# The Need to Quantify Pre- and Post-Rehabilitation Effectiveness

By Chuck Hansen[1]

## Introduction

Infiltration of groundwater through defects can considerably increase the operational expense and capital costs of a sewer system.

As a general rule, sewer owners and operators have widely believed that for every 1,000 linear feet (LF) or 305 meters (m) of lining or pipe replacement, approximately 8-10 million gallons per year (2.9 to 3.7 billion liters per year) of infiltration could be eliminated. Municipal bonds are sold to investors to raise funds; capital expenditures are budgeted; specifications are published to solicit tenders; contractors are selected; and, trenchless technologies are employed using various lining materials, coatings, and curing methods.

Trenchless rehabilitation has been a long-standing response to reduce inflow/infiltration; however an increasing number of utilities are either finding limited reductions in flow or returning to pre-rehabilitation levels of infiltration.

Recent studies have been limited to evaluating field samples of lining cross-sections to assess whether the originally planned lifetime of CIPP (typically assumed to be 50 years) was achievable. Yet, post-rehabilitation inspections are starting to uncover serious impairments that question widely held assumptions on the operating performance and overall effectiveness of CIPP, particularly if not properly installed or inspected.

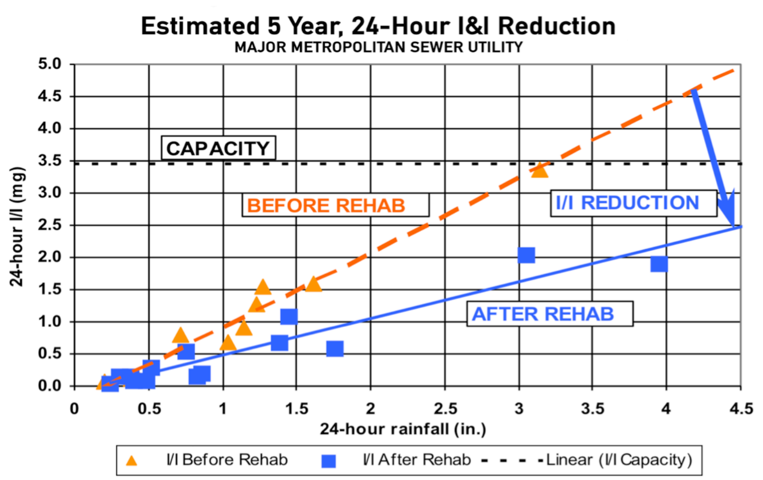


**Figure 1. Sample analysis from a large metropolitan sewer utility on expectations in I/I reductions from rehabilitation.**

While post-rehabilitation inspection of CIPP has been limited to CCTV inspection or pressure testing of pre-inverted liners, a new technology known as Electro Scan (ASTM F2550-13) has emerged to offer an unbiased, quantitative assessment of pre- and post-rehabilitated pipes that can provide a before and after defect rating of critical sewer and water assets.

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[1] Chairman, Hansen Investment Holdings, LLC, a private equity investment firm, Chairman, Electro Scan Inc., Chairman, ASTM, F36.20, Inspection and Renewal of Water and Wastewater Infrastructure, Former Chairman & Founder, Hansen Information Technologies Inc. (Sold in 2007). BSc (UC Berkeley, 1978), MBA (UCLA, 1982).

**Benefits of Establishing Pre- and Post-Rehabilitation Defect Ratings**

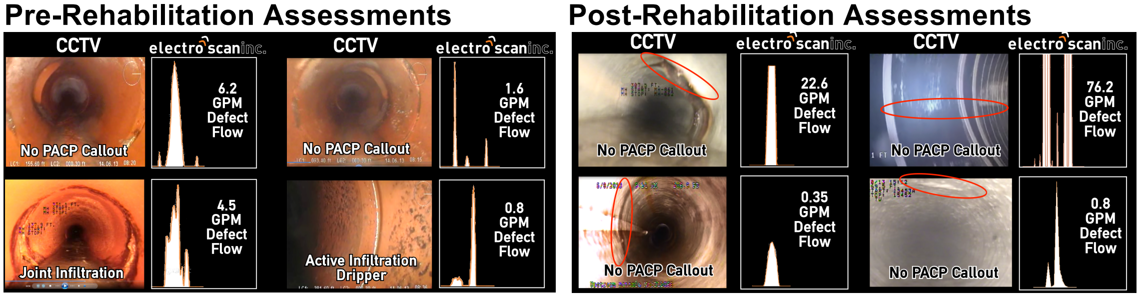
The advantages of providing pre- and post-rehabilitation defect flows, expressed in either gallons per minute (GPM) or litres per second (LPS), are numerous. Key benefits of a quantitative analysis of defect flows, before and after rehabilitation, include the ability to:

- Establish a baseline defect flow rating to prioritize critical sewers & water assets;
- Overcome shortcomings of visual observations and cataloguing using CCTV cameras;
- Quantify specific reductions in infiltration from rehabilitation, repairs, and renewal;
- Enforce minimum allowances for defect flows as part of manufacturer's warranties;
- Certify post-rehabilitated repairs, relining, and renewal of pipes;

Historically, CCTV surveys have been the principal means to identify points of water ingress into sewer and stormwater networks; however, its low success rate of identifying sources of infiltration, inability to be used in partially or fully surcharged pipes, limited ability to locate or quantify defects at joints -- sometimes referred to as *invisible* leaks -- and conflicting cataloguing of visual defects, has made CCTV an unreliable diagnostic tool to consistently find sources of infiltration or certify post-rehabilitated pipes.

In 2011 the USEPA benchmarked several emerging technologies in comparison to CCTV inspections.[2] CCTV defects that were categorized as potential leaks were closely examined to determine if any other technology showed defects at the same internal pipe location. As illustrated in Figure 2, this defect-by-defect comparison was able to show that Electro Scan technology identified pipe defects for 82% of the pipe defects shown by CCTV; however, the Electro Scan technology identified 2.1 times more defects than CCTV, including 4.8 times more defects at joints and 30 times more defective manhole-to-pipe joint locations.[3] In fact, CCTV missed many defects, including the largest defect flows identified by Electro Scan.

**Pre-Rehabilitation Assessments** **Post-Rehabilitation Assessments**




**Figures 2. Sample side-by-side CCTV and Electro Scan comparisons for pre- and post-rehabilitated pipes.**

While previous studies were limited to sewer mains, a 2013 EPA-funded study compared side-by-side comparisons of CCTV and Electro Scan for twenty-seven (27) service laterals.[4] In this study, Electro Scan found 3.6 times more defects than CCTV. Furthermore, CCTV consistently (1) missed major sources of infiltration found by Electro Scan, (2) used the same code for different-sized defects or leaks, (3) used different codes to catalogue the same-sized defect or leak, and (4) indicated defects, where no apparent electrical pathway to ground existed (i.e. a false-positive observation).

While not a complete replacement for visual inspection, sewer utilities that have switched their focus from sewer mains to service laterals to find sources of infiltration, may be better served by re-investigating its sewer mains using more accurate assessment technologies.

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[2] EPA Field Demonstration of Condition Assessment Technologies for Wastewater Collection Systems, 2011
[3] EPA Sewer Electro Scan Field Demonstration Revisited, (Moy, Wilmut, Harris), 2012.
[4] WERF and EPA, Sewer Lateral Electro Scan Field Verification Pilot, 2013.

**Growing Concern About Performance & Useful Life of CIPP and Other Rehabilitation**

Recent studies and benchmarks are showing an increasing number of impaired CIPP projects, questioning the operating performance and effectiveness of relining, especially resulting from poor installation and/or inadequate post-CIPP inspection techniques.

As part of a recent report published by the US EPA,[5] testing of CIPP was conducted in both large and small diameter sewers in two cities: Denver, Colorado and Columbus, Ohio, USA. Other US cities have subsequently been added to this ongoing study.

The purpose of the EPA study was to determine whether the originally planned lifetime of CIPP (typically assumed to be 50 years) was reasonable, based on the current condition of the liner. Despite the large public investment in CIPP, prior to this study there had been little quantitative analysis to confirm if structural or operating performance was as expected.

Field samples were retrieved from CIPP linings. Taken at numerous pipe locations, specific measurements and tests, included thickness, annular gap, ovality, density, gravity, porosity, flexural strength, flexural modulus, tensile strength, tensile modulus, surface hardness, glass transition temperature, and Raman spectroscopy.

In Denver, Colorado, for example, a total of 5,797 LF (1,767m) of lined pipe was surveyed that included sixteen (16) lines installed with CIPP in 1984, as shown in Figure 3. In the absence of more advanced assessment technologies, each surveyed liner was re-televised in 2009, finding a number of defects, including:

| | |
|---|---|
| Location: | City of Denver, CO: Monroe Street and 1st Street |
| Host pipe: | Circular, 8 in. diameter, vitrified clay pipe (VCP) |
| Burial depth: | 5 ft (above crown) |
| Liner dimensions: | 8 in. diameter; 6 mm thick |
| Resin: | Reichhold 33-060; an isophthalic, polyester, unfilled resin |
| Primary catalyst: | Perkadox 16 |
| Secondary catalyst: | Trigonox C |
| Felt: | Unwoven fabric (similar to products used today) |
| Seal: | Polyurethane, 0.015 in. thick (today CIPP liners use polyethylene coating) |
| Year liner installed: | 1984 |
| Liner vendor: | Insituform |
| Resin supplier: | Reichhold |
| Tube manufacturer: | Insituform |

**Figure 3. Lined pipe profile for the City of Denver pilot test.**

- Several break-in defects and lining failures at undercut connections that could be attributed to robotic cutters;
- Root intrusion via tap connections that resulted in partial blockage of the line;
- One (1) liner failure in the vicinity of a tap break in;
- One (1) liner failure where a bulge was found at the invert of the liner that prevented further advancement of CCTV equipment;
- One (1) liner failure attributed to improper restoration of a nearby lateral connection, with a significant portion of the polyurethane coating was hydrolyzed along this line;
- Similar occurrences of a liner connection cut shift.

While the study concluded that there was no reason to anticipate that liners would not last for their intended lifetime of 50 years (and perhaps beyond), the study failed to address or quantify the severe degradation in operating performance of the post-rehabilitation pipe where numerous break-ins, root intrusion, and failures were found.

While liner cross-sections should continue to be laboratory-certified, long-term operating performance of CIPP may not be assured, especially if proper installation and inspection protocols are not satisfied.

[5] EPA/600/R-12/004 | January 2012, A Retrospective Evaluation of Cured-in-Pave Pipe (CIPP) Used in Municipal Gravity Sewers.

## Case Study: Large Metropolitan Sewer Utility, USA

In April 2014, a large U.S. metropolitan sewer utility surveyed 8,718.6 LF (2,657m) of lined pipe. Representing forty-nine (49) reach-to-reach pipe segments, all lined in the year 2000, high rates of flow prompted the utility to undertake a comprehensive smoke testing survey. With only a limited number of defects found by smoke testing or CCTV inspection, Electro Scan was recommended for follow-on assessment, commencing in March 2014.

Representing the first large-scale use of Electro Scan to assess post-CIPP linings, all forty-nine (49) lined pipes shown in Table 1 were found to have defect flows; 46 lined pipes (94%) registered greater than 1,000 gallons per day (0.043 LPS) of defect flow; and 19 lined pipes (39%) registered greater than 10,000 gallons per day (0.438 LPS) of estimated defect flow.

