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sewer system
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Pennsylvania township gets proactive on inflow and infiltration to prevent bigger problems.

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COVER PHOTO: Brandon Dice of the Hamilton Township Municipal Authority drills a hole at an infiltration point to pump grout into the soil surrounding a manhole. The Pennsylvania utility has adopted new technology and a comprehensive approach to fighting inflow and infiltration. (Photography by Kevin Blackburn)



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Published four times yearly by COLE Publishing, Inc.
1720 Maple Lake Dam Rd., PO Box 220, Three Lakes, WI 54562

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SUBSCRIPTIONS: I&I™ is included quarterly (Jan., April, July, Oct.) along with a one-year (12 issues/monthly) subscription to Municipal Sewer & Water™ (MSW). MSW and I&I are free for qualified subscribers in the United States, Canada and Mexico. A qualified subscriber is any individual or company in the United States, Canada and Mexico that maintains, manages, designs or installs municipal or commercial sewer, water and storm infrastructures. To qualify, visit www.mswmag.com or call 800-257-7222.

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EDITORIAL CORRESPONDENCE: Address to Editor, I&I, P.O. Box 220, Three Lakes, WI, 54562 or email editor@iandimag.com.

REPRINTS AND BACK ISSUES: Visit iandimag.com for options and pricing. To order reprints, call Jeff Lane at 800-257-7222 (715-546-3346) or email jeff.lane@colepublishing.com. To order back issues, call Nicole at 800-257-7222 (715-546-3346) or email nicole.labeau@colepublishing.com.

CIRCULATION: 16,295 copies, four times yearly.

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A contractor for the Naperville Water Department lines a large-diameter sewer main as part of a broad approach to infrastructure rehabilitation.

PHOTO COURTESY OF NAPERVILLE WATER DEPARTMENT



ONE BASIN AT A TIME

City shifts focus away from individual problem lines and sees big results in inflow and infiltration reduction

By Cory Dellenbach

Tony Conn is pleased with how far the city of Naperville, Illinois, has come in fighting inflow and infiltration over the last two decades.

As the city’s water distribution and collections manager, Conn is responsible for wastewater collection, stormwater pumping, water distribution and water supply and he’s seen the changes firsthand.

“We’re working through a 10-year I&I program right now, but we’re working on updating it currently,” Conn says. “I can definitely see us going another 20 to 30 years with I&I reduction work with a city our size.”

The city has seen big changes with its flows since starting a program in the late 1990s to target I&I. Since 1998, the population of Naperville has increased by roughly 30,000 people — or about 20%. Yet, when looking at the average amount of water treated at the Springbrook Water Reclamation Center, flows have decreased by roughly 18% over the same period.

THE OLD WAYS

In 2004, Naperville had a population of 142,000, with 2,49 million feet of sanitary sewer main, 2,85 feet of service lines, 19 lift stations, 11,500 sanitary manholes and one treatment plant.

The city began experiencing heavy rainfall events in the early 2000s that put officials on alert. In October 2001, the city experienced a 4.5-inch rainfall over a 12-hour period. There were approximately 200 reported sanitary sewer backups, predominately in nine subdivisions of the city. The city had

“In 2016 we started a program where we do microbasin flow monitoring to help us with future projects, so when we’re done with this area, we know where to go next.”

Tony Conn

already identified the area affected as a major contributor of infiltration and was actively renewing laterals using pipe bursting technology. The city was also lining mainlines and rehabilitating manholes, yet it still encountered the serious flood.

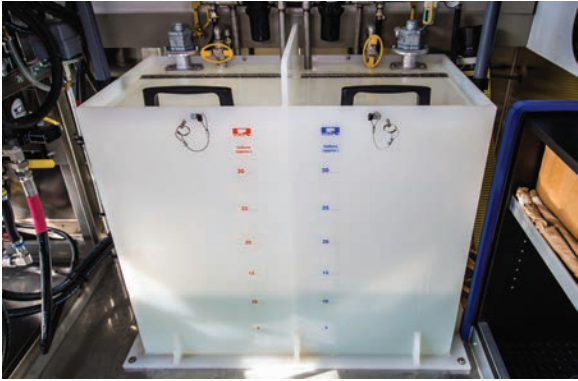
“Back in the day, everybody was like, ‘You attack the worst stuff,’” Conn says of the plan in the early 2000s. “Before 2003 we were lining sewer mains all over the city.”

MAKING A CHANGE

The utility department spent almost a year televising sanitary mains and service lines, visually inventorying manholes, surveying buildings and acquiring information from homeowners. They also investigated sanitary sewer and manhole rehabilitation techniques and followed up with a six-year rehabilitation plan.

(continued)

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The Naperville team takes a basin-by-basin approach to inspection and rehabilitation.

“That’s when we found out you can line a piece of pipe but water is going to migrate to the next place, so it’s either going to migrate to a manhole or a lateral,” Conn says.

In 2003 the city began focusing on spending the dollars on an entire subdivision before moving on to the next.

“We would line the sewer mains, the water would migrate to the laterals and we’d line the laterals,” Conn says. “Then the water would migrate to the manholes, and we would take care of all the assets in that basin to stop water migration to actually achieve I&I reduction.”

SIGNIFICANT RESULTS

It didn’t take long for the new approach to yield results.

“We’ve had such great success with doing rehab this way that it’s the only way we operate now,” Conn says. The city has since added grouting of manholes and laterals to its work in the years since.

Customer service calls have gone down from 600 in 2007 to 280 in 2018. Sewer maintenance costs have also dropped, with a shift from annual root cutting to jet flushing every four years, equating to \$39,000 in savings per year.

Treatment plant flow is now at 19.75 million gallons per day, compared to 26.75 before the I&I reduction plan.

Naperville also experienced its wettest June in history in 2015, receiving 2.2 more inches of rain in 2015 than in 2013, resulting in groundwater being 4.3 feet higher than the 2013 levels. Groundwater was 5.8 feet higher than the sewer crown that year as well, but thanks to the I&I work already completed, there were zero wastewater backups that year.

MORE TO COME

Conn says current work is still focused on areas where they know there are I&I problems, but with a city so big, officials knew planning ahead was a necessity.

“We’ve had such great success with doing rehab this way that it’s the only way we operate now.”

Tony Conn



A Naperville Water Department crew member sets up at the bottom of a manhole for rehabilitation work.



