Automating Collection System Maintenance with Bar-Coding

Doug Hammond and Kenneth J. Horton

When Melbourne's Wastewater Collections Department looked for processes to improve, the maintenance work order system was a prime candidate. Maintenance management, a paperwork nightmare, is scheduled by a computerized maintenance management system. Work orders are issued based on manufacturer-recommended intervals for collection system equipment. The job is not done until the paper work is complete.

Personnel are issued work orders, perform the maintenance, and complete the paper work by hand. The paperwork is then submitted to office personnel for entry into the computer. Reducing data entry and paperwork results in cost reduction and increase in efficiency.

With a vision of a paperless office as a goal, the city began working with Horton Engineering to develop a method to automate the operation. In the initial phase, the city purchased two American Microsystems M2000 barcode readers and Microbar, a barcode printing software designed by American Microsystems. Codes are now being developed to define maintenance transactions and identify spare parts and inventory items. A five step process has been defined to handle work orders from creation to completion.

The initial phase introduces the user to barcoding and its use in a maintenance environment with existing computer software. The automation of the work order system had several focal points, all related to improving operational efficiency. Reducing data entry, reducing computer keyboard time, and eliminating most manual data entry were the main areas of interest.

Preventive Maintenance

Melbourne's wastewater collection system has 70 lift stations, each assigned up to eight levels of maintenance. Three levels of electrical and mechanical maintenance are currently scheduled for each lift station.

Each lift station has its own standard operating conditions, or fingerprint. Whether a lift station services a public school or an industrial complex, it is subject to peak operations and low operations. Maintenance should not coincide with peak operations.

Melbourne has created maintenance routes using a golf course layout. On a typical golf course, after half of the course has been played, the players find themselves back at the clubhouse. Similarly, the players return to the clubhouse at the end of play. By using the same format when defining a maintenance route, travel time to the first station is reduced and the work crew returns to base after the last station. The route also takes into consideration natural barriers such as rivers, canals, and streets.

Preventive maintenance includes mechanical and electrical maintenance. Mechanical preventive maintenance is scheduled on 3-, 10-, and 18-month intervals. Electrical preventive maintenance is performed on 2-, 8-, and 16-month intervals.

Computer Data Entry Time

Administrative personnel use work orders generated by Station Data, a computerized maintenance management system by Horton Engineering, to track and schedule preventive maintenance. Station Data is integrated with Data Flow Systems TAC 11 telemetry.

Reduction of the paper trail was the ultimate goal. It required human interaction to create a work order and assign it to a crew. When the crew finished, the work order was completed by hand to include mileage, time on location, and parts used. The paper work was then submitted to computer operations. Only then could the data be keyed into the computer.

Default Values Reduce Data Entry

A review of work orders revealed several trends. Unless extra parts were required, the mileage was constant for each station. Time spent on location was a function of the maintenance code performed. Horton Engineering investigated methods of assigning default values to these work order fields. If data were not entered, the default values were used.

Software and Database Enhancements

Extra fields were added to the site database for the expanded operations. A field for labor time was required in either the maintenance code database or as a field attached to the maintenance level in the site database. It was decided to put the default labor time in both and allow the user to choose with a configuration parameter.

The option to toggle data entry mode between keyboard and barcode entry mode was added. This gives backwards compatibility to users without barcode equipment and a fall-back mode in case of equipment failure.

Bar Code Hardware

There are several types of barcode scanners. An LED wand requires direct contact to read a barcode. A CCD Scanner must be within 3 inches, and foot print is limited. A laser barcode reader requires external power supply and operators must be educated on usage to prevent eye damage.

The easiest barcode interface, called a PC keyboard wedge, simulates entry from a PC keyboard. Normally additional software is not required in the PC. If you use a serial port device, you must then consider baud rate parity stop bits. Software may be required to transfer data from the COM port to the keyboard buffer.

Creating User Interest and Excitement

When you give a user a barcode wand, it's like giving a child a crayon—if you don't provide the child with a coloring book at the same time, you may find crayon drawings on the wall, floors, and other undesirable places.

Similarly, before installing a bar code reader, be sure there is something worth scanning, like custom inventory tags, property identifier numbers, or catalog numbers. If labels are not available when the wand is installed, you may find the user scanning a lot of UPC and ISBN codes into your data file. Cigarette packs,

The author using a bar code reader at a remote lift station.

twinkles, and paperback books are common targets when valid labels are not available.

Using a barcode reader should be fun and simple, accurate and easy. If the user has to scan a label and then enter a quantity via keyboard, it may take more work than just keyboard input. Labels should be readable with a single scan. Scanning should eliminate at least one data entry step.

Bar Code Formats

There are several formats. If you deal with retail goods, UPC may be a good choice. Because manufacturers put labels on everything, you won't have to print your own. But UPC restricts you to a fixed length field of only numbers. If you plan to scan identifiers that contain letters or special characters, CODE 39 or CODE 128 will do the trick.