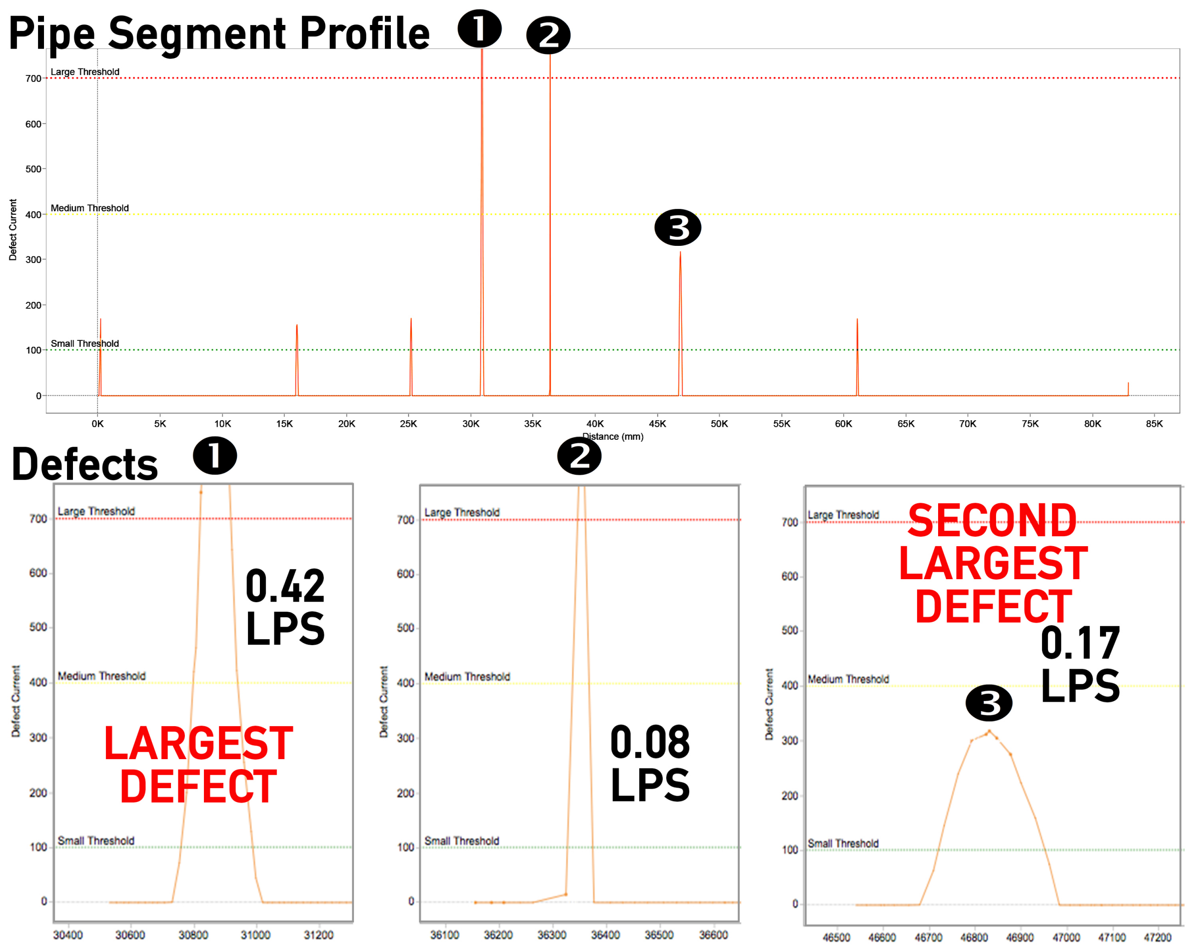
| | | Distance | | | Filtered | Number of Defects | | | | Defect Flow (GPM) | | | | Estimated | Estimated |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | mm | ft | Raw Data Points | Data Points | Small | Med | Large | TOTAL | Small | Mod | Severe | Total | Defect Flow (Gallons Per Day) | Defect Flow (Litres Per Second) |
| | Electro Scan ID | 2,657,420 | 8,719 | 196,187 | 121,527 | 157 | 34 | 25 | 216 | 57 | 76 | 200 | 333 | 479,822 | 21.0 |
| 1 | 00000179_apr012014_144919PM | 73,685 | 241.7 | 5648 | 4158 | 25 | 1 | 3 | 29 | 8.59 | 3.84 | 30.00 | 42.43 | 61,099 | 2.7 |
| 2 | 00000175_apr012014_111742AM | 91,435 | 300.0 | 4701 | 3725 | 1 | 0 | 2 | 3 | 0.85 | - | 19.74 | 20.59 | 29,650 | 1.3 |
| 3 | 00000186_apr022014_092453AM | 22,244 | 73.0 | 1573 | 763 | 2 | 0 | 2 | 4 | 0.34 | - | 17.62 | 17.96 | 25,862 | 1.1 |
| 4 | 00000178_apr012014_140110PM | 96,692 | 317.2 | 4988 | 4211 | 1 | 5 | 0 | 6 | 0.76 | 14.99 | - | 15.75 | 22,680 | 1.0 |
| 5 | 00000102_mar262014_154308PM | 75,310 | 247.1 | 4704 | 2724 | 1 | 2 | 1 | 4 | 0.19 | 4.98 | 10.00 | 15.17 | 21,845 | 1.0 |
| 6 | 00000180_apr012014_145714PM | 82,865 | 271.9 | 4451 | 3576 | 5 | 0 | 2 | 7 | 2.61 | 3.97 | 6.66 | 13.24 | 19,066 | 0.8 |
| 7 | 00000191_apr022014_113856AM | 94,769 | 310.9 | 4696 | 3619 | 0 | 1 | 1 | 2 | - | 2.48 | 10.00 | 12.48 | 17,971 | 0.8 |
| 8 | 00000176_apr012014_120759PM | 92,114 | 302.2 | 5410 | 4454 | 1 | 1 | 1 | 3 | 0.99 | 1.22 | 10.00 | 12.21 | 17,582 | 0.8 |
| 9 | 00000344_apr222014_111205AM | 38,109 | 125.0 | 3890 | 2168 | 4 | 0 | 1 | 5 | 1.35 | - | 10.00 | 11.35 | 16,344 | 0.7 |
| 10 | 00000171_apr012014_084724AM | 68,832 | 225.8 | 5116 | 3767 | 3 | 0 | 1 | 4 | 1.38 | - | 9.50 | 10.88 | 15,667 | 0.7 |
| 11 | 00000237_apr112014_090747AM | 62,299 | 204.4 | 5051 | 2803 | 1 | 0 | 1 | 2 | 0.67 | - | 10.00 | 10.67 | 15,365 | 0.7 |
| 12 | 00000347_apr222014_132003PM | 14,011 | 46.0 | 3877 | 888 | 3 | 2 | 1 | 6 | 1.12 | 3.20 | 6.27 | 10.59 | 15,250 | 0.7 |
| 13 | 00000169_mar312014_162416PM | 57,561 | 188.8 | 3079 | 2078 | 1 | 0 | 1 | 2 | 0.16 | - | 10.00 | 10.16 | 14,630 | 0.6 |
| 14 | 00000168_mar312014_161732PM | 32,279 | 105.9 | 1759 | 1242 | 0 | 0 | 1 | 1 | - | - | 10.00 | 10.00 | 14,400 | 0.6 |
| 15 | 00000353_apr222014_152723PM | 49,228 | 161.5 | 4859 | 2309 | 1 | 0 | 1 | 2 | 0.85 | - | 8.52 | 9.37 | 13,493 | 0.6 |
| 16 | 00000181_apr012014_152848PM | 86,032 | 282.3 | 4722 | 3808 | 1 | 1 | 1 | 3 | 0.42 | 3.26 | 5.57 | 9.25 | 13,320 | 0.6 |
| 17 | 00000221_apr082014_161927PM | 54,501 | 178.8 | 3748 | 2558 | 4 | 1 | 1 | 6 | 1.28 | 1.41 | 6.28 | 8.97 | 12,917 | 0.6 |
| 18 | 00000378_apr242014_153826PM | 54,592 | 179.1 | 3673 | 1963 | 5 | 1 | 1 | 7 | 1.91 | 2.67 | 4.10 | 8.68 | 12,499 | 0.5 |
| 19 | 00000348_apr222014_133601PM | 27,494 | 90.2 | 1975 | 1466 | 2 | 1 | 1 | 4 | 0.55 | 1.23 | 5.37 | 7.15 | 10,296 | 0.5 |
| 20 | 00000385_apr252014_095246AM | 36,018 | 118.2 | 5388 | 1884 | 13 | 2 | 0 | 15 | 4.22 | 2.78 | - | 7.00 | 10,080 | 0.4 |
| 21 | 00000190_apr022014_113039AM | 67,015 | 219.9 | 3963 | 2829 | 3 | 0 | 1 | 4 | 2.21 | - | 4.15 | 6.36 | 9,158 | 0.4 |
| 22 | 00000183_apr012014_165922PM | 44,817 | 147.0 | 2412 | 1856 | 0 | 0 | 1 | 1 | - | - | 6.10 | 6.10 | 8,784 | 0.4 |
| 23 | 00000374_apr242014_122905PM | 48,327 | 158.6 | 3347 | 2650 | 2 | 2 | 0 | 4 | 0.46 | 5.40 | - | 5.86 | 8,438 | 0.4 |
| 24 | 00000177_apr012014_135222PM | 22,649 | 74.3 | 2888 | 1203 | 1 | 1 | 0 | 2 | 0.46 | 3.98 | - | 4.44 | 6,394 | 0.3 |
| 25 | 00000358_apr232014_095823AM | 50,197 | 164.7 | 3482 | 2251 | 12 | 0 | 0 | 12 | 4.14 | - | - | 4.14 | 5,962 | 0.3 |
| 26 | 00000332_apr172014_140957PM | 60,254 | 197.7 | 3546 | 2625 | 5 | 1 | 0 | 6 | 1.49 | 2.62 | - | 4.11 | 5,918 | 0.3 |
| 27 | 00000172_apr012014_092348AM | 30,097 | 98.7 | 3172 | 1300 | 6 | 1 | 0 | 7 | 2.78 | 1.04 | - | 3.82 | 5,501 | 0.2 |
| 28 | 00000245_apr112014_144404PM | 73,151 | 240.0 | 4118 | 3754 | 0 | 1 | 0 | 1 | - | 2.91 | - | 2.91 | 4,190 | 0.2 |
| 29 | 00000330_apr172014_113224AM | 30,913 | 101.4 | 3023 | 1479 | 4 | 1 | 0 | 5 | 1.68 | 1.18 | - | 2.86 | 4,118 | 0.2 |
| 30 | 00000352_apr222014_151801PM | 49,594 | 162.7 | 5153 | 3053 | 1 | 1 | 0 | 2 | 0.37 | 2.37 | - | 2.74 | 3,946 | 0.2 |
| 31 | 00000174_apr012014_110812AM | 39,033 | 128.1 | 2568 | 1801 | 1 | 2 | 0 | 3 | 0.19 | 2.41 | - | 2.60 | 3,744 | 0.2 |
| 32 | 00000182_apr012014_165448PM | 20,352 | 66.8 | 4805 | 936 | 5 | 1 | 0 | 6 | 1.33 | 1.24 | - | 2.57 | 3,701 | 0.2 |
| 33 | 00000197_apr022014_153244PM | 79,477 | 260.8 | 4365 | 3464 | 1 | 1 | 0 | 2 | 0.10 | 2.10 | - | 2.20 | 3,168 | 0.1 |
| 34 | 00000193_apr022014_133540PM | 70,465 | 231.2 | 4026 | 2633 | 5 | 1 | 0 | 6 | 0.99 | 1.13 | - | 2.12 | 3,053 | 0.1 |
| 35 | 00000345_apr222014_113115AM | 20,260 | 66.5 | 3551 | 1122 | 1 | 1 | 0 | 2 | 0.45 | 1.35 | - | 1.80 | 2,592 | 0.1 |
| 36 | 00000244_apr112014_143559PM | 40,704 | 133.5 | 1852 | 1509 | 10 | 0 | 0 | 10 | 1.75 | - | - | 1.75 | 2,520 | 0.1 |
| 37 | 00000220_apr082014_151116PM | 64,574 | 211.9 | 9922 | 3494 | 1 | 1 | 0 | 2 | 0.34 | 1.19 | - | 1.53 | 2,203 | 0.1 |
| 38 | 00000173_apr012014_100117AM | 115,343 | 378.4 | 6482 | 4531 | 2 | 0 | 0 | 2 | 1.36 | - | - | 1.36 | 1,958 | 0.1 |
| 39 | 00000326_apr172014_091952AM | 57,103 | 187.3 | 4196 | 2728 | 1 | 1 | 0 | 2 | 0.30 | 1.03 | - | 1.33 | 1,915 | 0.1 |
| 40 | 00000192_apr022014_132822PM | 63,978 | 209.9 | 3648 | 2845 | 2 | 0 | 0 | 2 | 1.20 | - | - | 1.20 | 1,728 | 0.1 |
| 41 | 00000196_apr022014_152354PM | 81,842 | 268.5 | 5030 | 4021 | 4 | 0 | 0 | 4 | 1.19 | - | - | 1.19 | 1,714 | 0.1 |
| 42 | 00000184_apr022014_083802AM | 14,911 | 48.9 | 2510 | 921 | 3 | 0 | 0 | 3 | 1.13 | - | - | 1.13 | 1,627 | 0.1 |
| 43 | 00000185_apr022014_092136AM | 70,228 | 230.4 | 3519 | 2510 | 2 | 0 | 0 | 2 | 0.92 | - | - | 0.92 | 1,325 | 0.1 |
| 44 | 00000222_apr082014_165915PM | 27,281 | 89.5 | 2991 | 1429 | 2 | 0 | 0 | 2 | 0.90 | - | - | 0.90 | 1,296 | 0.1 |
| 45 | 00000236_apr112014_085748AM | 51,013 | 167.4 | 3920 | 2561 | 2 | 0 | 0 | 2 | 0.86 | - | - | 0.86 | 1,238 | 0.1 |
| 46 | 00000246_apr112014_144719PM | 8,035 | 26.4 | 1175 | 374 | 2 | 0 | 0 | 2 | 0.78 | - | - | 0.78 | 1,123 | 0.0 |
| 47 | 00000363_apr232014_141617PM | 47,740 | 156.6 | 4175 | 2717 | 2 | 0 | 0 | 2 | 0.67 | - | - | 0.67 | 965 | 0.0 |
| 48 | 00000167_mar312014_161327PM | 62,002 | 203.4 | 3792 | 2760 | 2 | 0 | 0 | 2 | 0.54 | - | - | 0.54 | 778 | 0.0 |
| 49 | 00000325_apr172014_085541AM | 35,995 | 118.1 | 5248 | 2007 | 1 | 0 | 0 | 1 | 0.52 | - | - | 0.52 | 749 | 0.0 |
| | | 2,657,420 | 8,718.6 | 196,187 | 121,527 | 157 | 34 | 25 | 216 | 57.35 | 75.98 | 199.88 | 333.21 | 479,822 | 21.0 |

