A CASE STUDY IN INFILTRATION REDUCTION THROUGH TRENCHLESS TECHNOLOGY

SOUTH PALOS TOWNSHIP SANITARY DISTRICT
COOK COUNTY, ILLINOIS

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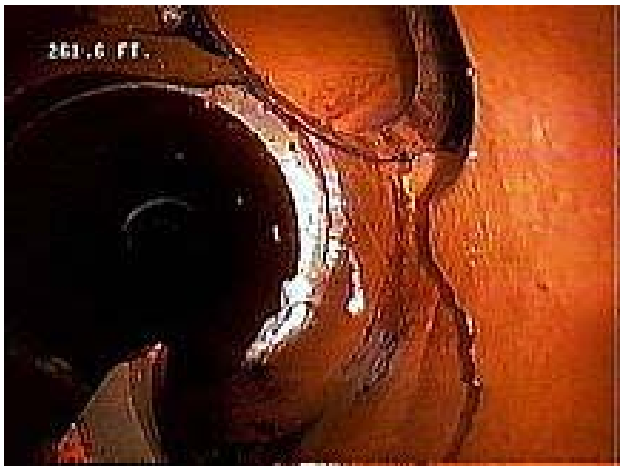
The connection points between sewer service laterals and a sewer main have long been identified as some of the weakest points in a typical sanitary sewer system. Communities nationwide commonly experience problems at these locations, which may have originated from substandard materials, construction methods and inadequate inspection at the time of the original installation. Many lateral connections are also fractured due to differential loading pressures over time or “hammer taps”. These problem areas allow significant groundwater infiltration, and in many cases are structurally unsound and capable of collapsing.

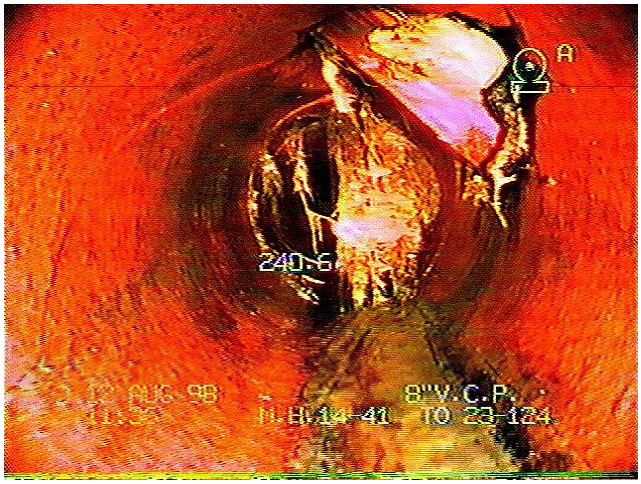
The South Palos Township Sanitary District (SPTSD), a small unincorporated residential community in the southwest suburbs of Chicago, has experienced major infiltration and inflow (I/I) since its sewer system was originally constructed in the early 1970s. The SPTSD system contains only 11 miles of sanitary sewer mains serving a mere 562 homes, 2 churches and an elementary school, yet regularly experienced peak flows in excess of 1.70 MGD for 1” rainfall events. The excessive I/I introduced into the sanitary sewer system, coupled with a rolling topography throughout the area, contributes to sanitary sewer overflows (SSOs) at several low-lying manholes throughout the community. The absence of storm sewers in the community contributes to the problem.

The SPTSD found itself facing court-enforced mandates and completion deadlines from the Illinois Environmental Protection Agency (IEPA) and Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) to rectify the sanitary sewer overflow problem due to the potential environmental and public health hazards associated with these occurrences. In late 1995, the SPTSD appointed Robinson Engineering, Ltd. of South Holland, Illinois as its District Engineer charged with studying and solving the longstanding SSO problem.

In 1996, Robinson performed a comprehensive sewer system evaluation survey consisting of automated flow monitoring at strategic points throughout the system to quantify the dry and wet weather flows. All 245-sewer manholes were visually inspected during wet weather periods to identify leaking frames, walls and manhole benches. Finally, a comprehensive dye water flood testing and sewer televising program was performed to identify sewer mains and laterals within the public right-of-way that were subject to infiltration.

The dye water flood testing consisted of plugging culverts on each side of the street, flooding both ditches or swales with water colored with green dye tablets, and simultaneously inspecting the sanitary sewer main below by means of closed circuit television. Although the sewer main was typically located in one of the parkways parallel to the street, ditches on both sides were flooded simultaneously to identify leaking service laterals from the opposite side. The sewer televising equipment was capable of panning left or right and rotating 360^{o} to inspect and identify each lateral leaking the green dye.





The results identified by this investigation were dramatic: over 83% of all sewer sections tested positive for green dye, resulting in the televising of 37,500 lineal feet of sewer main. A total of 188 sewer service laterals leaked green dye within one hour after the flooding tests began. Most of these locations contained dye almost immediately by the time the television camera entered the sewers, which confirmed the immediate wet weather impacts identified in the flow monitoring analysis.

