of Redding's regular sewer pipe jet cleaning operations as follows:

- Clean Pipe from downstream manhole (MH).
- Pull hose out of upstream MH and remove jet.
- Attach sliding pipe plug and sonde to jet hose and place in sewer (1 minute)
  The sliding pipe plug is used to block the sewer so the pipe is kept full in the region of the sonde. This provides electrical contact between the sonde over the entire circumference of the pipe wall. The sliding pipe plug blocks the water flow while it is pulled through the pipe. The sonde contains a pressure gauge that provides continuous monitoring of the water depth in the region of the sonde as it is pulled through the pipe.
- Fill pipe in region of sonde with water through jet hose (1 to 5 minutes).
  The length of time depends on the existing sewer flow and the diameter and gradient of the pipe.
- Record electro-scan data while using jet hose to pull sliding pipe plug and sonde to downstream MH (10 minutes for 300 ft). Enter location data in the computer and turn ON sonde.
- When the sonde has been pulled to the downstream MH, the hose and sliding pipe plug is pulled out and the sonde disconnected (1 minute).
- While the jet cleaner moves off the MH, refills with water and cleans the next pipe section, the sonde is retrieved from the tested section, moved to the next MH and is prepared for attachment to the jet hose.

Jet truck down-time to electro-scan a 300 ft pipe section is 10 to 15 minutes.

It should be noted that Electro-Scanning can be carried out without a jet truck. The only requirement is that the pipe is sufficiently free of obstructions and that a source of water is available to fill the pipe in the region of the sonde. Sewerage is usually a sufficient source of water if the existing flow is greater than 30%.

Electro-Scan Data Analysis

Electro-scan Histograms were generated for all the electro-scan data collected. An example summarizing 14 pipe sections and about 4,200 ft of pipe is shown in Figure 3. It is observed that Victor Ave 4 and Deerfield Ave 5 have the greatest percentage of defects.

Oxford Rd 2, Deerfield Ave 1 and Lindeena Ln 1 also show a significant percentage of defects graded as large and other indicating that these pipe sections have a few large defects, possibly associated with service connections. It was considered likely that spot repairs might significantly reduce the infiltration volume from these pipe sections.

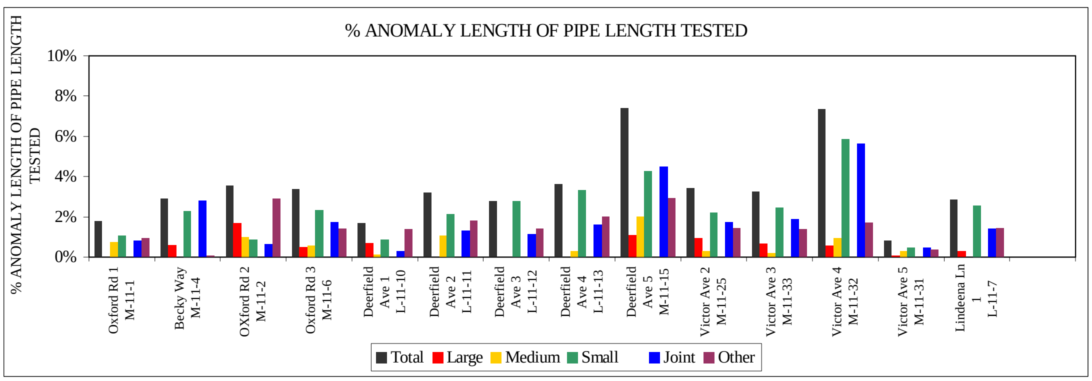


Figure 3. Electro-Scan Histogram Redding Pilot Study

Figure 4 is part of the Electro-Scan current trace of Lindeena Ln 1 This trace shows very small anomalies below the threshold level at most of the joints. There are small anomalies at three joints. The service connection locations are marked with "△". The Electro-Scan shows that the most significant pipe defects occur at the service connections located at 45 m (149 ft) and 47 m (155 ft).

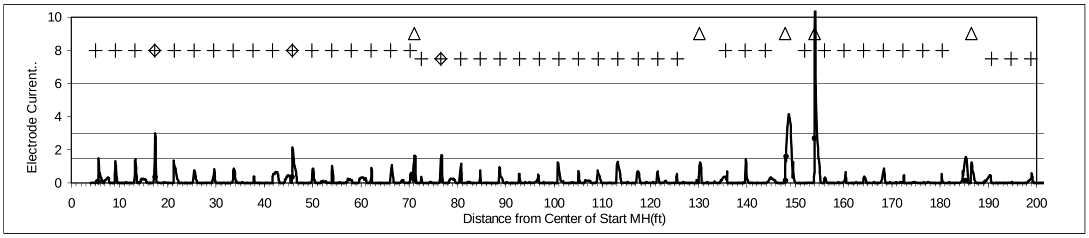


Figure 4. Electro-Scan: Lindeena Ln 1, Redding Pilot Study

Figure 5 is part of the Electro-Scan current trace of Deerfield Ave 1 This trace shows very small anomalies below the threshold level at many of the joints. There are small anomalies at three joints. The Electro-Scan shows that the most significant pipe defect occurs at the service connection located at 6.7 m (22 ft).

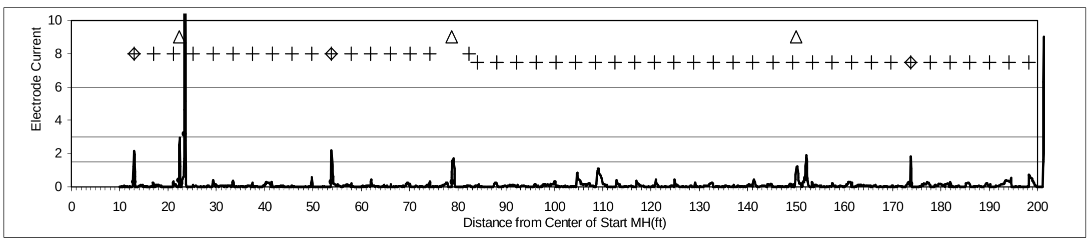


Figure 5. Electro-Scan: Deerfield Ave 1, Redding Pilot Study

Ground Truthing Electro-Scan Data

Spot repairs were used to verify the Electro-Scan data. This method provided direct inspection of the pipe and any defects found could be immediately repaired.

Using the trace analysis method described above, electro-scan data was used to select twelve sites for spot repair. When the pipe was exposed smoke testing was used to verify thatthe pipe leaked and the defect was photographed.

Pipe defects were found and repaired at each of the selected locations. The position given by the electro-scan was accurate thus enabling the maintenance crews to make repairs efficiently. Figure 6 shows the faulty service connection joint at Lindeena Ln 1. Figure 7 shows the service connection at Deerfield Ave 1 This connection leaked because the steel bands were loose.

Figure 6. Spot-Repair Lindeena Ln 1

Figure 7. Spot Repair Deerfield Av 2

Wet Weather Flow Reduction

Prior to spot-repairs the collection sub-basin had storm event flows in excess of 1.7 megalitre (450,000 gallons) per day and the system surcharged and at times overflowed. There have been comparable storm events since the completion of the twelve spot repairs. Although every wet weather event is unique, the sub-basin maximum flow since the repairs was a more manageable 0.9 megalitre (250,000 gallons) per day. More defects have been targeted and are scheduled for repair.