Prefix, Suffix, Sequence

When designing a custom barcode, the user can encode almost anything. By using a prefix and suffix on the barcode, the user can later identify the encoded information by simply glancing at the barcode. For instance, a barcode with the prefix and suffix set to "W" and "F" respectively, may indicate that the encoded information is a work order number performed on a Friday.

Many barcode printing packages can generate a sequence of numbers. The user assigns the beginning number and the ending number and the software creates the sequence. By using the prefix and suffix options with this tool, the user will find that creating a custom menu is extremely simple.

Additionally, when the string is prefaced with data base command sequences, the user can add a new record, modify an existing record, or perform any database function normally executed through keyboard entry. Similarly, the user can have a suffix that skips to the appropriate field in the record or closes the record and goes to the next.

Aspect Ratio and Density

To determine how tall a label should be, you must consider the aspect ratio. The longer the code, the taller it should be. A wand is gripped similar to a magic marker on a white board. Scanning motion typically is easiest when the wrist remains stationary and the motion is an arc from the elbow. If the label is long and skinny, it will require a dedicated effort to "stay within the lines."

Density measures how close the barcode lines are printed. If your labels are printed with a laser printer you can choose a high density. If labels are printed with a dot matrix printer, use a lower density. Attempting to print a high density label with a dot matrix printer may make the label unreadable or require multiple scans.

Wider bars/spaces in the barcode are easier to interpret and less subject to hostile conditions such as voids and specks of dirt. For the most effective and reliable scanning, implement with the lowest possible density.[1]

Custom Menu Considerations

Quiet area is white space that a reader requires to determine the starting and ending point of the barcode. If you are using a CCD scanner, the label should be smaller than the scanner head. The quiet area should be large enough that only one bar code is readable at a time.

Protecting Reusable Labels

Bar-codes are printed on adhesive labels and affixed to bins and shelves for inventory or sheets of paper containing part numbers and quantities. Some of these will be scanned multiple times.

Care should be taken to protect labels that will be used multiple times. This is very important if a contact scanner is employed. It's not so much a problem with CCD or Laser scanners that don't come in contact with a bar code label. Use of a laminate that is not clear will introduce distortion to the protected page. Do not use "Scotch tape" and economical page protectors that appear frosted. Durable page protectors and clear packing tape work well.

Human Readability

The contents of the bar code label should always be printed on the label in text. Equipment failure caused by a dirty scanner, dirty label or electronics failure should not prevent the user from recording data. Manual entry will serve as a backup means of data gathering.

During the project planning phase, there was thought of placing a unique identification label at each location. Scanning the label would verify that the employees actually visited the site and performed the maintenance. By not placing readable text on the label, it would be encoded.

However, scanning the label normally prints the contents to the hand held device. It was decided to add text, although each site's label has a check sum character to provide some uniqueness.

Future of Project

The second phase of barcode integration into Melbourne's maintenance program will commence shortly. Currently, the city is awaiting the arrival of a hand-held scanner unit to be used as a means of on-site data collection.

Portable Hardware Selection Process

The city has approved the purchase of a CompSee APEX 2 handheld barcode unit for use in the field to handle each of the separate codes that would be used to generate barcodes for the maintenance department. This includes alphanumeric strings in upper and lower case. It also has to be able to read ASCII characters such as line feeds, carriage returns, and arrow keys

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[1] Richard B. Meyers, "Ten commandments of barcoding," *Automatic ID News*, June 1994

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Stopping Force Main Collapses and Establishing Corrosion Control

Luis Aguiar, Armand J. LeBeau, and David B. Williams

Accelerated internal corrosion degrading through the crowns of large diameter pipelines can collapse sewers and create havoc for public utilities. As with many agencies, the Miami-Dade Water and Sewer Department (WASD) has experienced such failures in localized wastewater transmission pipelines and treatment plant conveyance systems. Unique to this problem is that these failures have been in force mains and full pipe conveyance systems versus more typical corrosion seen in gravity interceptors. To address the problem, WASD has established a three-phase corrosion control program to identify locations of potential failure and to develop effective solutions.

Background

The WASD wastewater collection system covers a service area of approximately 975 square miles within Dade County. WASD operates three major facilities within the area that treat an average of about 315 MGD of wastewater. WASD also operates and maintains over 940 wastewater pumping stations and approximately 2,400 miles of gravity and force main piping.

Pipeline corrosion is often seen in gravity sewers or other similar facilities where the wastewater flows in open channel hydraulic conditions (i.e., the pipeline is not full). In these conditions, hydrogen sulfide (H_2S) in the wastewater off-gases into the air space above the liquid (free) surface. Some H_2S will absorb onto the crown of the sewer, and in the presence of oxygen (O_2) and bacteria, sulfuric acid (H_2SO_4) will form. The acid will then attack the pipeline interior surface. Conversely, force main's are designed to operate under full pipe flow conditions. Nevertheless, if oxygen is consistently present, then corrosive conditions can exist within force mains just as in gravity sewers.