**Table 1. Detail Electro Scan results for survey of forty-nine (49) post-CIPP, with two highlighted post-CIPP lines May 2014.**

Given such a significant percentage of lined pipes (at less than half their useful life) showing moderate to severe defect flows, sewer utilities with current or near-term CIPP projects should consider altering acceptance criteria for post-rehabilitated of their sewer mains.

### *Highlights of an Electro Scan Survey of a Post-CIPP Sewer Main*

A selected analysis of one (1) of the forty-nine (49) post-CIPP sewer mains electro scanned, showed several defects, as shown in Figure 4, representing a combined estimated defect flow of 19,066 GPD (0.84 LPS). As Electro Scan measures the area of each defect (i.e. height and width or start & end), it should be noted that while the highest *defect currents* are noted in Defect ❶ and ❷, Defect ❸ actually contributes the second highest defect flow rate as shown by its larger calculated area.




**Summary Data**

| Defect Grade | Defect Start (mm) | Defect End (mm) | Defect Length (mm) | LPS FLow | LPS Defect Area |
|---|---|---|---|---|---|
| S | 191 | 236 | 45 | 0.03 | 0.03 |
| S | 15,987 | 16,086 | 99 | 0.05 | 0.05 |
| S | 25,167 | 25,243 | 76 | 0.05 | 0.05 |
| L | 30,860 | 31,066 | 206 | 0.42 ❶ | 0.42 |
| L | 36,354 | 36,354 | 0 | 0.08 ❷ | 0.08 |
| S | 46,831 | 47,030 | 199 | 0.17 ❸ | 0.17 |
| S | 61,056 | 61,117 | 61 | 0.04 | 0.04 |

**Figure 4. Individual scanned pipes, ranked sixth (6th) out of a total of 49 pipe segments. Total pipe segment defect flow of 19,066 GPD, .084 LPS, or 72,190 LPD), including two (2) Large Defects and five (5) Small Defects. 00000180_apr012014_145714PM**

Many U.S. sewer utilities use ASTM F1216 to guide acceptable thickness requirements for CIPP lining projects, requiring service providers to conduct a post-construction CCTV inspection for each sewer main. Yet, without proper identification of potential defects, and their respective estimated flow rates, sewer utilities may be forced to address the operating performance of these same lines -- well before the end of a pipe's expected useful life.

### *Highlights of an Electro Scan Survey of a PVC Pipe*

Within reasonable cost, utilities tend to consider CIPP lining as its default procedure for rehabilitation. However, rehabilitation guidelines and specification, typically state that:

> **For 18-inch diameter sewers and smaller, if an existing sewer has been rehabilitated or is entirely PVC or Cast/Ductile Iron pipe, then the utility specifies that CCTV inspection data should be used to evaluate the sewer's condition. For sewers constructed in PVC, if the inspection data indicates the sewer is in good condition, i.e., no structural defects, no infiltration/ inflow sources, and no significant operations and maintenance defects, then no rehabilitation is required.**
>
> **Source: Large Metropolitan Sewer Utility's Design Management Manual, Appendix, May 2014**

So, how did Electro Scan evaluate a typical 8" PVC pipe, without CCTV showing measurable defects? While the majority of PVC pipes had no recorded defects from CCTV, a single 8" PVC pipe, scanned in March 2014 showed 1,077 GPM (4,076 LPD).

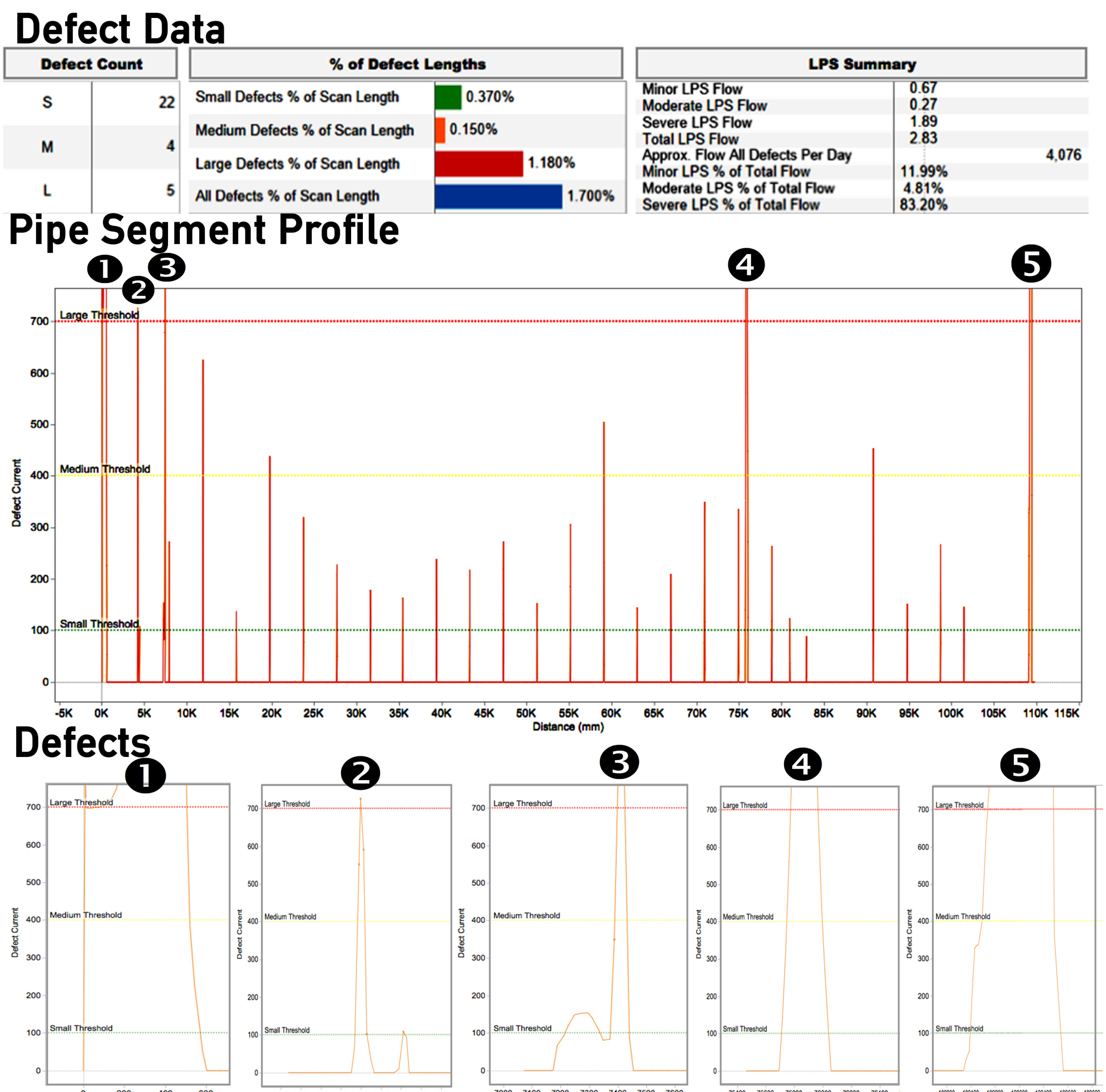



**Figure 5. Electro Scan results from an 8" PVC pipe 00000145_mar302014_103257AM.**

## Case Study: Municipal Sewer Utility, Florida, USA

Recently, a medium-sized metropolitan sewer utility on the Atlantic Coast of Florida had its consulting engineer conduct a historical analysis of flows at its wastewater treatment plant, after experiencing repeated rainfall dependent I/I peaks due to high rates of infiltration occurring where wet-weather flows are heavily influenced by groundwater levels.