Manhole walls are sprayed to seal out I&I.



Tony Conn, Naperville Water Department distribution and collections manager, has helped guide the comprehensive approach to I&I abatement.

“In 2016 we started a program where we do microbasin flow monitoring to help us with future projects, so when we’re done with this area, we know where to go next,” Conn says.

Flow monitors are installed for a six-month period in basins depending on annual rainfall-dependent I&I, breaking the basins down to as little as 1,000 feet all the way up to 18,000 feet.

“It really helps us pinpoint where the worst I&I is in that basin and we’ll start in that area and fan out to cover the rest of the basin,” Conn says. “So we’re hitting the big-ticket items first and then fanning out and hitting all the water migration.” **I&I**




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Reversing the Current

Pennsylvania township gets proactive on inflow and infiltration to prevent bigger problems

STORY Jim Force | PHOTOS Kevin Blackburn

The Hamilton Township (Pennsylvania) Municipal Authority is dealing with infiltration and inflow for all the right reasons. And a consent decree is not among them.

“We’re trying to be responsible and proactive, to work on it now and budget for it rather than waiting for a consent decree and then having to borrow,” says Sharon Purnell, manager of the municipal authority. “We want to have a way to pass critical information along to crews who come to work for the authority, and leave things as best we can for the next generation.”

The current team is hard at work with its GIS mapping system to identify, track and log crucial information about its 70-mile sewer system. And they’re using state-of-the-art Electro Scan technology, which utilizes electrical current to detect, measure and quantify defects.

The pipe section to be inspected is fully flooded using the authority’s Vactor truck, and the Electro Scan probe is pulled back through. There is a cone attached to the end of the probe that helps to keep the probe fully submerged with water.

The scan results help with prioritization, and the information is valuable in making educated decisions in regard to remediation.

“If electricity can get out, water can get in,” Purnell explains.

It has its advantages over CCTV, she says, in that it enables the township’s crews to simulate full-pipe storm flow conditions without having to wait for wet-weather events with a limited window for sewer condition assessment. “We will scan a specific basin or area, prioritize the top 10 to 20 lines and follow up with CCTV to further investigate to visually see what the conditions are. They are both important and complementary tools in sewer condition assessment.”



Joshua Eyer with the Hamilton Township Municipal Authority lowers a RauschUSA CCTV camera into a sewer line for inspection.

“We can look at the results on the run and make intelligent decisions right there on the spot. It’s easy to follow up with our CCTV unit.”

Sharon Purnell



Justin Hollenshead sets up the location data and starts an Electro Scan inspection from inside the camera truck.

ELECTRO SCAN INSPECTION TECHNOLOGY

Electro Scan inspection unambiguously locates and measures in gallons per minute all potential leaks that are typically missed by CCTV, such as bad joints, cracks, holes, fractures, bad service reconnections and poorly cured liners. The technology was named to *Fast Company's* prestigious list of 2019 World's Most Innovative Technologies at SXSW in Austin, Texas, and is being used for locating infiltration and for certification of trenchless rehabilitation throughout the U.S. and U.K.

The technology is based on the concept that nonconductive materials naturally prevent electricity from passing through, or along, the wall of a pipe. "Electrical current should never be able to 'leak' from inside a pipe unless there is an opening in the pipe wall," says Mike App, vice president of Electro Scan. "A defect in the pipe that leaks water will also leak electrical current. The larger the defect, the greater the electric current flow as described in ASTM F2550."

Electro Scan ES-620 probes (such as the ones used at Hamilton Township, Pennsylvania) measure 32 inches long by 2.875 inches in circumference. They can be pulled downstream by a jet truck, are compatible with existing CCTV equipment and can detect leaks in dry or completely submerged pipes.

A smaller ES-38 unit, which Hamilton Township also owns, can be used to detect leaks in sewer laterals.

"There is no question the spot repairs made a difference, but there was still more going on in the pipe that we could not see with CCTV."

Sharon Purnell

A camera is positioned into a sewer line for inspection.

HAMILTON TOWNSHIP

Hamilton Township is situated near the borough of Chambersburg, about an hour southwest of Harrisburg. The township's sewer system conveys wastewater to the Chambersburg wastewater treatment plant. The system consists of 14 pumping stations, three meter stations, 1,215 manholes and 70 miles of sewer line — 85% consisting of PVC and the rest asbestos concrete cement that's now 30 to 40 years old. The system provides service to just over 4,000 customers.

The Chambersburg treatment plant was recently expanded due to the Chesapeake Bay strategy; as a result, the township's capacity increased from 760,000 gpd to 2.0 mgd.

But even then, I&I could be a problem. Heavy rains — such as last year when the area recorded a record 61 inches of rainfall — can result in more than 3 mgd of flow through the sewer system to the Chambersburg plant. The average daily flow in 2018 for Hamilton Township Municipal Authority was about 965 gpd.

NEW TECHNOLOGY

To address the I&I issues, the township adopted a sewer system management plan in 2009 and developed a comprehensive metering plan using Tele-dyne ISCO 2150 area velocity meters to analyze the reaction of the system to wet-weather events. At the same time, Hamilton's sewer crews used its RauschUSA CCTV camera as well as smoke testing and manhole inspections to try to spot cracks and breaks. Spot repairs were made using acrylamide grout, trenchless point repairs and dig-and-replace techniques. During heavy rains, crews often went out at night to isolate pipe sections in an attempt to identify I&I issues.

"There is no question the spot repairs made a difference, but there was still more going on in the pipe that we could not see with CCTV," Purnell says. "We could only see the pipe conditions above the waterline. Had we had Electro Scan then, we would have realized more than spot repairs were warranted."

The results were reported in a paper presented by Purnell and Mark Grabowski of Electro Scan at the No-Dig Show in Denver in March 2015.

Beneath Commerce Street — a busy thoroughfare — the Electro Scan device identified 51 locations of potential defects along 1,080 feet of asbestos concrete cement pipe, with an estimated leakage of 23 gpm, or over 33,000 gpd, assuming a 1-foot head. That's more than 10% of the average daily flow through this pipe of 248,000 gpd, coming from four pumping stations and





From left, Brandon Dice, Todd Hummer, Justin Hollenshead and Joshua Eyer discuss sewer repair plans while retrieving the inspection camera.

by gravity flow from four different developments, according to the township's metering system. Extreme wet-weather events have yielded as much as 1.2 mgd with a peak hourly flow of 83,650 gpd.