Establishing that O_2 is necessary for force main corrosion, WASD needed to determine how O_2 had entered full pipe conditions. Five mechanisms of air entrainment were suspected to be occurring in the force main transmission system:

- Air can be introduced into the force main at pumping stations through turbulence within a wet well, vortex funneling, or through pump seals where negative pressures exist. The oxygen entrained by any of these mechanisms will normally rise to the pipe crown immediately downstream of the station. Failures within the WASD system attributed to this mechanism have occurred to a 20-inch force main on March 16, 1995 and to a 54-inch force main in 1985, 1988, and March 1994.
- As wastewater flows through a conveyance system, deposited materials create anaerobic conditions, ultimately producing carbon dioxide (CO_2), methane, and H_2S. Entrained air creates an ideal situation for H_2SO_4 (acid) corrosion.
- When negative pressures exist in a force main, air can enter at such high points as air release valves, vacuum breaker valves, and defective or compromised pipe.
- Where gravity conditions exist, air can enter from the discharge end of a force main and cause corrosion. A failure due to this mechanism occurred in a 48-inch force main in January 1994 and again in June 1995.
- Under certain conditions, dissolved oxygen may be introduced to a force main by high pressures. Pressure may be reduced downstream causing some oxygen to be released and added to an existing crown bubble at a high point.
- Pipe joints or other protrusions can interrupt the smooth flow of wastewater at or near the crown of a pipe. If sufficient dissolved oxygen is in the wastewater, turbulence can create slightly reduced pressure causing oxygen to come out of solution.

Methodology

To determine high-risk areas within the WASD system, a three-phase corrosion control program was initiated:

Phase 1

- Initial review of record drawings with an emphasis on large diameter pipelines (30 inches or greater).
- Interviews with WASD staff to determine system history.
- Listing of high risk pipelines to prioritize planning efforts.

Phase 2

- In-depth review of record drawings to create a database of system pipelines with diameter of 18 inches or greater.
- Evaluation of industrial and external sources of corrosion.
- Identification of transitions from pressure to gravity flow.
- Inspections of air release valves, manholes, and pumping stations throughout the system.
- Sampling of wastewater and gas from air release valves, manholes, and pumping stations.
- Development of chemical feed contingency plans.
- Transient hydraulic analysis of critical pipelines.
- Expansion and reprioritization of high risk pipelines list.

Phase 3

- Inspection of pumping stations and development of corrective actions.
- Inspections of "high risk" pipelines.
- Development of capital improvement program listing and cost estimates for system rehabilitation.

The first step in developing a listing of high risk pipelines was an extensive review of record drawings, contractor submittals, and other existing records. Other anecdotal information relating to system operation and past failures was obtained through staff interviews. Important information obtained included pipeline materials, age, lining material, historical failures, rerouting abilities, and the strategic importance to the WASD system.

Inspections and sampling of the system air release valves then focused on items that indicate corrosion potential: air release valve off-gas times (indicator of air entrainment and/or gas production), gas sampling (included H_2S, and O_2), and wastewater sampling (included total and dissolved sulfides, dissolved oxygen and pH).

Simultaneous inspections of pumping stations documented corrosion impacts and determined whether air entrainment was occurring. The focus of the inspection was to determine whether water was cascading into the wet well or if vortexing was occurring.

Results

Phases 1 and 2 of the corrosion control program determined the following information about the WASD wastewater force main transmission system:

1. Wastewater samples, as shown in Table 1, indicated dissolved sulfides at levels sufficient to support corrosion throughout the system (sample population = 240).
2. Of 99 air release valves inspected, 31 exhibited off-gas times over 60 seconds, 19 of which exhibited off-gas times of over

300 seconds. The off-gas times measured ranged from 0 to 9900 seconds.

3. Testing of gas samples from some air release valves indicated the presence of oxygen and hydrogen sulfides in the gas space. Twenty-nine different air release valves had oxygen levels greater than 0.1%, of which 15 had oxygen levels greater than 1.0%. A summary of other gas sampling information is contained in Table 2.

Table 1. Waste water Sampling Data

Parameter	Low Value (mg/l)	High Value (mg/l)
Dissolved Sulfides	0.1 >	11.5
Dissolved Oxygen	0.2	6.6

Table 2. Air Release Valve Gas Sampling Data

Parameter	Low Value	High Value
Oxygen	0.1%	14.0%
Hydrogen Sulfide	4 ppm	>999 ppm

4. Many pipelines in the system are constructed of unlined concrete and are over 25 years old.
5. Thirteen of the 28 pumping stations inspected were operated with wet well water levels below the invert of the influent pipeline. The resulting turbulence creates the potential for H_2S release and air entrainment. The air can then collect within the transmission force main.