Problem: *the sewer utility had been spending over $3 million annually on CIPP lining for the previous four years, upstream to its treatment plant.*

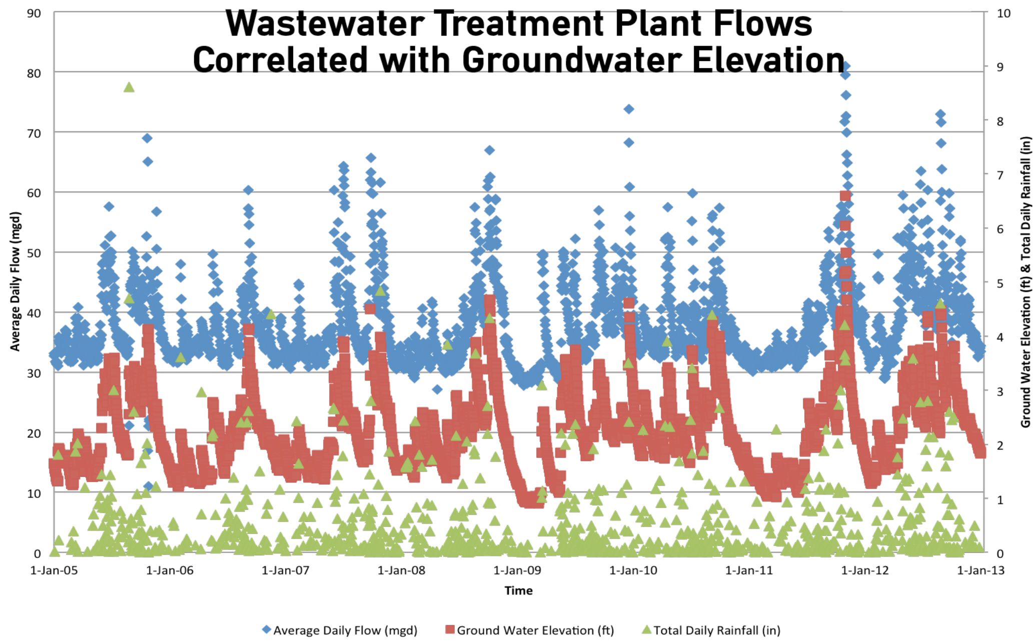



**Figure 6. Inflow & Infiltration Analysis at WWTP, 2005-2012.**

While flow monitoring had effectively identified constant or increased flows at the wastewater treatment plant, the absence of an unbiased pre- and post-rehabilitation testing protocol deprived the sewer utility from knowing which pipe segments were causing the majority of problems and granularity (i.e. location within each pipe segment) of specific defects.

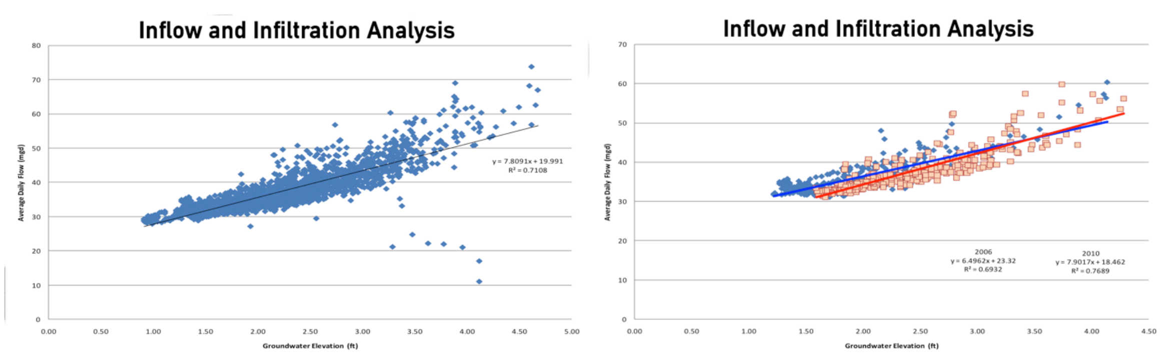



**Figure 7. (Left) WWTP flows correlate strongly with groundwater elevation, while (Right) correlation has not changed over time.**

While CIPP has been used as a long-standing response to help reduce I/I, sewer and water utilities have employed a wide range of other repair, replacement, and renewal alternatives, including point repairs, slip lining, flood grouting, and new pipe construction. Yet, an increasing number of utilities are finding either limited reduction in flow or a return to pre-rehabilitation infiltration levels after significant investment from one or more cycles of master planning, condition assessment, and rehabilitation.

**Case Study: Municipal Sewer Authority, Virginia, USA**

Two sub-basins within the James City Service Authority, VA, experienced persistent infiltration, even though they were 20-30 years old and constructed with PVC pipe material. Despite undergoing multiple rounds of condition assessment, followed by rehabilitation of identified defects, infiltration rates had remained unchanged.

In 2005, all water mains in Lift Station (LS) Basin 1-8 and 1-9 were replaced, with all pre-rehabilitated sewers evaluated using CCTV and visual inspection of manholes. Within the two basins, forty (40) sewer mainline segments were replaced (i.e. 4,320 LF of 8" gravity mains), 28 open-cut sectional or point repairs were made (i.e. 1,250 LF of 8" gravity mains), 14 manholes were replaced, and 17 manholes were lined with cement mortar.

Subsequent to repairs and rehabilitation, post-rehabilitation flow monitoring, using field-calibrated algorithms and SCADA, indicated that flows in both service areas increased significantly during wet weather events; 10-year 24-hour Peak Hour Flows for both basins were 5-to-7 times greater than the Peak Flow Thresholds. Hydraulic modelling, using rain and flow monitoring, was conducted during 2008 and 2009, projecting the 10 year-24 hour Peak Hour Flow to be 1,574 gallons per minute (gpm) at LS 1-8 and 959 gpm at LS 1-9 [Note: Peak Flow Threshold was 214 gpm for LS 1-8 and 183 gpm for LS 1-9].

In 2009 and 2010 both basins were smoke tested and re-televised using a Red Zone SOLO Robotic camera. Some open channel flow monitoring was performed and wet weather inspections were performed in the LS 1-9 basin to observe flows in manholes located upstream from the lift station. Two or three defective manholes were discovered (and again), all other significant defects were repaired.

As shown in Figures 8 & 9, 2013 flow monitoring captured trends for a rain event occurring February 8, 2013 totalling 1.75-inches of rainfall. The rain began at 9:00PM on 7 February 2103 and ended at 10:00AM on 8 February 2013, indicating that flows began to spike upward around 12:30AM on 8 February 2013, and continued at an elevated rate of flow throughout the day [Note: Flow monitoring trends reset to zero at approximately midnight, indicating both systems were susceptible to I/I since flows responded fairly early to wet weather and remained elevated following cessation of the precipitation].

Figure 8. LS 1-8 Flow Monitoring Trend, post-rehab effort

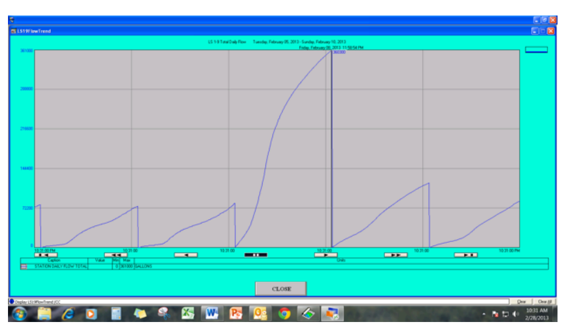


Figure 9. LS 1-9 Flow Monitoring Trend, post-rehab effort.

**The Need to Establish Pre- and Post-Rehabilitation Defect Flow Ratings**

While it is the responsibility of the owner or operator to set realistic and attainable goals, what goals are realistic and are they attainable with current trenchless technologies?

Although documenting I/I program successes (and failures) is helpful, a more rigorous protocol is needed. While a more robust installation specification and increased inspection and reporting may be useful, an unbiased, quantitative analytical tool is needed that can systematically and consistently measure defect flows in pre- and post-rehabilitation pipes.

**The Three Rs of Rehabilitation**

| Program | Recover Capacity (I/I Reduction) | Repair Damage (Structural) | Reduce Maintenance |
|---|---|---|---|
| Priorities | Capacity & Flow Analysis | Age, Condition, Etc. | Maintenance Records Review |
| Primary Approach | Replacement, Comprehensive | Point Repairs | MH-to-MH |
| Construction Approach | Traditional Bid | In-House | Retainer Contracts |
| Quantitative Analytics | Pre & Post-Rehabilitation Defect Flow Analysis | Pre & Post-Rehabilitation Defect Flow Analysis | Asset Management, CMMS, and GIS |
| Basis for Funding Level | Master Plan | Condition Assessment | Maintenance Records Review |

**Table 2. The Three (3) R's of Rehabilitation.**

A new standard that may provide a solution has been issued by ASTM Committee F36.20, ASTM F2550-13, *Standard Practice for Locating Leaks in Sewer Pipes By Measuring the Variation of Electric Current Flow Through the Pipe Wall.* As part of this standard, it is recommended that Electro Scan 'testing be taken *before* and *after* any pipe repair, relining, or renewal activity to compare electrode current values, and to use closed-circuit television (CCTV) video to re-examine pipes to determine if any visual defects were missed or not recorded during initial examination."

So, what (exactly) is *Electro Scan* and where did it come from? More importantly, how can a sewer utility adopt this tool given the significant investment already made in legacy inspection technologies?

**A New Tool to Systematically and Consistently Locate & Measure Defect Flows**

Originally funded by the German government in the 1990s, testing was conducted in late 2001 by the Institute for Underground Infrastructure (IKT) of Gelsenkirchen, Germany.

As illustrated in Figure 10, early prototypes of the innovation required a sewer or stormwater channel to be closed off and flooded with water, with a reference electrode inside the pipe and grounding electrode positioned on the surface to attempt a closed circuit to identify cracks, defects, or fissures.

While earlier prototypes utilized a single electrical contour emitted from its probe, resulting in a wide distribution of electric current, later prototypes implemented a tri-electrode array, creating a focused current, to increase its locational accuracy.

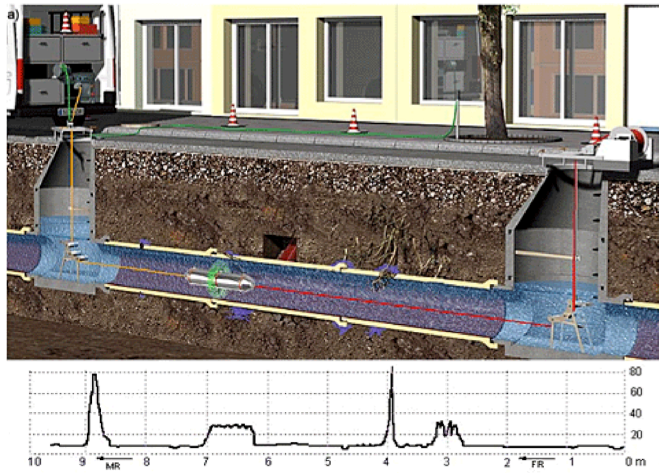


**Figure 10 – Early electro scan single electrode prototype set-up.**

Now known as Electro Scan, further refinements were made to improve its measurement accuracy. Undergoing independent testing by the USEPA, results were first published in 2011, entitled *Field Demonstration of Condition Assessment Technologies for Wastewater Collection Systems*, Kansas City, MO [EPA/600/R-11/078] and with a subsequent addendum published in 2012, entitled *USEPA Sewer Electro Scan Field Demonstration Revisited*, [Moy, Wilmut and Harris]. In 2013, an ASTM standard was granted by Subcommittee F36.20, referenced as F2550-13, was enacted.