Hamilton Township had never televised this section because of flooding and closure of the road to traffic during wet-weather events.

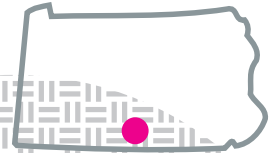
At a second site — known as Fern Lane — a 980-foot section of 10-inch PVC pipe runs along a creek bed and was suspected of serious I&I because flows increased when creek levels rose. Because of flooding, the pipe had never been inspected by CCTV since installation in 1977. The Electro Scan probe indicated, however, that the pipe was in good shape with low levels of potential infiltration. Only 10 defects were identified, having a total flow of about 4 gpm. Instead, the increases in flow were attributed to inflow, which will allow the township to concentrate on flow rather than pipe defects in the future.

SCANNING FOR LEAKS

Based on the results of the pilot study, Hamilton Township decided to purchase its own Electro Scan technology, including a model ES-620 for sewer inspection and a model ES-38 for probing small-diameter pipes, including laterals. "Ballpark, our cost was around \$200,000 for both," Purnell says. "There was a discounted cost for the lateral unit, and we decided to take advantage of that."

Currently, Hamilton is using the technology to inspect additional sections of sewers that have been troublesome in the past. In a recent project, the township inspected an entire gravity flow basin — known as Washington Street — which was one of the first sewer lines installed back in the 1970s. "We scanned everything we had access to," Purnell says. "It's an asbestos cement pipe trunk line that underlies a busy highway and travels over a creek and into the Chambersburg trunk line interceptor.

"We looked at the worst areas and followed up with our CCTV system. Based on condition assessment and meter data from the area velocity flowmeters, we could see there was potential for surcharging in one section of



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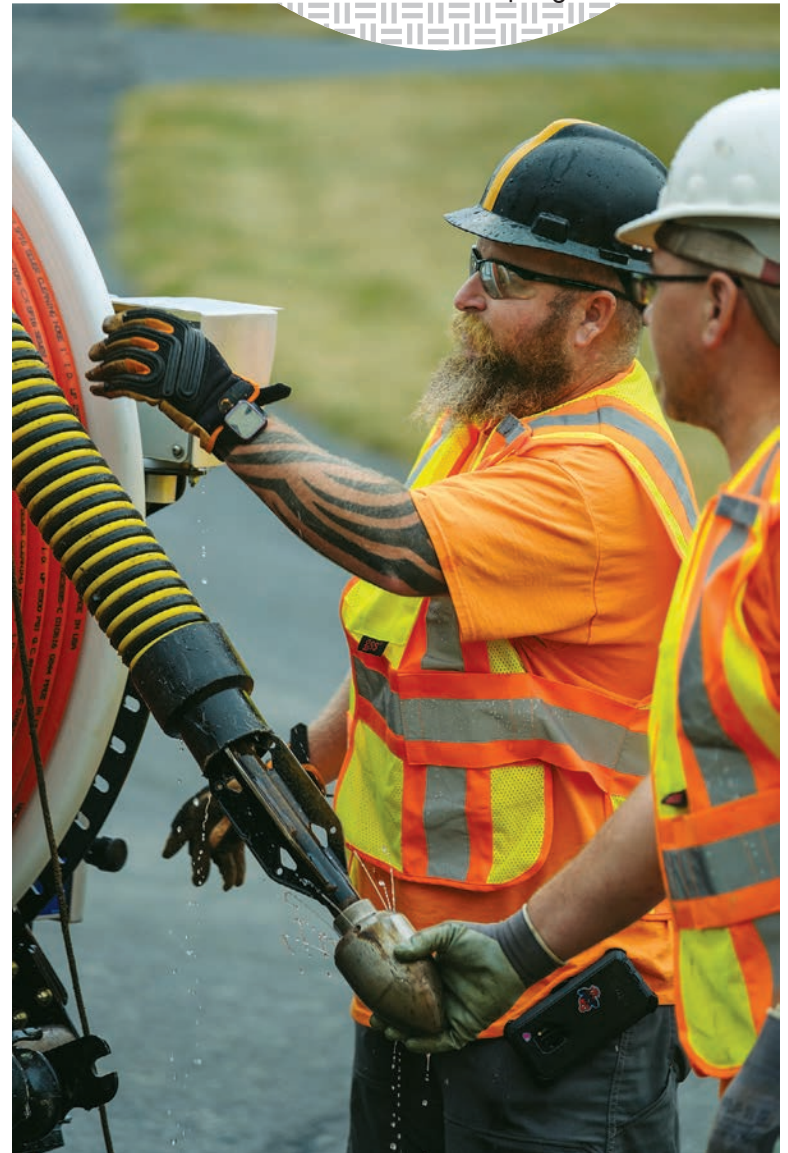
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Hummer (left) and Dice roll up the jetting hose after cleaning a sewer line.



Brandon Dice (left) and Todd Hummer use an RD7100 locator (Radiodetection) to pinpoint the camera's location in a lateral line and mark where they have to dig for repairs.



Dice inspects a leaking manhole.

“Using a variety of tools including technology in conjunction with hydraulic modeling, we have developed a better understanding of the reaction within our sewer system in wet-weather events.”

Sharon Purnell

line during a major storm event. Additionally, we decided to abandon another section of mainline and tie into a newer interceptor.”

The township then used pipe bursting (Doli Construction) to completely replace the defective line. “It went rather well,” she says. In one area, the existing pipe was concrete-encased and had to be dug up and replaced.

Purnell says the Electro Scan technology is user friendly and easy to work with. “We set up our ground and have the electric current we need for the scanning. Electro Scan displays visual graphs to monitor the electrical current, water height and speed. We can look at the results on the run and make intelligent decisions right there on the spot. It’s easy to follow up with our CCTV unit.”

Before, she explains, with CCTV it was difficult for township crews to see defects underwater, but now with the Electro Scan technology, defects are detected in a fully submerged pipe. “We are able to prioritize condition assessments and follow up with CCTV in the worst areas identified. It’s been very useful.”

LOOKING FORWARD

The monitoring, inspection and rehabilitation strategy is enabling Hamilton Township to approach future challenges responsibly and cost effectively.