The highest risk areas were identified based on materials (e.g., unlined concrete); age, strategic locations (e.g., proximity to surface water, unparalleled pipeline) History of corrosion and/or failure; sampling information indicating conditions conducive to corrosion; and inspection information indicating conditions conducive to corrosion (i.e., cascading influent to pumping station wet well).

Table 3 lists seven of the pipelines that were identified as high risk, the reasons for selection, and actions that WASD is taking to prevent failure, correct deficiencies, and minimize problems that might result.

To summarize, the WASD force main system was found to have a high potential for corrosion due to high levels of dissolved sulfides in the wastewater; pockets of gas in the force main system, many exhibiting the presence of oxygen; the fact that many force mains throughout the system are constructed of concrete, are over 25 years of age, and are unlined; and the cascading of wastewater into the wet wells of some pumping stations.

WASD Actions

WASD management has to date taken the following actions:

- Created a High Risk Pipeline Planning Committee to initiate shutdown contingency planning and alternative flow route planning for high risk pipelines.
- Established corrosion related design guidelines for pumping stations and force mains.
- Initiated a wastewater treatment plant corrosion evaluation.
- Developed chemical feed contingency plans.
- Budgeted for additional manpower to implement an expanded air release valve exercising program.
- Formed a pipeline inspection crew.
- Constructed a new Cross Bay pipeline and inspected the old Cross Bay pipeline.
- Initiated construction of two parallel pipelines.
- Completed siphon structure inspections and rehabilitation and initiated chemical feed at one pumping station.

The corrosion control program has enabled WASD to correct existing problems and focus future efforts on implementing preventive actions designed to reduce the corrosion precursors, specifically oxygen. The Phase 3 effort will include the development of pumping station and pipeline corrective action capital improvement lists. Long term WASD plans call for staff training related to pumping station maintenance and operation, system characteristics monitoring, and inspections to proactively identify and correct problems.

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Table 3. Identified High Risk Pipelines

Pipeline	*Reason*	*Action*
1(54-inch)	Age, material, history, sampling, inspection	Parallel pipeline constructed, manned internal inspection of old pipeline in progress
2 (48-inch)	Age, material, history, sampling, inspection	Shutdown contingency plan completed, flow rerouting capability under construction
3 (48-inch)	Age, material, history, sampling, inspection	New intracoastal crossing designed; construction planned for late 1997; further investigation of existing pipeline planned
4 (54-inch)	Age, material, gravity, inspection	Pipeline rehabilitation by sliplining
5 (72-inch)	Age, material, location	New Cross Bay line completed; Old Cross Bay Line inspection completed and rehabilitation design in progress
6 (60-inch)	Age, material, location, sampling	Contingency plan developed; pipeline assessment completed; parallel pipeline under design
7 (48-inch)	Age, material, history, sampling, inspection	Shutdown contingency plan completed; sections rehabilitated; new parallel pipeline constructed and in-service; old pipeline to be dive inspected

Service Laterals - the Last Frontier in Sewer System Rehabilitation

Jens Peter Larsen, James N. Struve, Whit Van Cott, and David McLaughlin

The Broward County Southern Regional Wastewater Collection System serves the cities of Hollywood, Dania, Hallandale, Miramar, Pembroke Pines, along with the town of Pembroke Park and a portion of unincorporated Broward County. It consists of 2,830,100 lineal feet of collection sewers covering 106.58 square miles. The collection system provides sanitary services for a population of 288,615. The city of Hollywood is the lead agency representing Broward County Southern Region. The city also maintains and operates the regional treatment plant, while each of the municipalities is responsible for maintaining and operating its own wastewater collection and transmission systems.

Hollywood, in southeastern Broward County, with an estimated population of 121,700 and covering about 25 square miles, operates and maintains a wastewater collection system (963,400 lineal feet) serving about 86,500 inhabitants in sewered areas totaling approximately 11 square miles. The sewered areas are scattered throughout the city, while the remaining unsewered portions are served by on-site disposal systems.

Because of excessive infiltration and inflow in the regional collection system, EPA cited Hollywood for violating its NPDES permit requirements by failing, on occasion, to meet its 85 percent TSS removal requirement. Excessive infiltration and inflow (I/I) diluted the influent wastewater and made the EPA "percentage removal" requirements difficult to consistently meet. In 1991 EPA issued an Administrative Order requiring that an I/I flow reduction program be undertaken within a stipulated time frame.

As the lead agency for the Broward County Southern Wastewater Region, Hollywood assumed the principal role in implementing the I/I flow reduction program for the entire regional collection system. The program consisted of three phases of work: an I/I analysis, a sanitary sewer evaluation survey (SSES) and a sewer system rehabilitation program.