Generating 12,000 to 20,000 data points, for each scan, including probe position, water pressure, defect current, total current, and other variables, proprietary international patent-pending algorithms were developed to allow for pipe assessments ranging from 3-36in (76-1000mm) diameter to quantify estimated defects flows (i.e. GPM, LPS) for individual defects and full pipe segments. For the first time, sewer owners, operators, consulting engineers and contractors are able to provide analysis for both pre- and post-rehabilitation pipe conditions.

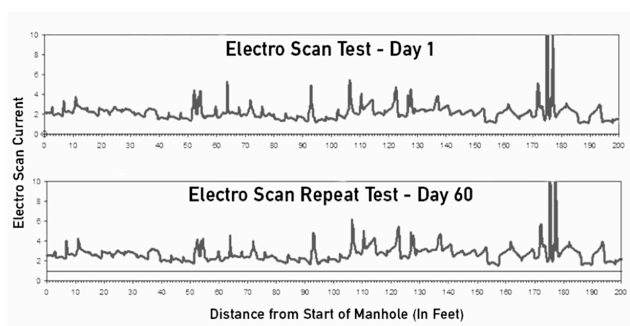


**Figure 11. EPA Electro Scan consistency test traces, Day 1 and Day 60**

Other improvements included more consistent data resolution (i.e. accuracy) and data fidelity (i.e. point-to-point difference matching) as demonstrated in independent testing.[6] As part of the EPA's 2011 *Field Demonstration of Condition Assessment Technologies for Wastewater Collection Systems*, shown in Figure 11, Electro Scan readings were taken on the same pipe, 60-days apart, with near exact readings, with similar test results later found in sewer lateral benchmarks.

[6] EPA/600/R-11/078, July 2011

## Electro Scan – Field Operation

Electro scanning is carried out by applying an electrical potential (voltage) between an electrode (probe) released inside an electrically non-conductive pipe and a grounding electrode on the surface, usually a metal stake pushed into the ground, attempting to close its electrical circuit.

The water in the pipe is at a level that ensures that the pipe is full at the probe location (i.e. not requiring the entire pipe to be filled with water). Provided electrical current is prevented from flowing along the inside or out of the pipe, the electrical resistance of the current path between the probe in the pipe and the ground stake, will be very low -- unless a defect exists that provides a pathway through the non-conductive pipe wall to ground (e.g. at a crack, defective joint, faulty service connection, over-cooked or defective liner), as shown in Figure 12.

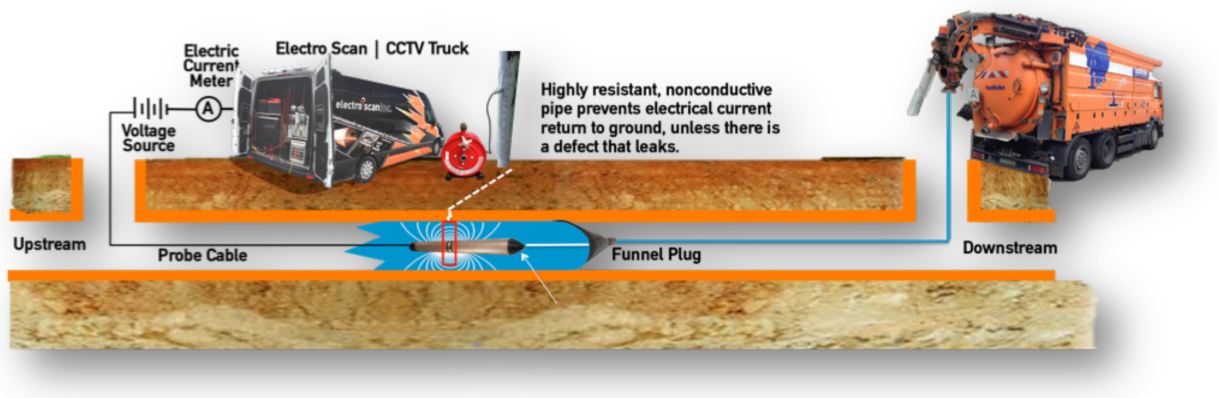



**Figure 12 - Electric Circuitry of a Sewer System,**

Most sewer pipe materials are made of brick, clay, concrete, plastic, resin, concrete, and reinforced concrete -- all poor conductors of electrical current. As a result, if a defect exists in the wall of the pipe, then *leakage* of electrical current will indicate the source of a potential leak, to the closest 0.4 inches (1 centimeter) whether or not water infiltration or exfiltration is occurring at the time of the scan.

Representing a low voltage (40 milliamps or three AA batteries), high frequency current, the greater the electric current flow through the defect in the wall of the pipe, the larger the size of the defect, allowing a specific location and estimated measurement to be recorded.[7]

Electro scanning is carried out by pulling its probe through the pipe at a speed of 30-45 ft per minute (10-15 m/min), measuring the variation of electric current flowing between the probe and the fixed electrode on the surface. When the probe is close to a pipe defect the electric current increases, as the defect results in a lowered resistance (break, opening) in the pipe wall.

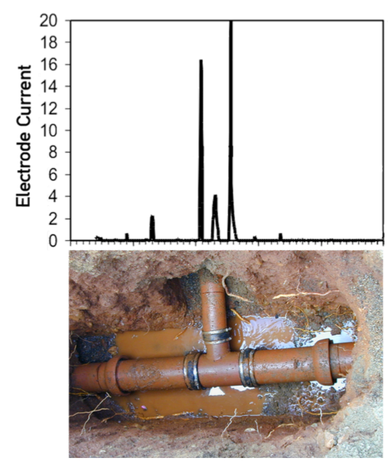



**Figure 13. Electro Scan Current Trace Verification With Excavation and Testing**

As shown in Figure 13, Electro Scan readings can be precisely aligned with defects confirmed by excavating the pipe, followed by either pressure testing or open-trench smoke testing. In this case, Fernco fittings had not been tightened, and missed by CCTV surveys.

---

[7] ASTM F2550-13.

As the probe is pulled through the pipe the electric current flow and position of the probe are recorded and correlated. When the middle of the probe is 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 probe is radially aligned with the defect.

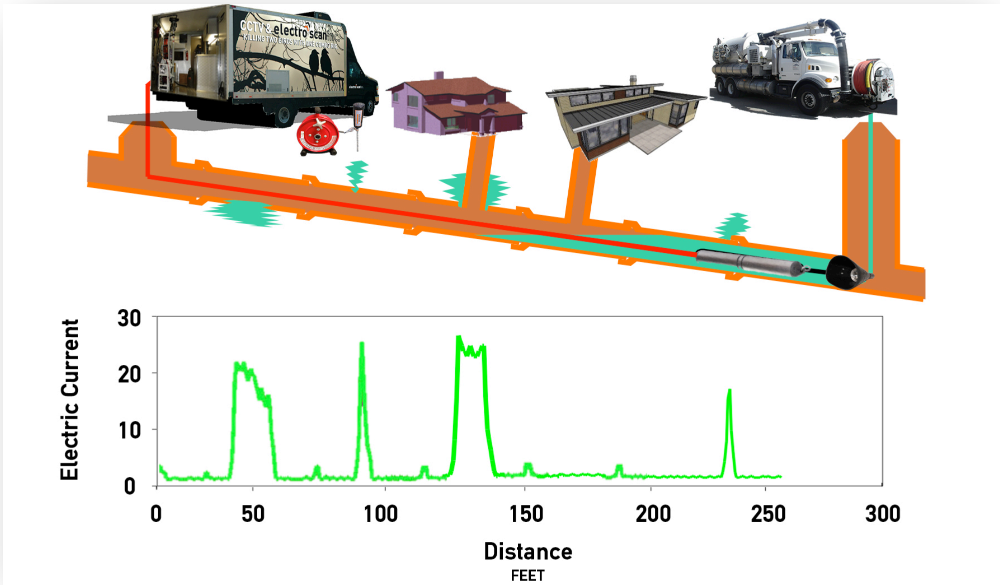



**Figure 14. Example electric current traces, by defect.**

As shown in Figure 14, regions on the current trace (i.e. where the current levels are above a threshold level), show specific defect areas in the wall of the pipe, with Electro Scan's patent-pending technology able to measure the amount of current flow through the defect, including its start and end position, to determine the total size of the defect.

Utilizing an adaptive design with existing CCTV vehicle-related cable and reels (Figure 15), field crews are able to change from CCTV to Electro Scan, and back, in 10 minute or less.[8]

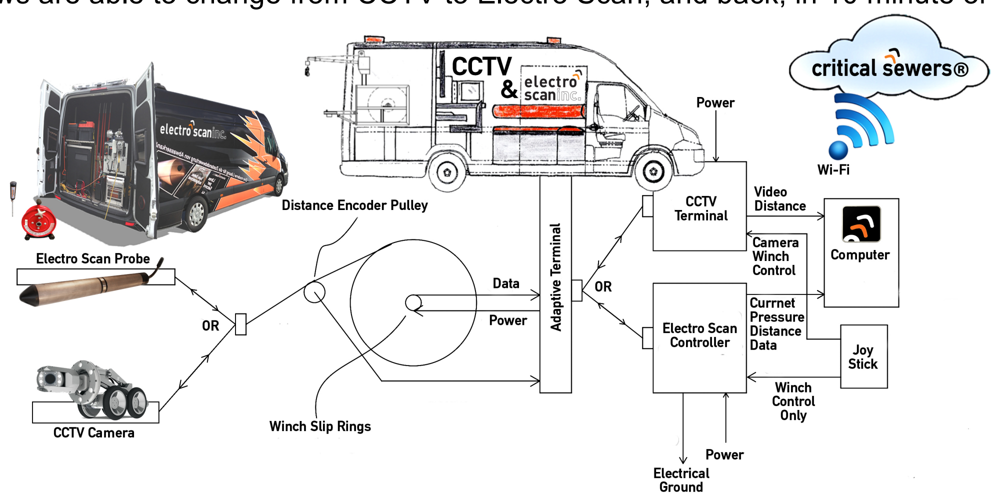



**Figure 15. Electro Scan's adaptive design with traditional CCTV trucks or vans.**

[8] Operations and Maintenance of Wastewater Collection, A Field Study Training Program, Chapter 5, 7th Edition, 2014.

Without reliance on subjective or qualitative identification of defect locations or sizes, operators manage the rate of speed and ensure that defect current levels perform within manufacturer's parameters, as shown in Figure 16.

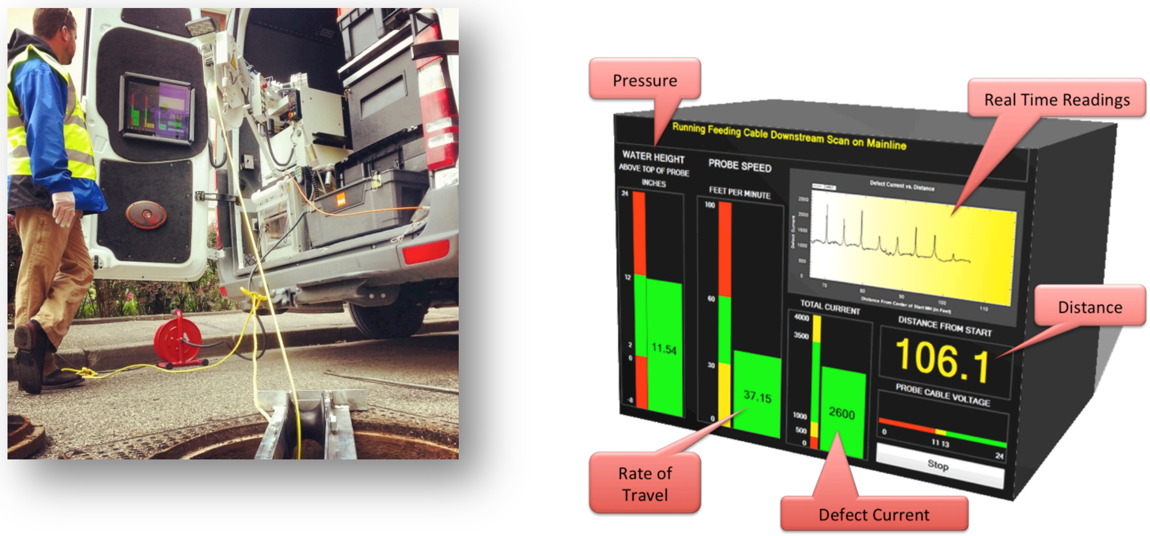



**Figure 16. Data automatically displayed on Operator's Real Time Console, requiring no data entry or interpretation during scanning process.**

Once a scan is complete, crews benefiting from a Wifi connection in the field may have results immediately uploaded to a cloud-based application where raw data is processed, filtered, and transmitted to a customer portal, as shown in Figure 17.