By getting a better handle on I&I, the township is hopeful it can sustain available capacity for long-term growth, lower sewage treatment costs, avoid penalties for exceeding its capacity allocation at the new Chambersburg treatment facility and police itself against any environmental regulatory orders in the future.

Already, Hamilton has saved money by recognizing pipe conditions that called for replacement or CIPP lining rather than spot repairs and identifying areas that were in better shape than they were thought to be.

Purnell, who has been with the township for 35 years, feels a sense of responsibility to Hamilton and for those who will come after. “We strive to be proactive and prepare for the future, to leave things in the best shape possible, and are doing the best we can.”

Combating I&I is challenging and never-ending. “Reflecting back, a lot has changed over the years, and our I&I efforts and program have come a long way. Using a variety of tools including technology in conjunction with hydraulic modeling, we have developed a better understanding of the reaction within our sewer system in wet-weather events. We have a way to collect and pass information along to the next generation of field personnel in the future.

“Overall, that’s a big benefit to the township and our ratepayers.” **I&I**

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ABATEMENT REQUIRES CONTINUOUS EFFORT

Study suggests ongoing rehab is necessary for significant inflow and infiltration reduction

By Jared Raney

After Nashville (Tennessee) Metro Water Services completed a sewer rehabilitation project in 1996, a long-term study showed that rehabilitation effectiveness decreased 7% over 12 years.

Early results showed 620 million gallons of infiltration, or approximately 35% of inflow and infiltration, were removed annually. At the end of the study, that number was down to about 28%, or 488 million gallons.

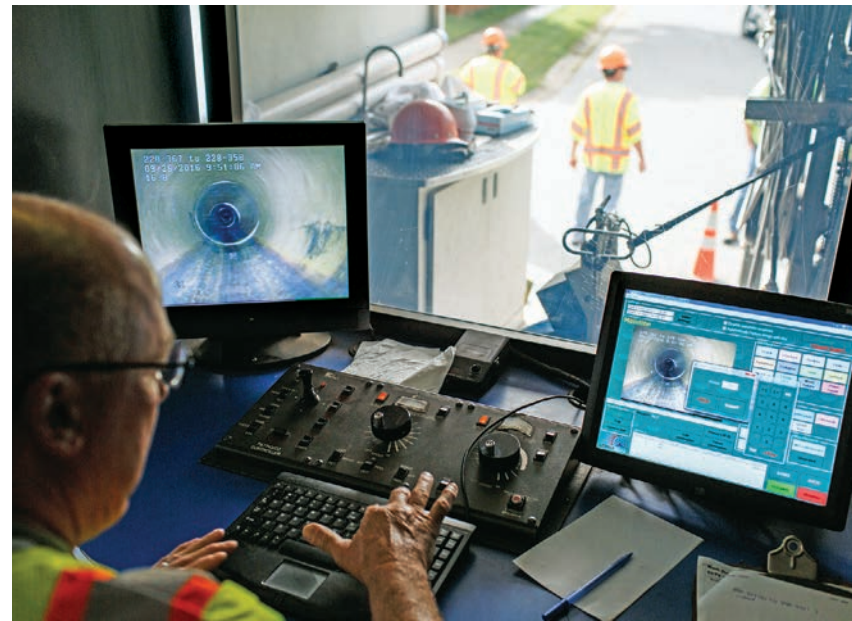
“The results could suggest that the level of effectiveness has deteriorated slightly in the past 10 years,” the study says. “However, it may also reflect the effect of continued deterioration of parts of the system that were not rehabilitated.”

It is important to note that even the later decreased removal numbers maintained the project’s original mitigation goals.

STUDYING LIFE SPAN

The project relied solely on cured-in-place pipe relining and didn’t encompass holistic mitigation, meaning the decrease could also be attributed to the limitations of a single-method approach. That being said, the study did not find any specific or concrete failings of the CIPP rehab.

“At the time of this project, inverting the saturated CIP material into the host pipe resulted in direct exposure of the resin-saturated felt to the inner surface of the deteriorated pipe,” the study says. “Due to the tight fit, and



A study of rehabilitation effectiveness in Nashville found no failings of cured-in-place linings, but did note an overall drop in effectiveness of inflow and infiltration removal over a 12-year span.



The study sought to determine how long rehabilitation products will remain effective for reducing groundwater infiltration as originally designed.

direct resin contact between the host pipe and liner, the follow-up inspections revealed that there were generally no annular spaces for I&I to ‘track down to the next available manhole.’

Taking a regional approach, another factor is that the CIPP rehabilitation only targeted a single area with significant I&I, without addressing larger systemwide concerns.

Entitled *Nashville Project Shows Long-Term Effectiveness of Sewer Rehabilitation for Infiltration Reduction*, the paper’s authors — George E. Kurz, P.E., DEE; Gregory A. Ballard, P.E.; and Leanne B. Scott, P.E. — sought to answer the question “What is the life span for these (rehabilitation) products, and how long will they remain effective for reducing groundwater infiltration as originally designed?”

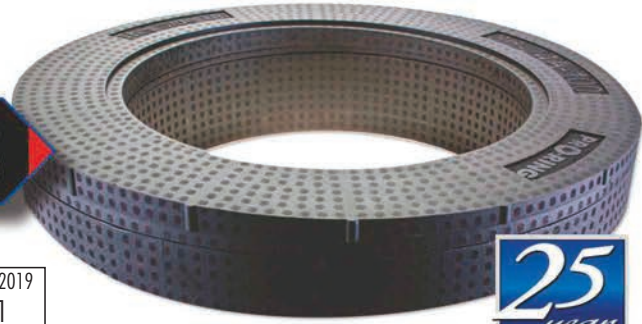
They found that although it is likely the CIPP liner had a reduced effectiveness in the years following its installation, it is unlikely that was the only or even the most-significant factor explaining the drop in removal rates over time.

As this study began in 1996, it also did not take into account I&I additions from system expansions over the decade that it was analyzing.

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Follow-up inspections after the Nashville project revealed that direct exposure of the resin-saturated felt liner to the inner surface of the deteriorated pipe eliminated annular spaces for I&I to migrate down the line.

BUILDING A BASELINE

Data was gathered via three permanent ADS Environmental Services flowmeters installed in 1990, as well as 16 temporary flowmeters installed in various subbasins, gathering data over four separate instances for the scope of the study, which ended in 2007.