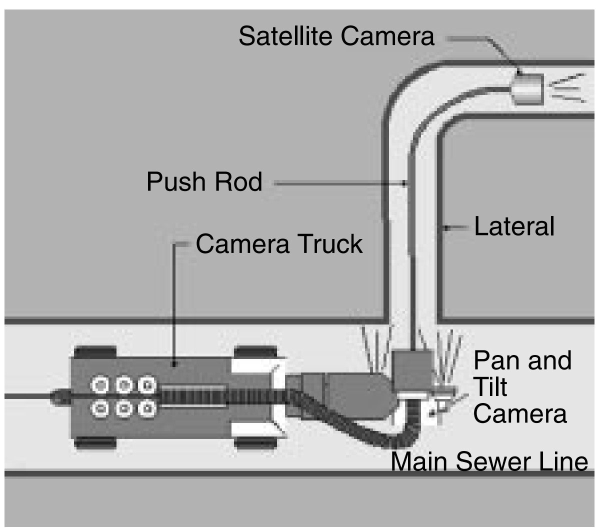
As a result of the I/I flow reduction program, short-term flow monitoring within Hollywood's individual collection basins revealed that 3.35 MGD of extraneous flow had been eliminated at a construction cost of $4.8 million. The repairs consisted of 237 manhole repairs, 355 main sewer line repairs, rehabilitation of approximately 99,000 lineal feet of main sewer line, and 158 lateral repairs. In spite of the city's recent effort, it is estimated that 7.30 MGD of I/I still enters the city's collection system.

During the initial phase of the reduction program, rehabilitation was predominantly focused on collection lines and manholes. However, service laterals can become a major source of I/I, especially during wet weather periods when the groundwater level rises. A national survey by state and local agencies found that the estimated percentage of total system infiltration from service laterals ranged from 30 to as high as 95 percent in some instances. Consequently, as part of its continued I/I flow reduction program, Hollywood initiated a lateral repair pilot program.

The objective of the lateral repair pilot program was to choose cost-effective repair technologies and to establish their effectiveness. Available lateral repair technologies evaluated include full line grouting, chemical grouting, cured-in-place liners, robotics/epoxy, pipe bursting, and dig and replace (excavate). Once technologies and methodologies have been developed, cost-effective lateral repairs will be incorporated into a citywide master plan for continued I/I flow reduction.

Lateral SSES

During the main sewer line televising phase of the SSES, more than 700 laterals were identified as "suspect." These were laterals through which clear water was flowing or which had root intrusion, thereby becoming a potential I/I source. Following pre- and post- construction and warranty closed circuit television (CCTV) inspection, 176 laterals were found to be discharging clear water each time a television inspection was made. From these 176 laterals, it was estimated that approximately 277,350 gpd of extraneous water entered the collection system. As time allotted, a majority of the 176 laterals were then CCTV inspected. The objective of CCTV inspection was to confirm the I/I source and to visually evaluate the laterals physical condition to facilitate cost effective recommended repairs.



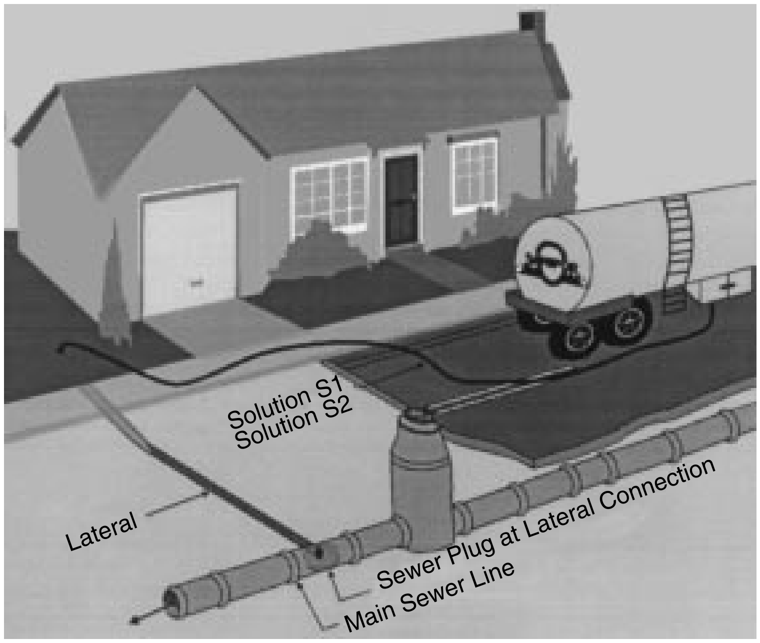
SAT-STARR Satellite Camera

The recently developed SAT-STAR satellite camera manufactured by Rausch was used for the lateral inspection. Being specifically designed for CCTV inspection of sewer laterals, the system offers many features over traditional main sewer line cameras. Entrance for lateral CCTV inspection is from the main sewer line, thereby eliminating the need for a lateral service cleanout. The system is equipped with a pan-and-tilt camera which positions the satellite camera directly in-line with the lateral opening. Once in alignment, the satellite camera is then "launched" from the camera truck into the lateral service. Depending on the lateral geometry (stacks, direct connections, etc.), the satellite can be extended up to 60 feet into the lateral. When the satellite camera is retracted from the lateral, the pan-and-tilt camera can then be used for main line CCTV inspection. The Rausch system also generates CCTV field inspection reports, which are printed on-site for immediate review. Reports include information relative to the sanitary sewer system to identify location and position of the lateral, and a schematic of the inspected lateral with defects noted is plotted. Optional equipment includes a snap-shot camera to photograph specific lateral defects and a radio-wave based wand to detect location and depth of satellite camera from the above ground surface.