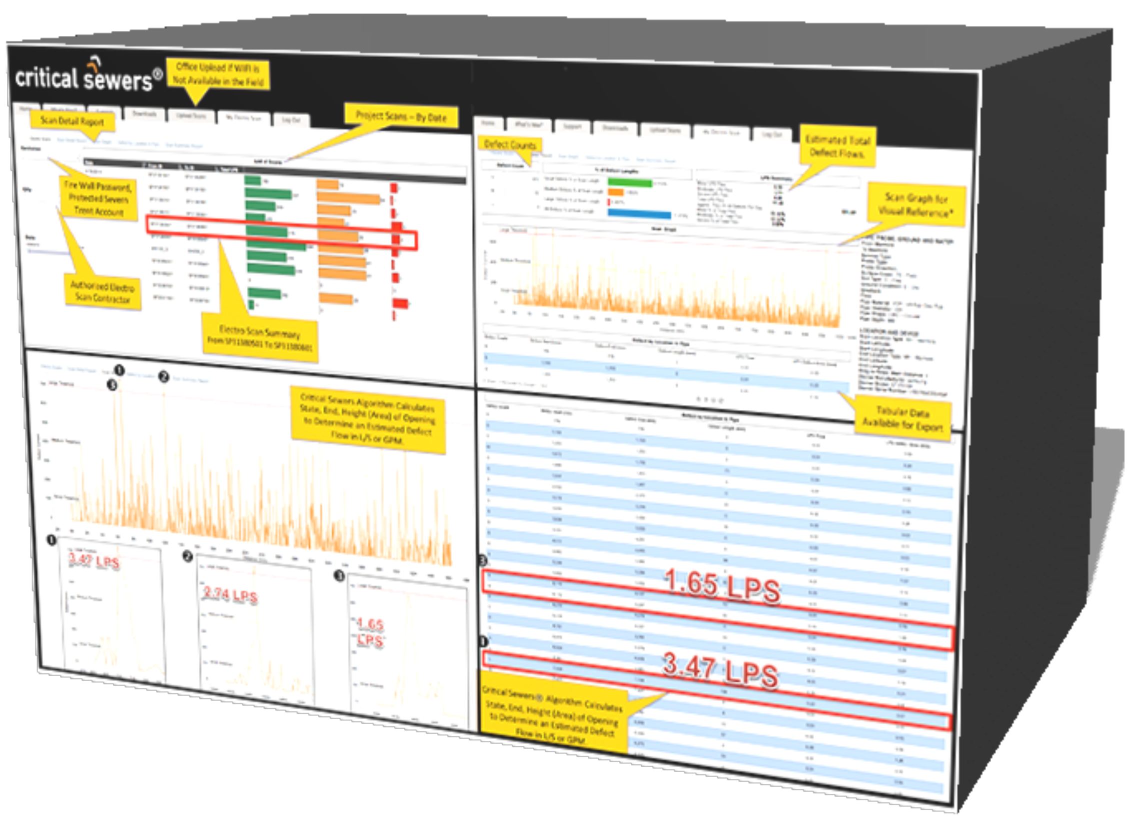



**Figure 17. Sample reports automatically available from a cloud application, without operator interpretation.**

**Case Study: Lancaster Area Sewer Authority, Pennsylvania, USA**

In 2014, the Lancaster Area Sewer Authority (LASA), a municipal sewer authority organized in 1965 under the Pennsylvania Municipality Authorities Act of 1945, conducted a benchmark test, in association with the US EPA Region 3 and the State of Pennsylvania Department of Environmental Production.

LASA owns, operates, and maintains a sanitary sewer system that serves approximately 32,500 customers, representing a population of about 107,000, including 500 miles of pipeline, 38 pumping stations, and a treatment facility designed to treat 15 million gallons per day. As shown in Table 5, four sewer segments underwent comparison of CCTV and Electro Scan.

| | | | | | CCTV According to NASSCO PACP Standards | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Structural Rating | | | | | | O&M Rating | | | | | | Overall Rating | | | | | |
| Sewer Segment | Pre- or Post-Rehab | Pipe Length | Pipe Diameter | Pipe Material | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | Rating | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | Rating | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | Raating |
| L432 - L431 | Pre | 280 | 8 | VCP | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 1 | 0 | 3 | 0 | 0 | 3 | 1 | 0 | 4 |
| L431 - L80 | Pre | 130 | 8 | VCP | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| MCE-8 - MCE-6 | Post | 400 | 8 | CIPP | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 3 | 1 | 0 | 8 | 4 | 0 | 3 | 1 | 0 | 8 |
| MCE-10 - L61 | Pre | 380 | 8 | VCP | 0 | 4 | 2 | 1 | 0 | 7 | 0 | 0 | 2 | 1 | 1 | 4 | 0 | 4 | 4 | 2 | 1 | 11 |
| TOTAL | | 1,190 | | | 0 | 7 | 3 | 1 | 0 | 11 | 4 | 0 | 7 | 3 | 1 | 15 | 4 | 7 | 10 | 4 | 1 | 26 |

| | ELECTRO SCAN | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of Defects | | | | TOTAL DEFECT FLOW | | | | | | |
| | | | | | Gallons | | | | | Litres | |
| Sewer Segment | Small | Med | Large | Total | Minor | Mod | Severe | Total GPM | Total Gallons Per Day | l/s | TOTAL LITRES PER DAY |
| L432 - L431 | 34 | 0 | 1 | 35 | 6.53 | 1.79 | 0.00 | 8.32 | 11,981 | 0.5249 | 45,350 |
| L431 - L80 | 21 | 0 | 0 | 21 | 4.30 | 0.00 | 0.00 | 4.30 | 6,192 | 0.2713 | 23,440 |
| MCE-8 - MCE-6 | 0 | 1 | 4 | 5 | 0.69 | 3.87 | 27.72 | 32.28 | 46,483 | 2.0370 | 176,000 |
| MCE-10 - L61 | 35 | 4 | 4 | 43 | 8.99 | 7.69 | 6.18 | 22.86 | 32,918 | 1.4420 | 124,600 |
| TOTAL | 90 | 5 | 9 | 104 | 20.51 | 13.35 | 33.90 | 67.76 | 97,574 | 4.2752 | 369,390 |

**Table 5. Benchmark Results, US EPA Region 3, State of Pennsylvania Department of Environmental Protection, Lancaster Area Sewer Authority, Electro Scan Inc., 20 May 2014.**

Key objectives for the benchmark were (1) to test Electro Scan's ability to automatically locate existing visually detected defects (Figure 18), (2) determine if Electro Scan could locate defects, not previously identified by CCTV (Figure 19), and (3) compare Electro Scan results from surveying a post-CIPP liner (i.e. pipe-within-a-pipe), with CCTV inspection of pre-CIPP conditions (Figure 20).

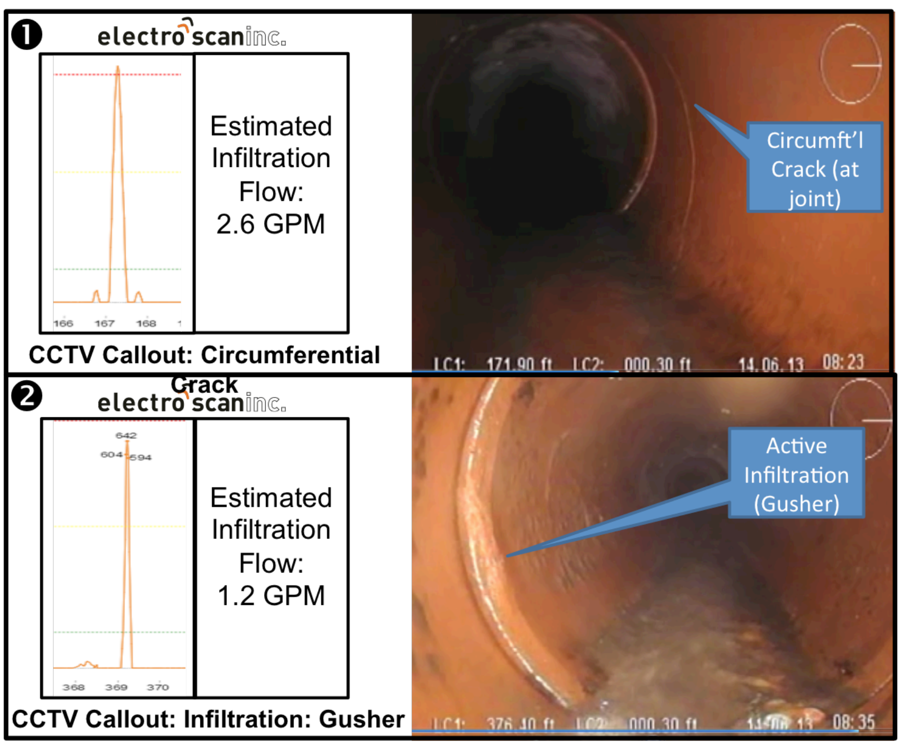



**Figure 18. Calibration of previously identified defects using PACP coding standards with Electro Scan.**

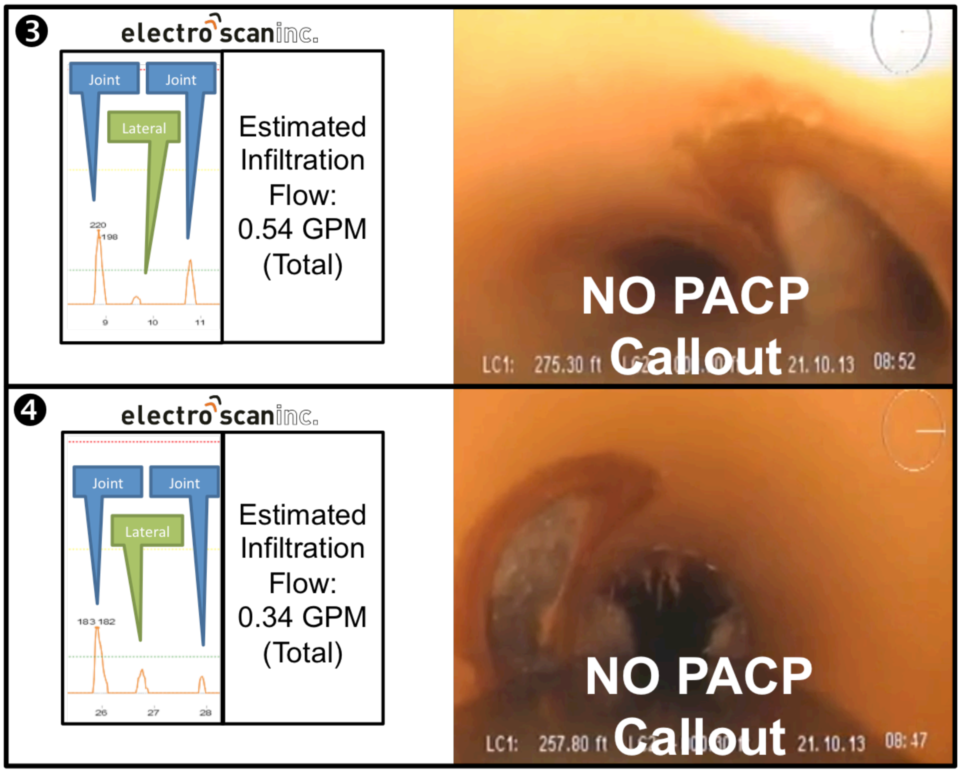



Figure 19. Electro Scan defects found, compared to No PACP defects found by CCTV.