Over 50 miles of 8- to 30-inch sewer lines, serving light commercial districts and neighborhoods of expensive older homes, small estates and upscale cluster homes, were part of the rehabilitation effort. It also addressed 315

service laterals. Four separate contracts within the “Sugartree” project relined 42,000 linear feet of pipe, about 15.5% of the overall system.

“The design goal established for the Nashville Overflow Abatement Program was to reduce I&I to a level where overflows in residential or sensitive areas would not occur more frequently than once in five years,” the authors say. “Statistics show that the largest 24-hour rainfall likely to occur at least once in five years is 4.5 inches. Therefore, to satisfy the design goal, the sewer system must convey all flow resulting from 4.5 inches of rain in 24 hours.”

Though the study did not ultimately conclude whether there were issues with the life span or long-term mitigation effects of the particular rehabilitation method under analysis, it did create a baseline to build on in future studies.

“Unsatisfactory I&I reduction following rehabilitation in some communities suggests that the process of groundwater migration from sealed areas to the next available defect is not well understood.”

“Unsatisfactory I&I reduction following rehabilitation in some communities suggests that the process of groundwater migration from sealed areas to the next available defect is not well understood,” the paper says. “This study cannot be considered a conclusive answer ... regarding life-cycle effectiveness of sewer rehabilitation for I&I removal. However, it may illustrate a general approach for conducting additional studies. In particular, the procedures for I&I analysis are critical and should be carefully evaluated for reproducibility and quality control.” **I&I**

By Craig Mandli

SEWAGE AUTHORITY REHABS, PROTECTS MANHOLES WITH POLYUREA COATING SYSTEM

PROBLEM:

The Rostraver Township Sewage Authority in Westmoreland County, Pennsylvania, was struggling to find rehabilitation solutions for its aging sewer system. Time was of the essence, as streets and basements in one particular neighborhood were flooding during every precipitation event.



SOLUTION:

After receiving a sewer system rehabilitation grant, the authority chose **OBIC Products' OBIC Armor 1000**, a multilayer, aromatic polyurea coating system, to rehabilitate several manholes in the affected neighborhood. It offers corrosion protection and chemical and impact resistance, even in subfreezing temperatures — an important consideration north of the Mason-Dixon Line. It's applied in a multilayer process that forms a durable, seamless waterproof membrane, with high abrasion resistance for harsh environments. Advanced Rehabilitation Technology first power-washed the manhole surfaces to remove built-up dirt and debris, then grouted a few areas to stop leaks. Surfaces were then thoroughly dried with indirect heat dryers to finish preinstallation preparation. No bypass pumping was needed, and no surface disruption occurred.

Result: The installation took approximately three hours for each manhole, including prep work, with the total project completed in 2 1/2 weeks. "I was fascinated with the end result," says Ann Scott, Rostraver manager, "in fact, with the ease of installation, the environmentally friendly product ... the entire process."

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MANHOLE CUTTER MAKES HAWAIIAN ROAD REPAIR MORE EFFICIENT

PROBLEM:

Major road construction companies like Grace Pacific maintain Hawaiian roads. These roads have an unusual amount of manholes and water valve structures, which present a problem for pavers. Most paving projects in the islands require milling the road before paving. The milling and paving are much easier if the manholes and water valve structures are removed and steel plated. This process allows the milling and paving machine to operate as if the structures are not there. Not having to work around these structures makes for a much smoother roadway.

SOLUTION:

Grace Pacific purchased the **Mr. Manhole system** for testing on the islands and subsequently made a second purchase. The company currently has two crews performing lowering and raising operations in conjunction with the paving crews. The crews have to maintain traffic during all operations so speed is very important. A typical lowering consists of cutting and pulling the manhole or water valve frame and placing a steel plate. The structure is GPS located, and after milling and paving, it is located and marked. The crews use the same cutting equipment to cut and restore the structure. The crews average about 25 minutes per structure to lower and about 30 minutes to raise a structure.

Result: Grace Pacific has completed 1,200 repairs to date with many more to come.

419-741-9075; www.mrmanhole.com



COMPANY STOPS INFILTRATION EASILY WITH SPOT REPAIR

PROBLEM:

When the Upper Saucon Township in Pennsylvania suffered infiltration in an 8-inch stormwater pipe, they inspected the situation. A leaking joint and small crack in the pipe were the cause. It wasn't a big break, but since the pipe break was directly under a street in a residential neighborhood, digging up and replacing the pipe would have taken a significant amount of time and caused substantial disruption for the residents.



SOLUTION:

The township determined that for small breaks, patch repair was a suitable solution. The 4-foot spot was repaired using the **ShortLiner system** from **Trelleborg Pipe Seals**, consisting of silicate resin and corrosion-resistant fiberglass mats. Free of VOCs and styrenes, the silicate resin is odorless and completely harmless to users.

Result: The 4-foot repair went in easily and upon inspection, and the result was smooth. Infiltration was stopped and with it the cost of needlessly treating groundwater and stormwater at the plant.

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Candle produces a volume of 40,000 cubic feet of smoke in just three minutes. Multiple W3C Smoke Candles can be used together to create larger volumes of smoke visible for longer periods of time. The company's fluid systems offer a liquid-based alternative for mainline sewer inspection and feature a stainless steel injector to maximize dry smoke output, producing a higher-quality, liquid-based smoke. Superior Smoke's testing techniques were developed over 60 years ago and are still made in the U.S.



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ADJUSTABLE RISERS KEEP MANHOLES AT GRADE

PROBLEM:

With a population of 66,000, St. Charles is Missouri's ninth-largest city and was the state's capital from 1821 to 1826. "We have old and new areas, which means we have a lot of odd-sized sewer structures," says Cory Rackley, lead equipment operator. "Adjustable risers make it much easier to raise all these differently sized manholes to grade."

SOLUTION:

Since 2008, Rackley has been using **Pivoted Turnbuckle Adjustable Manhole Risers**, made by **American Highway Products**, to raise manholes precisely to grade without excavation, significant traffic closures, and the need for equipment to lift and set heavy concrete rings. The riser is a sturdy, flexible, galvanized ring made with steel that uses a turnbuckle to adjust riser diameter. Installation is simple and fast; one man sets the riser in the original utility rims and uses a screwdriver as a lever to expand it to fit. Since the turnbuckle leverage applies thousands of pounds of force, the riser seats in the rim tightly, providing a new rim for the manhole with no rattling or looseness. When installed properly, Rackley has never seen one fail.