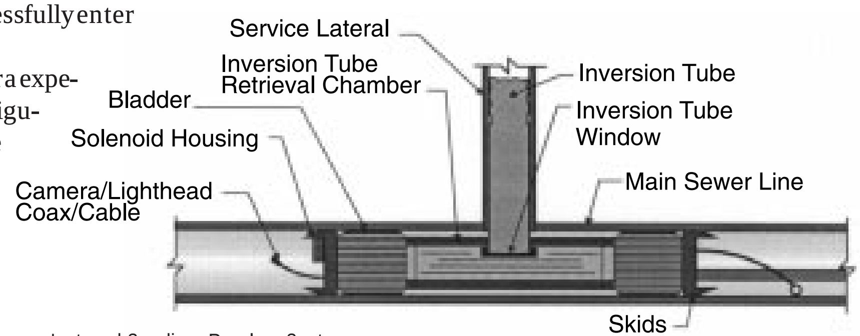
Some limitations of the Rausch system were exposed during the lateral CCTV inspection. Because of the size of the camera truck, the system was unable to access a recently rehabilitated fold-and-formed 8-inch sewer line. Additionally, slight joint offsets in non-rehabilitated 8-inch sanitary sewers also prevented camera truck passage. For sanitary sewer lines less than 15-inches, the satellite camera could only successfully enter the lateral service from the downstream direction.

Once inside the lateral service, the satellite camera experienced additional challenges. If a lateral stack configuration less than 5 feet was encountered, the satellite camera was unable to negotiate a 90 degree bend. Furthermore, stack lengths greater than 5 feet did not necessarily guarantee successful passage either. Laterals transitioning from 6- to 4-inches stopped the satellite camera unless the pipe inverts were matched. Lastly, the camera operator was unable to control the orientation of the satellite camera. Consequently, it could rotate in excess of 180 degrees, thereby creating difficulty in identifying potential I/I sources.

Nevertheless, the system provided useable video recordings of service laterals without the need for a service cleanout.



Sanipor Full Line Grouting Sytem



Lateral Sealing Packer System

Lateral Repair Technologies

There are a number of corrective technologies used to reduce I/I emanating from service laterals, including full line grouting, chemical grouting, cured-in-place liners, robotics/epoxy, pipe bursting, and dig and replace (excavate). Each has advantages and disadvantages dependent on the severity of the lateral defect and the existing site condition.

Because of time and finances, only one specialty contractor of each repair technology was chosen to perform the work. Selection was based on availability and performance. Specialty contractors included Sanipor of North America (full line grouting); TRB Specialty Rehabilitation (chemical grouting); Insituform of North America (cured-in-place liners); KA-TE USA (robotics/epoxy); and, Trenchless Replacement Service (pipe bursting).

Full Line Grouting

The Sanipor process for full line grouting employs a two-part chemical solution system that seals leaks in mains, manholes, and laterals. After being isolated and cleaned, the defective system is completely filled with the first chemical solution, Solution S1. A hydrostatic head of 3 to 5 feet above the groundwater table is maintained. Solution S1 is then allowed to exfiltrate into the soil surrounding the cracks and defects for 1 to 1.5 hours, depending on the extent of the defects and local soil conditions. Solution S1 is then withdrawn, leaving the areas surrounding the defects saturated.

The section is immediately refilled with the second chemical solution, Solution S2, which also penetrates into the soil surrounding the defects and combines with Solution S1 under a similar head of pressure to form a highly durable matrix. After a half hour, the remaining solution S2 is withdrawn and the sewer is returned to service.

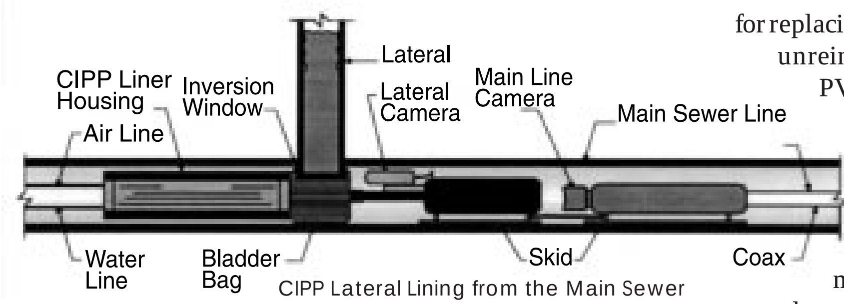
Chemical Grouting

In a typical chemical grouting repair application, a lateral sealing packer is towed through a main sewer line until its “inversion tube window” is aligned with the service lateral opening. The bladders are then inflated to isolate the lateral connection, and the “inversion tube” is extended into the lateral. With the tube completely extended and the internal pressure increased to the correct level, the lateral is pressure tested. During pressure testing, the lateral sealing packer is inflated and the pressure is monitored. If the pressure drops (indicating the presence of a defect), chemical grout is pumped through the lateral packer into the annular space between the inversion tube and the lateral pipe. Under pressure, the chemical grout material is then forced out into the soil through leaking joints, cracks, and other pipe defects.