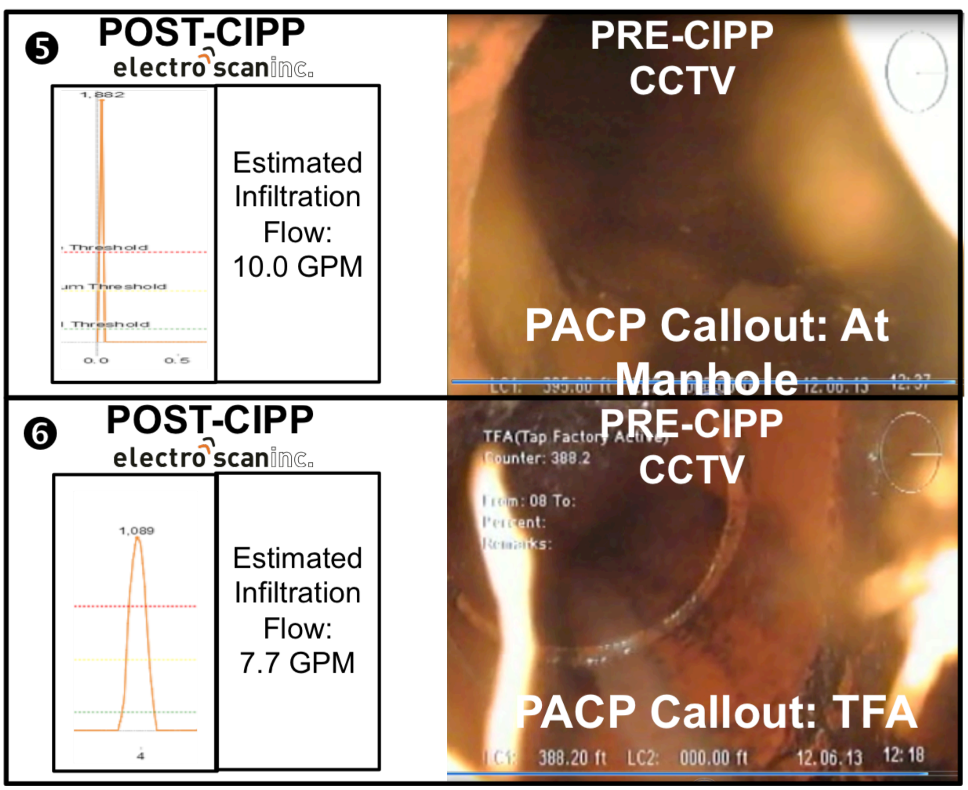



Figure 20. Post-CIPP Electro Scan results compared to pre-CIPP CCTV results, useful in diagnosing pipe-within-a-pipe problems were cracks were not grouted prior to CIPP.

**Case Study: Pre- and Post-CIPP Lining Assessment, Germany**

In 2014, a leading European manufacturer of CIPP, liners, and coating products made available two (2) contiguous sewer mains (Figure 21); one segment (upstream) that had been recently relined (Figure 22) and another segment (downstream) that had not been relined (Figure 23). Only one of the pipe segments was CIPP lined, as CCTV inspection did not indicate sufficient defects to warrant lining, with the manufacturer wishing to evaluate whether to undertake pre-CIPP testing to ensure all lines that should be lined, are lined.

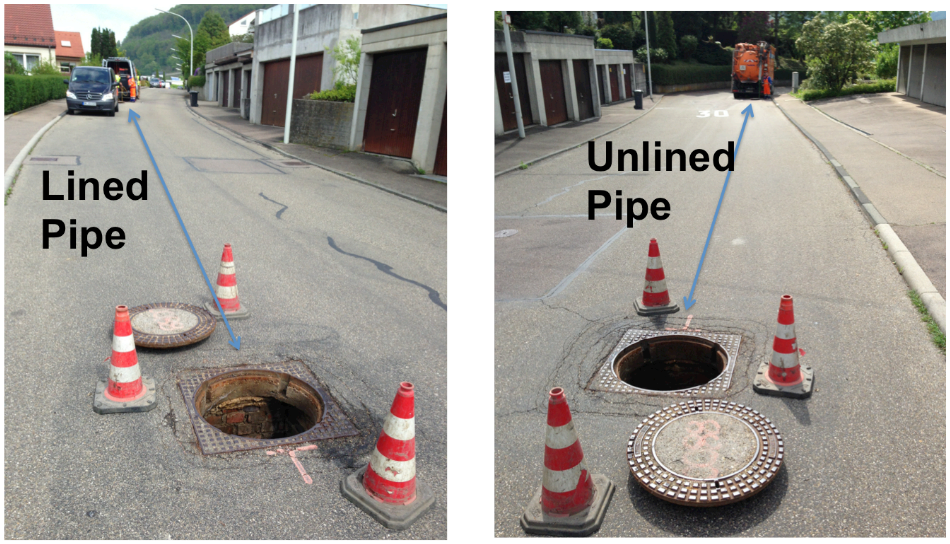



**Figure 21. Field photographs of upstream and downstream segments having lined and unlined pipe, respectively.**

***PRE-CIPP ASSESSMENT***

| Defect Count | |
|---|---|
| S | 6 |

| % of Defect Lengths | |
|---|---|
| Small Defects % of Scan Length | 0.429% |
| Medium Defects % of Scan Length | 0.000% |
| Large Defects % of Scan Length | 0.000% |
| All Defects % of Scan Length | 0.429% |

| LPS Summary | |
|---|---|
| Minor LPS Flow | 0.08 |
| Moderate LPS Flow | 0.00 |
| Severe LPS Flow | 0.00 |
| Total LPS Flow | 0.08 |
| Approx. Flow Of All Defects Per Day | 7,304 |
| Minor % of Total Flow | 100.00% |
| Moderate % of Total Flow | 0.00% |
| Severe % of Total Flow | 0.00% |

**Scan Graph**

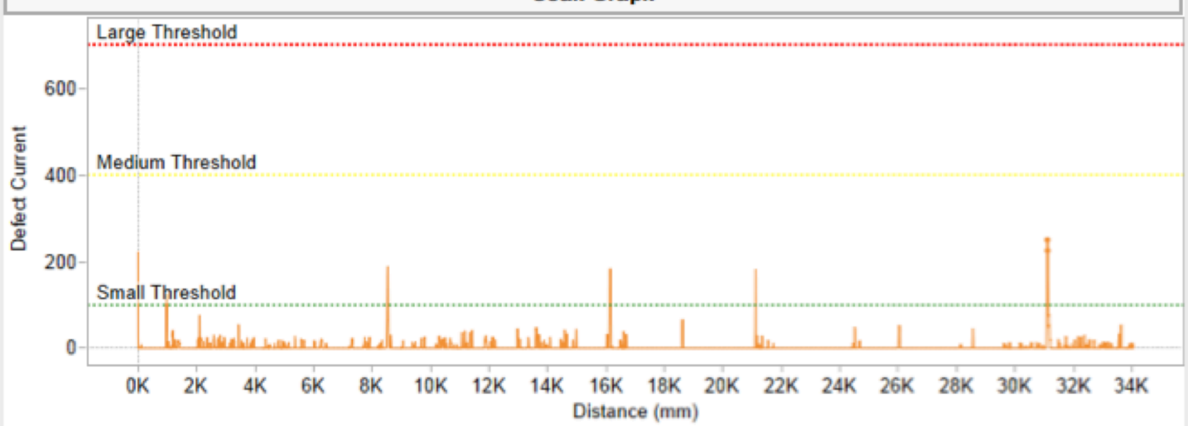



**Figure 22. Electro Scan report for non-CIPP sewer main segment, with six (6) small defects representing 7,305 litres per day of defect flow.**

### *POST-CIPP ASSESSMENT*

**Defect Count**

| **% of Defect Lengths** | |
|---|---|
| Small Defects % of Scan Length | 0.000% |
| Medium Defects % of Scan Length | 0.000% |
| Large Defects % of Scan Length | 0.000% |
| All Defects % of Scan Length | 0.000% |

| **LPS Summary** | |
|---|---|
| Minor LPS Flow | 0.00 |
| Moderate LPS Flow | 0.00 |
| Severe LPS Flow | 0.00 |
| Total LPS Flow | 0.00 |
| Approx. Flow Of All Defects Per Day | |
| Minor % of Total Flow | 100.00% |
| Moderate % of Total Flow | 0.00% |
| Severe % of Total Flow | 0.00% |

**Scan Graph**

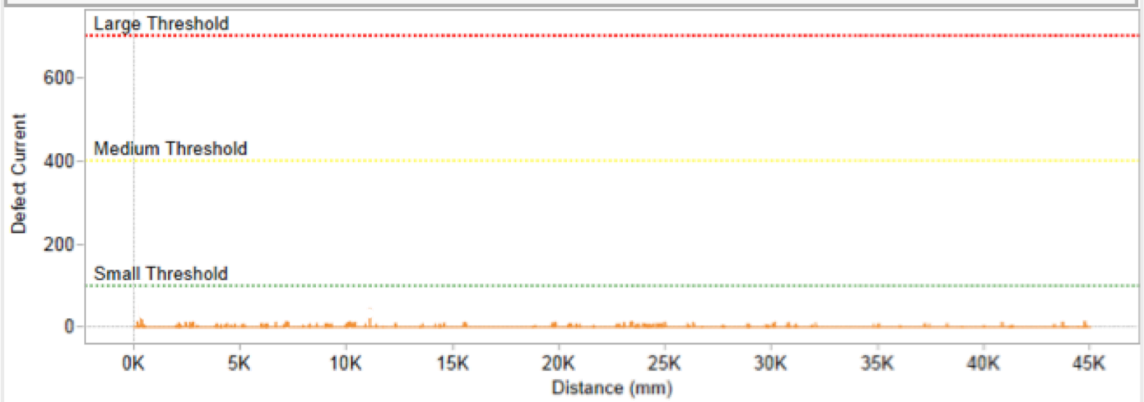



**Figure 23. Electro Scan report for CIPP pipe having no defect flows.**

Based on an extended field trial of similar pipe configurations, including variations by pipe size, liner types, coatings, and curing methods, it was determined that Electro Scan provided an effective and efficient method to assess both pre- and post-rehabilitation pipe conditions. While the lining company generally completes a pressure test of its liners, prior to inversion and curing, limiting its assessment to a Pass/Fail result without the benefit for identifying a specific location or size of defect along the pipe, it found Electro Scan could be used to triage pipes, before the start of rehabilitation, to identify potential risks to their clients of not lining upstream or downstream sewer mains segments.