Result: At-grade risers are better for roads in many ways. They don't set low, so water doesn't collect around the manhole lid causing excessive infiltration; and they don't set high, so vehicle tires don't jar the lid and rim continually. And since risers are usually set just before paving runs, the newly raised manhole is surrounded by new, contiguous pavement, and that prevents water and freeze-thaw damage in the pavement around the manhole.

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(continued)

SMOKE TESTING EMPLOYED ON SANITARY SEWER WITH MULTIPLE I&I ISSUES

PROBLEM:

As a member of the East Bay Municipal Utility District, the city of Berkeley, California, is currently under a consent decree to identify and remove significant inflow and infiltration from its sanitary sewer collections system. National Plant Services is under contract with the district to provide inspection and assessment services for all satellite communities. To provide sanitary sewer smoke testing services for the city's Phase 7 work, National Plant Services contracted with BlueWater Solutions Group.

SOLUTION:

BlueWater conducted smoke testing on over 140,000 linear feet of sanitary sewer utilizing the **30-L Fluid Smoke System** from **Superior Signal**. This smoke fluid system was essential on this project during the testing of several large-diameter gravity mains. Due to the available capacity within the mains, it typically took several minutes for smoke to emit from sources. In total, 102 I&I sources were identified, including 33 private and 69 public sources. The city has a private sewer lateral ordinance where any I&I sources identified on private property are required to be repaired.

Result: For each property where an I&I source was identified, a smoke testing return record was created and mailed to the property owner with follow-up instructions on how address the issue. Each return record included the property address, date and time of testing, photos of the front of the property with address, close-up photo and detailed sketch of the source.

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CONSTANT ROOT-INTRUSION PROBLEM FIXED WITH CIPP SOLUTIONS

PROBLEM:

The Family Plumber in Los Alamitos, California, had a longtime residential customer who was having a yearly issue with root intrusion. The city got involved, as the problem was spilling into the city sewer. A camera inspection determined that 75 feet of 4-inch cast iron was getting brittle and couldn't handle more cleaning. The homeowner had two options: dig up the yard and be without water for at least a week, or reline the pipe. After consulting the plumber, relining the pipe was chosen as the best and most economical solution.

SOLUTION:

The Family Plumber wanted to add CIPP as a service, and this was their first job. With **Pipe Lining Supply's** trained technician, they did on-the-job training. They dug a small access point in the yard, using a Renssi high-speed cable machine with a 4-inch chain knocker to prepare the pipe. They then used a 4-inch green calibration tube as a preliner since there had been lots of rain and groundwater infiltrating the pipe. They used the **Quik-Shot System**, a portable 70 cfm compressor, 4-by-3-inch embossed liner, Quik-Pox 60 resin, and hardener. To cure the liner, they used the Quik-Heater. The entire job took four hours to complete.

Result: After final city inspection, both the homeowner and city were impressed with the completed job. The homeowner saved money and helped ensure against roots in their sewer line in the future.

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After street work resulted in flooding issues near an intersection in Chattanooga, Tennessee, local business owners teamed with the city to install permeable pavers that alleviated the problem.

KEEPING STORMWATER OUT OF THE SYSTEM

Chattanooga's use of permeable pavers solves a flooding problem and sets an example

By Kevin Earley

The problem of excessive storm runoff has a lengthy history for the city of Chattanooga, Tennessee. The antiquated water drainage system, which combines the city's sewer system with its storm drains, poses ongoing challenges for city planners and engineers.

Common in many older municipalities, the simple system does its job until a torrential downpour, which overstrains the capacity of the treatment plant and causes overflow of raw sewage into the Tennessee River, a haven for outdoor enthusiasts and a source of drinking water for communities across the Southeast.

Due to updated 2014 mandates by the Environmental Protection Agency to reduce overflow, Chattanooga instituted multiple stormwater management programs, including a requirement for all new builders to capture rainwater before it enters the sewer. One of the ways they're doing that is through the use of permeable interlocking concrete pavement.

The role of PICP in water abatement reflects an industry paradigm shift. It's a solution to water management that works with the existing system. Realistically, cities across the country will have to replace outdated sewer systems in the decades to come, but the time and cost involved is astronomical and will most likely have to be done in increments. PICP systems offer viable long-term options that not only solve water runoff problems, but alleviate the strain on besieged sewer systems.

IMPROVEMENT PLANS

In 2011, Max Poppel and Dan Rose opened The Crash Pad, a boutique hostel for adventure travelers located on Johnson Street's south side. In 2013, as the travel refuge became increasingly popular, the pair decided to expand their enterprise by building a restaurant/bar on the adjacent property. But before finalizing plans for the restaurant, dubbed the Flying Squirrel, the partners had to overcome a major obstacle. Chattanooga's old-style sewer



system, along with recent repaving efforts, had resulted in a temporary flooding problem that created ankle-deep pools at the intersection of Johnson and Passenger streets.

The partners asked city officials for some possible solutions, one of which was a straightforward partnership proposal: Poppel and Rose would pay for PICP to completely resurface Johnson Street. In turn, the city would handle the entire installation. The proactive plan would eliminate the flooding, address the intersection's structural issues and meet the city's stringent stormwater management requirements for new construction.

"The cost of the pavers roughly corresponded to the amount of street improvements we were going to have to do anyway," Poppel says.

"There have been zero problems with rainwater. The water goes right through the surface of the pavement, gets underground and is held there."

Mark Heinzer

After a careful vetting process, Belgard permeable pavers manufactured by Adams Products in Rockwood were chosen for this pilot project. The pavers are specifically designed to manage water runoff while creating an aesthetically pleasing road surface with a herringbone pattern and curb-free design.

"The stylish look gives it a European feel," Poppel says. "We had always envisioned an active, approachable street with plenty of room for pedestrians and bikers."

STOPPING THE FLOOD

Mark Heinzer, engineering manager for drainage and flood control for the city, has been at the forefront of implementing environmental changes for water management.

“The use of PICP helped meet the redevelopment stormwater requirements and avoid the cost of installing stormwater management infrastructure directly on the proposed site.”