Cured-In-Place Pipe(CIPP) Liners

The installation of lateral liners is similar to that in main sewer lines. Typically, lateral liners are inserted through the cleanout at the resident’s property line, but they can also be inserted from the main sewer line. The lateral liner is physically constructed to match the length and diameter of the service lateral. The liner material is a fabric, impregnated with a liquid resin, typically either polyester, vinyl ester, or epoxy.

Installation involves pulling the resin-saturated fabric liner and an inflation hose through either the service lateral or the main

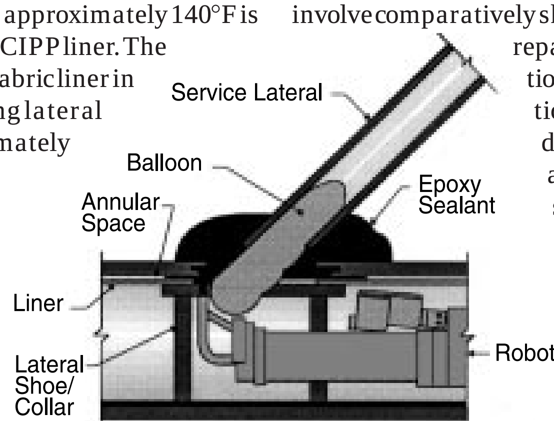


CIPP Lateral Lining from the Main Sewer

sewer line. The alignment of the liner is closely monitored by a CCTV camera positioned in the main sewer line. Once the liner is aligned in the proper position, the inner hose is inflated via a combination of air (6-10 psi) and water (30 psi) pressure causing the liner to regain its original circular shape. Hot water at approximately 140°F is introduced and recirculated within the CIPP liner. The hot water accelerates the curing of the fabric liner in a tight fitting state against the existing lateral service wall. Total cure time is approximately two hours.

Robotics/Epoxy

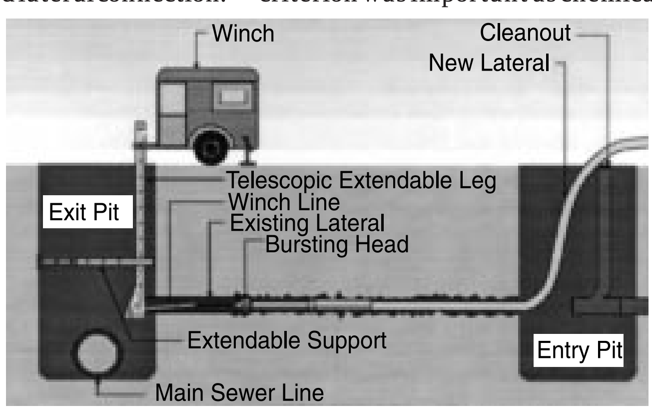
The KA-TE USA patented robotic process utilizes a lateral shoe/collar to repair service lateral to main sewer line connection failures. The shoe/collar is constructed of a flexible plastic shield with an opening that corresponds to both the inside diameter of the host pipe and of the service lateral. Before the collar is installed, a specialized grinding robot prepares the application site by grinding away unwanted material. Once this is completed, the grinding robot is retrieved and replaced with a filling robot. The filling robot positions the lateral shoe/collar precisely against the main sewer line at the service lateral opening and then places an inflatable balloon through the opening and creates a sealed, temporary mold at the failed lateral joint connection. With the balloon in place, the filling robot injects an epoxy sealant from its dispensing magazine into the annular space. After the epoxy sealant is allowed to harden, the lateral shoe/collar is retrieved by the robot and re-deployed at the next failed lateral connection. The robot can also be used to repair protruding and recessed laterals.



"Lateral Shoe/Collar" Sealing System

Pipe Bursting

Pipe bursting is a method for inserting a new pipe of equal or larger diameter into an existing host pipe by fragmenting the existing pipe work and forcing it into the surrounding soil. The new pipe is then inserted into the enlarged hole. Bursting the pipe is accomplished by using either pneumatic or hydraulic bursters. Depending on the system, the burster is either directionally guided or towed by a winch. The new pipe is either towed or jacked immediately behind the burster. Excavated entrance and exit pits are required at the beginning and end of lines to facilitate the installation of the pipe bursting equipment and the new pipe. Pipe bursting is suitable for replacing pipes made of brittle material, such as vitrified clay, unreinforced concrete, asbestos cement, cast-iron, and some PVC and reinforced concrete pipes. It is not appropriate for the replacement of steel, ductile iron, polyethylene pipes, or composite pipes.