Many sewer utilities have shifted their focus from *sewer mains* and *manholes* to *laterals*, in a growing effort to find and fix unexplained or unabated sources of infiltration. Yet, while many international service lateral lining companies have enjoyed substantial growth in sales as the cost of lining an individual property owner’s connection ranges from €4,000 to €11,000 ($5,500 to $15,000) per lateral, sewer utilities may achieve higher cost benefits more accurately assessing sewer mains and manholes and fixing previously unidentified problems, rather than customer laterals.

Furthermore, Electro Scan’s ability to rapidly and accurately test sewer mains represents a major advantage over traditional pressure testing or packer equipment, used in combination with grouting equipment. While grouting provides a chemically-reactive solution that may partially fill or block water pathways, used in combination with Electro Scan, sewer utilities may wish to take a look at combining grouting and CIPP for a more comprehensive and preemptive solution to rehabilitation.

**Case Study: Mark and Cheddar, Somerset, Wessex Water, England**

***Mark, Somerset – Pre-Rehabilitation Assessment***
In 2012, members of the Wessex Water Rehabilitation Team recognized the need for a 21st Century appraisal tool for leak detection in gravity sewers, not dependant on water table elevation during seasonal rainfall events; especially since CCTV cameras often fail to identify infiltration or cannot be used when pipes are surcharged.[9]

Representing the first Water and Sewer Company (WASC) in the United Kingdom to trial Electro Scan, Wessex Water surveyed several kilometres across its region, identifying several improvements to the equipment to better address the British market and quantifying cost/benefit returns.

With all schemes administering the investigations of the electro scan technology completed to programme and within cost, electro scan was trailed in Mark, Somerset, England where forty-three (43) sewers were identified as the most critical assets. Infiltration rates of 12 litres per second (190.2 gallons per minute) or 1000m$^3$ litres per day (273,900 gallons per day) were documented, costing the company an estimated £120,000 ($180,000) per annum in operational expenditure. Selected results are shown in Table 6.

Client: Wessex Water

Site: Mark Causeway, Somerset — Upstream Pipeline Ref: ERN10675

| Summary List of Electroscan Data | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scan No | Scan ID | Date | From | To | Pipe Details | | | analysis_defect_grade | | | | Litres per second |
| | | | | | length of scan (m) | dia (mm) | Material | None | Large | Medium | Small | |
| 1 | sww1_0151_nov72013104703am | 11/07/2013 | MH02 | 6001 | 19.37 | 100 | VC | | 3 | | | 0.40 |
| 2 | sww1_0152_nov72013112528am | 11/07/2013 | MH04 | MH03 | 11.84 | 100 | PF | | | | 10 | 0.10 |
| 3 | sww1_0153_nov72013113129am | 11/07/2013 | MH04 | 6901 | 9.36 | 100 | VC | | 5 | | 1 | 0.25 |
| 4 | sww1_0154_nov72013120947pm | 11/07/2013 | MH05 | 6901 | 5.72 | 100 | VC | | | 1 | 2 | 0.05 |
| 5 | sww1_0155_nov7201313641pm | 11/07/2013 | MH08 | 4701 | 13.64 | 100 | VC | | 4 | 1 | 7 | 0.50 |

**Table 6. Selected electro scan results from the Wessex Water Somerset project.**

With the UK's Environmental Agency expects to have every £1 *cost* of flood defence deliver £8 of *benefit*, engineers for Wessex Water documented a conservative cost/benefit of at least £10-15 using the Electro Scan technology; especially in geological areas where groundwater-induced hydraulic lithology threatens the stability of adjacent buildings.

***Cheddar, Somerset – Post-Rehabilitation Assessment***
Wessex Water has been a leader testing of CIPP, utilizing epoxies that adhere to the host pipe, preventing the well-known problem of post-exothermic contraction annulus, which can occur during the cooling of typical polyester linings. Having successfully tested Electro Scan in pre-rehabilitated pipes, Wessex Water's Julian Britton surveyed a number of epoxy-lined pipes in the village of Yarely, near Cheddar, Somerset, finding post-CIPP linings completely watertight.[10] "So, without a doubt, at its best CIPP lining is an excellent method of renovating ageing assets, but it is only close adherence to standards and a thorough specification that will give the client peace of mind," according to Julian Britton, Critical Sewers Manager, Wessex Water. *Caveat emptor!*

[9] UKSTT, Holistic approach to infiltration and inflow exclusion, Liam MacFarlane, Critical Sewers Engineer, Wessex Water.
[10] Quality Assured Benefits of CIPP: A Client's Perspective, Julian Britton, Critical Sewers Manager, Wessex Water, Trenchless International Magazine, Issue 24, July 2014.

## Sample Reporting of Pre- and Post-Rehabilitation Defect Flows

Independent benchmarks, new international standards (ASTM F2550-13), recent industry awards and acknowledgements[11], and a growing reluctance with legacy CCTV inspection results, created a tipping point[12] that is shifting sewer utilities to adopt more reliable assessment tools, including their able to quantify, rank, and prioritize critical sewer and water pipes.

Since Electro Scan data represents an automated measurement tool, not manually manipulated or subject to visual interpretation, it is recommended that Electro Scan readings be taken before any rehabilitation to establish a baseline defect flow of the pipe segment. While Electro Scan is only limited in length of its scans by the cable & reel already available on the user's CCTV van or truck, pipes may be readily scanned that are full of water or with fats, oil, and grease, as the low voltage, high frequency current will 'see' through these typical visual obstructions.

Once rehabilitation has been completed, scanning may be done whenever legacy CCTV inspections occurs, providing a pre and post-rehabilitation defect flow as illustrated in Figure 24 and summarized in Table 7.

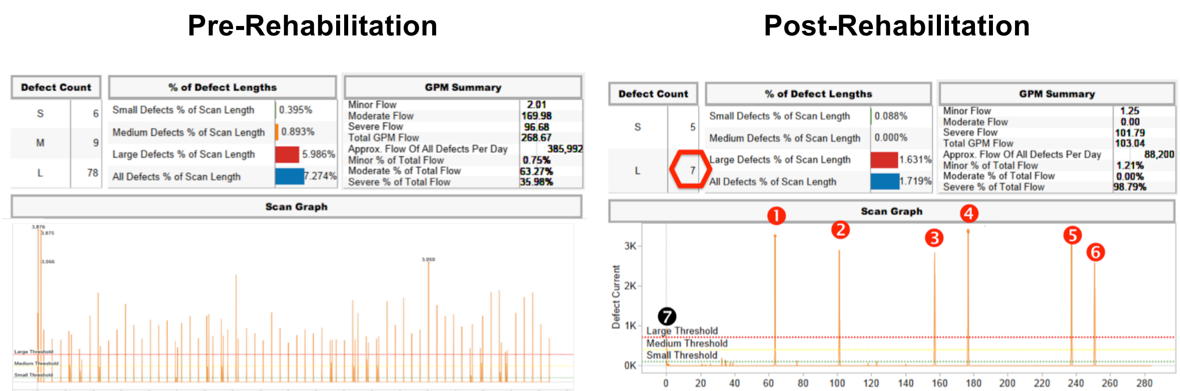



**Figure 24. Sample Pre-Rehabilitation and Post-Rehabilitation, i.e. before and after, condition assessment reporting.**

| | Defect Count | | | | Defect Flows | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | S | M | L | Total | Small | Mod | Severe | Total GPM | Total GPD | Total Litres Per Day |
| Pre-Rehab | 6 | 9 | 76 | 91 | 2.01 | 169.98 | 96.68 | 268.67 | 385,992 | 1,461,138 |
| Post-Rehab | 5 | 0 | 7 | 12 | 1.25 | 0.00 | 101.79 | 103.04 | 88,200 | 333,873 |
| Change | -1 | -9 | -69 | -79 | -0.76 | -169.98 | +5.11 | -165.63 | 297,792 | -1,127,265 |
| % Change | -100% | -100% | -91% | -87% | -38% | -100% | +5% | -61% | -77% | -77% |

**Table 7. Sample pre- and post-rehabilitation comparison.**

Not limited to scanning post-CIPP liners, Electro Scan is also suited to evaluate point repairs, newly constructed pipes, and pipes that have been epoxy coated. While Electro Scan is not currently certified to scan metallic pipes, it is appropriate for any metallic pipe that has been lined.

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[11] WEFTEC Product Innovation of the Year (2013), No-Dig/NASTT New Product of the Year, South West Water, England PURE Award, The New Economy Magazine, Best Water & Sewer CleanTech Award.

[12] *The Tipping Point: How Little Things Can Make a Big Difference, Malcolm Gladwell, defined as* "the moment of critical mass, the threshold, the boiling point."

## Conclusion

Electro Scan represents a next generation assessment tool for locating and measuring defects found in pre- and post-rehabilitated sewer and water pipes, including the ability to estimate defect flows in gallons per minute or litres per second.

Based on a growing number of international case studies, independent studies, and competitive benchmarks, it is apparent that:

- Sewer utilities continue to be challenged in eliminating sources of infiltration;
- Legacy condition assessment techniques, specifically, Smoke Testing and CCTV, may be misrepresenting the operating condition and expected performance of pre- and post-rehabilitated pipes;
- Sewer utilities that have focused resources on assessing service laterals, may be better served by re-investigating sewer mainlines utilizing more effective and efficient assessment technology, like Electro Scan;
- Recent studies on the useful life of CIPP may not be adequately capturing the operating performance of previously CIPP lining projects, due to problems at installation, unavailability of post-CIPP assessment tools, and defective service reconnections;
- Used in combination with chemical grouting, Electro Scan provides a rapid and accurate assessment tool, superior to slow moving packers, that may help sewer utilities to cost justify the re-introduction of grouting to their portfolio of rehabilitation alternatives;
- Revised acceptance standards for inspection and reporting of CIPP lining and other pipe rehabilitation may be required;
- At its best, CIPP lining is an excellent solution for renovating ageing assets, but is highly dependent on strict adherence to proper installation and inspection standards, before projects can be accepted;
- While not a replacement to CCTV, previous analysis and ranking of critical sewer assets by CCTV inspection and other methods, may need to be re-assessed or replaced, given Electro Scan's commercial availability and adaptive design with existing CCTV trucks and vans.
- Sewer utilities may achieve a higher cost benefit by more accurately assessing sewer mains and manholes and fixing previously unidentified problems, rather than focusing on customer or private sewer lateral rehabilitation.

## About the Author

Chuck Hansen is Managing Director of Hansen Investment Holdings, LLC, a private equity firm with a portfolio of investments, including Electro Scan Inc. In April 2014, Mr. Hansen was appointed Chairman of ASTM Subcommittee F36.20, Inspection and Renewal of Water and Wastewater Infrastructure, currently overseeing standards for a number of innovative assessment technologies, including laser profiling, video micrometer measurement devices, and renewal of a number of industry standard rehabilitation methods.

Prior to becoming Managing Director of Hansen Investment Holdings, Mr. Hansen was Chairman & Founder of Hansen Information Technologies, founded in 1983 and a leading provider of asset management systems used by over 1,000 municipal utilities, with over 1 million CCTV inspection reports and 6 million defects contained as part its customer's databases. Sold in 2007 to US-based Infor Global for $100 million, Mr. Hansen lives in California with his wife Deborah, a civil engineer, and 4 children.