Darryl Sapp

He was involved in the Johnson Street retrofit project from its onset and recalls that the endeavor was a launching point for the city’s PICP initiative. Heinzer notes that the Johnson Street project delivered a dual service to the area by creating an appealing and versatile new road surface that solved an existing drainage problem.

“It captures that excess water at its peak, reducing the potential for overflow, and the road structure has maintained its integrity,” Heinzer explains. Nearly six years after installation of the pavers, the engineer reports, “There have been zero problems with rainwater. The water goes right through the surface of the pavement, gets underground and is held there. We’ve had absolutely no problems since the project with any kind of flooding.”

Darryl Sapp, Adams Products’ commercial consultant, explains the structural ingenuity that has allowed the Johnson Street makeover to remain in top condition and flood-free years after construction.

“The permeable pavers allow for rainwater to be captured before entering the sewer system,” Sapp says. “The water passes directly through a wearing surface into an underlying stone reservoir that temporarily stores the surface runoff before infiltrating into the subgrade soil.”

This is a stark contrast to the street’s previous traditional blacktop, which allowed no water absorption and created runoff problems during heavy rainfall.

“The use of PICP helped meet the redevelopment stormwater requirements and avoid the cost of installing stormwater management infrastructure directly on the proposed site,” Sapp says.

In addition, the paver system has proven much more cost-effective than traditional blacktop pavement. Potholes are now a thing of the past, and underground maintenance issues are vastly simplified. Heinzer cites the example of a recent waterline break that occurred beneath Johnson Street. “The Belgard PICP pavers were removed, the broken line was fixed and the pavers were repositioned.” If the road had still been blacktopped, jackhammers would have been required to tear up the pavement and the road surface would have had to be repaved after the fix. The permeable pavers saved time and money and avoided a noisy, messy repair on the bustling street.

AWARD-WINNING DESIGN

The Johnson Street retrofit project has been widely acknowledged for its innovative stormwater design solution to address urban flooding. The Crash Pad became the first hostel in the world to attain LEED Platinum certification for implementing green building design. In addition, Rose and Poppel were awarded the Tennessee Governor’s Environmental Stewardship Award in 2014 for excellence in green building for their contributions to the project — a high honor for a pair who went into business with the goal of “supporting our climbing and sushi habits.”

Due to the success of the Johnson Street retrofit and similar projects, the city of Chattanooga has endorsed PICP as a low-impact development solution to capture stormwater before it enters the sewer system. In addition, the city has developed an incentive program for property owners who replace asphalt parking lots with PICP.

Belgard’s permeable pavers have played an integral role in Chattanooga’s Johnson Street retrofit project. Six years after installation, the roadway serves as a thriving prototype for future designs.

ABOUT THE AUTHOR

Kevin Earley is a LEED Green Associate and a contributor to the American Society of Civil Engineers’ Permeable Pavement manual and current permeable paver design standards. **I&I**



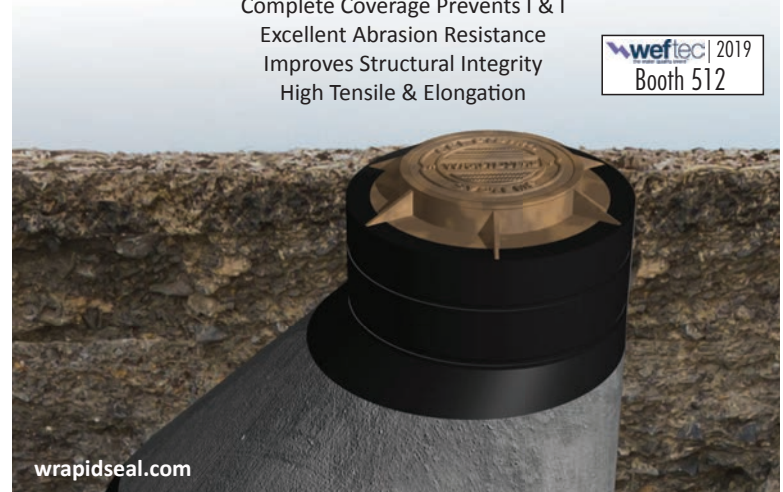
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LONG-TERM SOLUTIONS, AND SAVINGS

A holistic approach to rehabilitation proves more cost-effective over time

By Jared Raney

Picture a pipe with three cracks in it: Two are small, and only one is large enough to let in a significant amount of water. Many would say, “Fix the large crack because it will be cheaper than fixing all of them, and it should stop the majority of intrusion.”

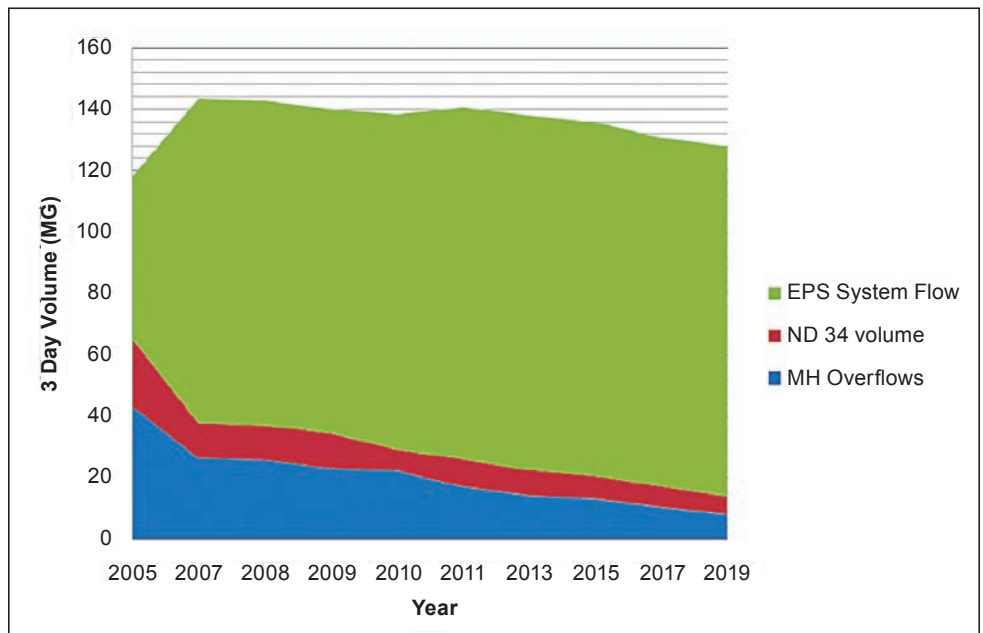
But after fixing only the large crack, you find that water is still getting in, and even worse, the two previously small cracks are deteriorating even faster than before.