Pipe Bursting

Dig and Replace (Excavate)

Because of the high cost, total or partial replacement of service laterals is generally limited to seriously deteriorated or structurally damaged pipe for which sealing or lining is impractical. However, this alternative may be most practical if the condition of the lateral is beyond repair. Replacement gives the highest strength and longest useful life, but it is the most expensive method of rehabilitation.

Point repairs are generally made at specific locations and involve comparatively short lengths of laterals or fittings. Point repair procedures for laterals using excavation require locating the leaking pipe sections and completely exposing them by digging. The damaged pipe is removed and replaced with either a new pipe section or pipe fitting. Pipe connections are made using either flexible band couplings or adapters or couplings with compression joints. New pipe bedding material is then placed and compacted to the pipe's spring line.

When either pipe bursting and dig-and-replace technologies are employed, the excavated areas must be restored to original conditions. Thus, the cost must include costs for surface restoration, such as pavement, curb and gutter, and lawn replacement. In instances where permanent structures overlay service laterals or when areas are inaccessible to excavating machinery, these type of repairs are impractical and will prove to be too costly relative to the other lateral repair technologies.

Lateral Repair Selection Criteria

Following lateral CCTV inspection, each videotape was reviewed. During the review process, the estimated amount of leakage and location of the infiltration source was identified. This criterion was important as chemical grouting is limited to approximately the first 4 feet and robotics/epoxy is limited to the first lateral joint from the main sewer line.

Depending on the type and severity of the lateral defect, the lateral was then selected for either a structural or non-structural repair. This criterion was important because neither grouting technology improves the structural integrity of the lateral.

The geometry of the lateral connection to the main sewer line was also considered. CIPP liners are limited to single service connections and to straight line portions of a "Christmas tree" type lateral stack configuration. The depth of the lateral connection at the main sewer line must be considered, especially in coastal areas such as South Florida where groundwater levels are only 3 to 5 feet below grade. Repair costs for pipe bursting and dig-and-replace repairs increase significantly when main sewer line depths are greater than 7 feet.

After videotape review, field visits were made to each potential rehabilitation location to identify site constraints (landscaping, fencing, trees and shrubs, driveways, etc.) that would prohibit pipe bursting and dig-and-replace repairs. Both repair technologies require excavation and surface restoration.

Table 1. Criteria for Selecting Recommended Lateral Repair Technologies

Repair Technology	Leak Location	Structural Repair	Lateral Geometry	Lateral Depth	Site Constraints	Number of Recommended Repairs
Full Line Grouting	No	No	No	No	No	5
Chemical Grouting	Yes	No	No	No	No	19
CIPP Liners	No	Yes	Yes	No	No	5
Robotics/Epoxy	Yes	Yes	No	No	No	4
Pipe Bursting	No	Yes	No	Yes	Yes	3
Dig and Replace	No	Yes	No	Yes	Yes	9
					TOTAL	**45**

Conclusions

Chemical grouting, robotics/epoxy, CIPP liners installed from the cleanout, dig-and-replace repairs, robotics/epoxy, CIPP liners installed from cleanout to main sewer line, and dig-and-replace repairs are proven lateral repair technologies as demonstrated through Hollywood's sewer system rehabilitation program.

In regard to lateral repairs, chemical grouting is best suited for sealing leaky joints and small cracks within 4 feet from the main sewer line; robotics/epoxy is best suited for sealing off the annular space upon lateral reinstatement following main line rehabilitation and for sealing joints and cracks at the lateral connection to main sewer line interface; CIPP liner installation is best suited from the cleanout and when the main sewer line has also been rehabilitated with a CIPP liner; and, dig-and-replace repairs are necessitated when the service line is totally or partially deteriorated and pipe bursting can not be utilized.

During the program, 12 CIPP liners were installed, 95 robotic/epoxy repairs were performed, and 48 dig-and-replace repairs were made. Lateral rehabilitation technologies tried in the field during initiation of the city's lateral repair pilot program include 15 repairs by chemical grouting and two repairs by CIPP liners installed from within the main sewer line.

Effectiveness of the repairs have yet to be evaluated. Technologies to be tried in the field during the continuation of the pilot program include additional CIPP liners to be installed within the main sewer line, full line grouting, and pipe bursting. Although great advances have been made during the initial phase of the pilot program, and new lateral repair technologies have been explored, it is evident that the "final frontier" has not been conquered.

Table 2. Estimating Costs for Repairing 6-inch Diameter Lateral

Full Line Grouting	$1,200 - $1,500
Chemical Grouting	$400 - $600
CIPP Liners	$2,500 - $3,000
Robotics/Epoxy	$1,400 - $2,000
Pipe Bursting	$1,500 - $5,000
Dig and Replace	$2,700 - $15,000

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