The televising data and manhole inspection data were thoroughly analyzed and correlated to the quantitative flows measured through flow monitoring, and estimates of the I/I contributions (in gpm) were made for each sewer main, sewer lateral and manhole in the entire system. A cost-effective analysis was performed to determine a priority order for the hundreds of identified defects, and a recommended plan for rehabilitation was developed. A computerized system model demonstrated that a combination of I/I removal and construction of a relief sanitary sewer at a key bottleneck location would be required to eliminate the overflows.

The recommended plan included approximately $1.5 million in trenchless sewer rehabilitation, a $250,000 lift station rehabilitation and a $2.0 million relief sewer. Unfortunately, due to its small size, nonexistent commercial/industrial tax base, and limited bonding capability, the South Palos Township Sanitary District had no means with which to fund such an ambitious project. In late 1996, the District utilized all of its available funds by awarding a $400,000 contract for cured-in-place lining for the first phase of the rehabilitation work, which included the highest priority sewer main lining.

The District then applied to the IEPA for a low interest loan, and was successful in obtaining $1.5 million in loan funding in fall 1997. Robinson Engineering, Ltd. developed plans, specifications and contract documents for three separate rehabilitation contracts which were reviewed and approved by the SPTSD, MWRDGC, and IEPA. The first contract consisted of cured-in-place sewer lining of over 18,000 lineal feet of 8”-12” sanitary sewer, while the second consisted of the rehabilitation of some 117 sewer service laterals. The third contract was for modernization of the District’s main lift station.

For the service lateral contract, it was recognized that different technologies existed, though most were new and as yet unproven. Therefore, bids for rehabilitating the service laterals were accepted for both traditional excavation and replacement (BASE BID), or by trenchless cured-in-place pipelining (ALTERNATE BID). All alternate bid products and methods were required to include a 3-year maintenance bond to provide additional protection for the District against potential failure of these yet unproven lateral liner systems. The proposal documents were structured such that both the base bid and alternate bid would accomplish the same goal of eliminating groundwater infiltration into approximately 117 defective sewer service laterals within the public right-of-way. The technical specifications required that the laterals be replaced or lined from the connection at the sewer main to the property line, in order to eliminate the infiltration occurring in the parkway ditches. Post-rehabilitation dye water flood testing and televising were required to confirm that the infiltration had in fact been eliminated from the repaired laterals.

The SPTSD also recognized that there were certain non-economic costs and social impacts associated with the base bid approach. In particular, the inconveniences and disruption involved with excavating streets, driveways, and parkways, the loss of pavement longevity due to additional joints and long-term trench settlement, extended noise and air pollution, and the difficulties encountered matching new grass to existing residential lawns all had adverse effects on District residents.

When bids were received, the low alternate bid was higher than the lowest base bid. The District nonetheless awarded the $382,000 contract to Performance Pipelining, Inc. of Ottawa, IL although its bid was $22,000 higher (6%) than the lowest base bid. The relatively small monetary increase was viewed to be acceptable due to the minimal disruption and improved project schedule made possible by lining the laterals.

Performance Pipelining, Inc. began work during December 1997 by excavating small pits at property lines, exposing the existing 6” vitrified clay pipe laterals, and cleaning the laterals using a 10,000 psi high pressure sewer jet manufactured by Harben, Inc. Most of the existing laterals contained a combination of bad gaskets, open joints, multiple fractures and tree roots. Installation of cured-in-place liners from the excavation pit to the main line was then completed using technology similar to sewer main cured-in-place installations, with a small protrusion at the connection point with the main. The protruding edge was then cut by means of an internal cutter similar to those used in main line

CIPP applications. This method was successful in substantially improving the structural integrity and reducing infiltration within the defective lateral pipe, however, paper-thin gaps at the connection point were suspected since the lateral liner was separate from the sewer main. It was recognized that, over time, infiltration may eventually find its way back into the connection points. The liner installation was followed by constructing sewer cleanouts finished to grade, and proceeded at the rate of about one per day during the harsh winter weather conditions.

For two months, crews fought freezing air compressors, sewer cleaning machines and mostly frozen workers. Subsequent rains and snowmelt resulted in surcharged sewers and SSO conditions, causing numerous lost days where work could not be performed. The court-enforced deadlines and fines faced by the SPTSD did not account for bad weather; the sewer lining crews pressed on.

During the first third of the project (approximately 40 laterals), Performance Pipelining used the pit excavation and cleanout method to repair the laterals. In the meantime, its research and development team was busy perfecting a unique, innovative inversion method named T-Liner, which enabled 100% trenchless installation of CIPP liners into service laterals via the sewer main. Excavation pits at the property line were no longer necessary. More importantly, the T-Liner system provided the powerful benefit of a guaranteed watertight seal at the connection point between the sewer lateral and the main, confirmed through hydrostatic testing and air testing.

Passing a 5psi air test was viewed as a critical achievement, which confirmed that the T-Liner could guarantee a watertight seal. The air test is performed by installing inflatable plugs in the main line on either side of the cured T-Liner, and also in the cleanout (if existing) on the service lateral line. Air is injected through the inflatable plug to 5psi, and test approval is achieved by holding 5 psi for a minimum of 10 minutes.

The cured-in-place T-Liner system provides a full circle spot repair to the sewer main at the lateral connection, with the integrally manufactured lateral liner inverted from the center of the sewer main liner up the lateral. The 16” long sewer main sleeve and the lateral liner are one continuous, homogeneous CIPP piece, with the full circle tee connection providing a watertight seal at the lateral connection.

During March 1998, Performance Pipelining, Inc. requested to try the new T-Liner system on the South Palos Township project. Performance Pipelining demonstrated to Robinson Engineering that the new system could pass the 5psi air test, negotiate difficult sewer conditions during installation, and work in either lined or unlined sewer mains. After Performance agreed to be responsible for all costs associated with excavation and replacement if the T-Liner failed, permission was granted to try the T-Liner on one of the scheduled laterals on the project.

The first T-Liner was used for a “short” side lateral; i.e. the service lateral was for a home on the same side of the street as the sewer main. The first installation installed a 16” long, 8” diameter main line sleeve with a 12’ long, 6” diameter lateral liner. The entire installation took about two hours, passed the air test, and was viewed by a television camera sitting in the sewer main just upstream of the repair. The installation was a grand success, and authorized for use for the remainder of the South Palos Township project.

The last two-thirds of the project (approximately 80 laterals) was completed using the T-Liner system in about 95% of the cases. As the project progressed, “long” side T-Liners was installed, with average lateral lengths averaging 40-50’. The longest T-Liner installed on the project consisted of a 12” sewer main sleeve coupled with a 55’- 6” lateral sleeve. As the crew became more proficient with the new system, three and sometimes four T-liners per day were being installed. Approximately 70% of the T-Liner laterals were connected to sewer main lines that had been previously renewed by cured-in-place pipe. The other 30% were connected to vitrified clay sewer mains that had not been lined.

Residents throughout the community were pleased that no excavation whatsoever was required for these repairs, project engineers were satisfied that a watertight liner system was being installed, and the South Palos Township Board of Trustees incurred no additional costs for the superior product being used. The SPTSD was so pleased with the product it authorized additional 29 laterals to be lined on the project. Performance Pipelining utilized the T-Liner system on 27 of these 29 laterals, requiring excavation pits at only two locations due to extremely long service laterals over 100' in length.

The project specifications required that dye water flood testing of the ditches above the laterals be performed a minimum of 30 days after installation. After the T-Liner system was put into use, air tests were performed at all locations containing an existing cleanout. Every single location on the project passed the required test on the first attempt – not a single lined lateral leaked.

It has long been known by collection system owners, operators and professionals that significant portions of I/I enter the system through service laterals and at their connections to the main line. Post-rehabilitation flow monitoring conducted at four locations throughout the District substantiates that considerable infiltration reduction was achieved since initial monitoring was performed in spring 1996. Monitoring locations were identical, and antecedent moisture conditions similar, before and after sewer rehabilitation. As summarized in Table 1, a 59.6% reduction in daily infiltration was achieved by CIPP lining of approximately 25,000 lineal feet of sewer main (43% of system) and 150 sewer service laterals (27% of total).

TABLE 1 – BASE INFILTRATION (gpd)

(total system)

Year	Period	MH-12	MH-3	MH-62	MH-141A
1996	spring	2,058	14,160	30,840	63,660
1998	fall	1,650	8,160	20,442	25,716
% reduction		***19.8%***	***42.3%***	***33.7%***	***59.6%***

A daily infiltration reduction of 37,944 gpd translates into 13.85 MGY of I/I which is no longer conveyed through MWRDGC interceptor sewers or treated at its wastewater treatment plant. Excessive I/I contributes to additional conveyance, operation and maintenance costs and treatment facility expansion costs for wastewater system owners. The following analysis estimates the cost

benefits of the South Palos Township I/I reduction program. Conveyance costs pertain to larger interceptor sewers required to be constructed to transport excessive I/I.

Reductions in peak wet weather flows were also achieved. Table 2 summarizes the 4-hour peak flows recorded for two similar storms before and after the sewer-lining project. It can be seen that peak flow reductions ranging from 40% - 60% were achieved in the three-sub area monitoring locations tributary to the system outfall (MH-141A). The slight increase in the peak flow at the outfall is attributed to the slightly larger rainfall event (10%), improvements which increased a lift station's pumping capacity by roughly 40%, and also private sector downspouts and footing drains which have not yet been disconnected.

TABLE 2 – 4-HR PEAK FLOWS FOR ½" RAINFALL

Date	Storm	MH-12	MH-3	MH-62	MH-141A
5/09/96	0.50"	36,530	92,110	51,390	107,970
10/02/98	0.57"	21,700	36,470	21,750	144,340
% change	***+10.0%***	***-40.6%***	***-60.4%***	***-57.8%***	***+33.7%***

In the three monitored areas unaffected by the lift station improvements, the estimated 4-hr peak I/I reduction for a one-half inch rainfall event is approximately 100,000 gallons. Various storm hydrographs will obviously produce differing rainfall intensities and duration, however, in most cases infiltration remained in the SPTSD system for 3-4 days after a rainfall. Actual 24-hour flows for this project tended to be 5-6 times the 4-hour peaks for the day of the storm event, and 3-5 times the 4-hr peak for 2-3 days after the storm. For purposes of this analysis, the total estimated rainfall-induced flows will be conservatively estimated to be ten times the 4-hr peak flow. Therefore, it is estimated that 100,000 x 10 = 1,000,000 gallons of I/I were removed from the system for a typical ½" rainfall event.

The Chicagoland area experiences an average annual rainfall of approximately 33 inches. While the actual rainfall distribution varies from year to year, an average of five rainfall events per month, averaging ½" per event, is a reasonable approximation to estimate the annual rainfall-induced inflow which has been eliminated from the SPTSD system. At an average of 1 MGD per event, it is estimated that 30 MGY of rainfall-induced I/I was eliminated by the sewer-lining program.

Therefore, the total estimated annual I/I removed is estimated as

13.85 MGY base infiltration	+	30.00 MGY rainfall-induced 1/1	=	43.85 MGY	=	0.120. MGD

In 1985, as part of a regional cost-effective analysis, the MWRDGC estimated its one-time conveyance costs at $\$142.3*(MGD)^{0.42}$ per foot of interceptor sewer, operation and maintenance costs at $83/MG treated, and the one-time construction cost for I/I-related treatment facilities expansion at $\$5,400,000\ (MGD\ I/I)^{0.85}$. While these costs are applicable to this particular case, it is recognized that a wide range of costs will exist for various agencies depending on their geographical area, population density, treatment facilities and other site-dependent factors.

For the South Palos Township case, the total cost savings (in 1985 dollars) can be estimated as:

Conveyance:	$\$142.3 \times (0.120\ MGD)^{0.42}$	=	$58.41/foot
	$58.41/ft x 13.6 miles x 5,280 ft/mile	=	$4,194,052
Operation & Maintenance:	$83 x 43.85 MGY	=	$3,640/year
Plant Expansion:	$\$5,400,000\ (0.120\ MGD)^{0.85}$	=	$527,879

Assuming an average annual construction cost increase of 2.5% since 1985, these cost savings can be estimated in 1999 dollars as follows:

Conveyance:	$\$4,194,052 \times (1.025)^{14}$	=	$5,926,086
Operation & Maintenance:	$\$3,640 / year \times (1.025)^{14}$	=	$5,143/year
Plant Expansion:	$\$527,879 \times (1.025)^{14}$	=	$745,879

Finally, the conveyance and expansion costs should be annualized over their expected lifetimes so that a true annual cost can be determined. Through their experience, MWRDGC and USEPA recommend expected useful lifetimes of 30 years for treatment plants and 50 years for interceptor sewers. Thus, the total annual cost savings can be estimated as:

Conveyance:	$5,926,086 / 50 years	=	$118,522/yr
Operation & Maintenance:	$5,143 / year	=	$5,143/yr
Plant Expansion:	$745,879 / 30 years	=	$24,863/yr
	Total Annual Cost Savings Achieved:		$148,528/yr

This relatively simple analysis shows that the $1.5 million expended for sewer rehabilitation will "pay for itself" in approximately 10 years through lower conveyance, operation and maintenance, and treatment costs. The design lifetime of the CIPP sewer lining products which were the cornerstone of the I/I removal program is estimated at 50 years, meaning that the benefits of I/I reduction will actually result in 40 years of cost savings. This fact underscores the long-term value of the trenchless rehabilitation techniques employed on this project.

The South Palos Township Sanitary District project provided an excellent opportunity to unveil a long-awaited solution to sealing the lateral and sewer main connection. The T-Liner product, which guarantees a verifiable airtight seal at the connection point, is believed to be the first of its kind, and substantially contributed to the dramatic flow reductions which were achieved. As technological advancements continue make these solutions possible, we can look forward to look forward to other exciting techniques to solve our sewer system infrastructure problems in the near future.

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