Now scale that concept up to an entire collections system and you have the principal finding of a long-term study in New Castle County, Delaware, by environmental consulting firm Malcolm Pirnie (a division of ARCADIS).

“The overarching rehabilitation philosophy has been one of holistic rehabilitation, to offset the migration of water within the pipe bedding to the next-easiest point of entry,” according to the white paper, *Rehab Effectiveness – Why Holistic Rehab is Required for Significant I&I Reductions*.

Simply put, if you plug one hole, the water will just go to the next, unless you address all the issues within a given segment.

“Migration of water within the pipe bedding to the next point of entry makes it extremely difficult to get



Results of dry weather analysis in one project area shows that reductions for all parameters are very close, indicating the entire diurnal curve has shifted downward, which is a strong indication for the effectiveness of the rehabilitation process.

“Migration of water within the pipe bedding to the next point of entry makes it extremely difficult to get significant reductions by rehabilitating a pipe here and a pipe there.”

significant reductions by rehabilitating a pipe here and a pipe there,” the paper says.

And that idea doesn’t just apply to individual pipes. The same principle can apply across basins and even entire systems. If only conducting mainline or manhole rehab without addressing laterals, I&I can simply end up impacting another area of the system and causing more damage as a result.

“Experience, review of work by others, and discussions with others in the industry have led us to the conclusion that piecemeal rehabilitation does little to actually reduce flows or volume,” according to the paper’s authors, Paul Batman, Jim Shelton and John Paul Travis. “In fact, it was noted during an early rehabilitation project that rehabilitation of the mainlines and laterals actually increased leakage in the adjacent manholes.”

MITIGATION PLAN

Malcolm Pirnie collected pre- and post-rehabilitation flow data over several years across at least five individual projects and compared them to untouched “control” areas. The study compared projects that addressed singular rehabilitation efforts and combined methods.

New Castle’s reduction program covered the 400 miles of sanitary sewer main in its Brandywine Hundred Basin — nearly a quarter of the overall system. Such a large endeavor required careful consideration of which methods to use and when.

They hired Malcolm Pirnie to develop the rehab program and do the evaluation, with the goal of assessing early projects to increase efficiency as they continued working through the system. They performed a life-cycle cost analysis to optimize funding, which meant using minimal repair methods in pipes that were in good shape overall, despite leakage.

“The objectives of the rehabilitation effectiveness monitoring for these projects are to confirm that completion of each rehabilitation project results in significant I&I reduction, and also to quantify the effectiveness of the

rehabilitation methods selected, in order to better predict flow reductions over the long term of the program, and optimize the selection of rehabilitation methods for future projects,” the paper says.

They determined that over the life of the project, holistic rehab was the best way to achieve significant reductions and provided the best bang for their buck.

For example, many I&I mitigation projects ignore private-side infiltration. While the paper acknowledges that there are times when the logistical challenges are insurmountable, it also found that private-side projects are often the most cost-effective.

“The reductions from sump pump disconnections are very high, particularly considering the low costs involved compared to the cost of pipeline rehab,” the paper states. “For a system exhibiting significant inflow sources that aren’t found by smoke testing, an intensive sump pump identification and disconnection program is likely a very cost-effective solution for I&I reductions.”

“The reductions from sump pump disconnections are very high, particularly considering the low costs involved compared to the cost of pipeline rehab.”

GOING HOLISTIC

One significant change that New Castle County made during this time was to alter its bidding approach. Instead of hiring a single contractor to manage the entire scope of an I&I mitigation project, they decided to break their contracts into individual specialties. This gave them the ability to demand more stringent specs for the work and allowed for greater oversight.

“Most rehabilitation contractors specialize in one or two technologies and are not equipped to properly manage the number of subcontractors necessary to perform a wider variety of technologies,” the paper says. “It has forced rehab contractors, who are typically used to just ‘doing it like we always have,’ to pay much closer attention to their workmanship in the field, to provide quality and consistency in the products.”

The paper also says prices have increased slightly to reflect the new procedure but that so far it has been worth the cost, and contractors have “learned to meet the expectations, and are providing a higher-quality product as a result.”

A subbasin dubbed Talleybrook best demonstrates the efficacy of holistic rehab — it was rehabbed under the new technology-specific contracts, which allowed Malcolm Pirnie to compare methods as they were performed in isolation. They found a statistical indication that mainline grouting performed without lateral connection grouting had little impact on I&I reduction, compared to the combined effect.

The paper concludes, “For those planning or considering rehabilitation for I&I reduction, it is important to stress that the application of rehab technologies should be done systematically and holistically in order to achieve the best reductions.” **I&I**



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FIGHTING THE RAIN

Connecticut utility tackles problems with porous interceptor pipe

By Pete Litterski

The Berlin (Connecticut) Water Control Commission's wastewater collections system is back in top form with the completion of a \$2.2 million inflow and infiltration project that included relining 9,700 feet of interceptor ranging from 12 to 18 inches.

The project took a few extra months to complete thanks to an unusually rainy stretch of weather, but Ray Jarema, water production manager, says the town's system is much improved.

Jarema, who oversees the operations of the commission's freshwater production and distribution, as well as the town's wastewater collections system, says that the interceptor, which includes a key stretch through a wetlands area, had shown signs of "significant leakage" but was not at a critical stage. The line is part of a system that was first installed in the semirural town in the 1970s. An engineering firm was hired in 2017 to study flows and inspect the interceptor with cameras.

"We looked at this more as preventive maintenance. This part of our system hadn't been touched since the 1970s."

Ray Jarema

"We looked at this more as preventive maintenance," Jarema says. "This part of our system hadn't been touched since the 1970s."

Although many property owners still use onsite septic systems for their wastewater, Jarema's department oversees 37 miles of sewer lines and 10 pumping stations that collect approximately 1 billion gallons of wastewater per year and delivers it to the Mattabassett District Water Pollution Control Facility in neighboring Cromwell. That treatment plant processes wastewater from New Britain, Berlin, Cromwell, Middletown, Newington, Rocky Hill



Ray Jarema oversees the operations of the Berlin Water Commission's wastewater collections system.

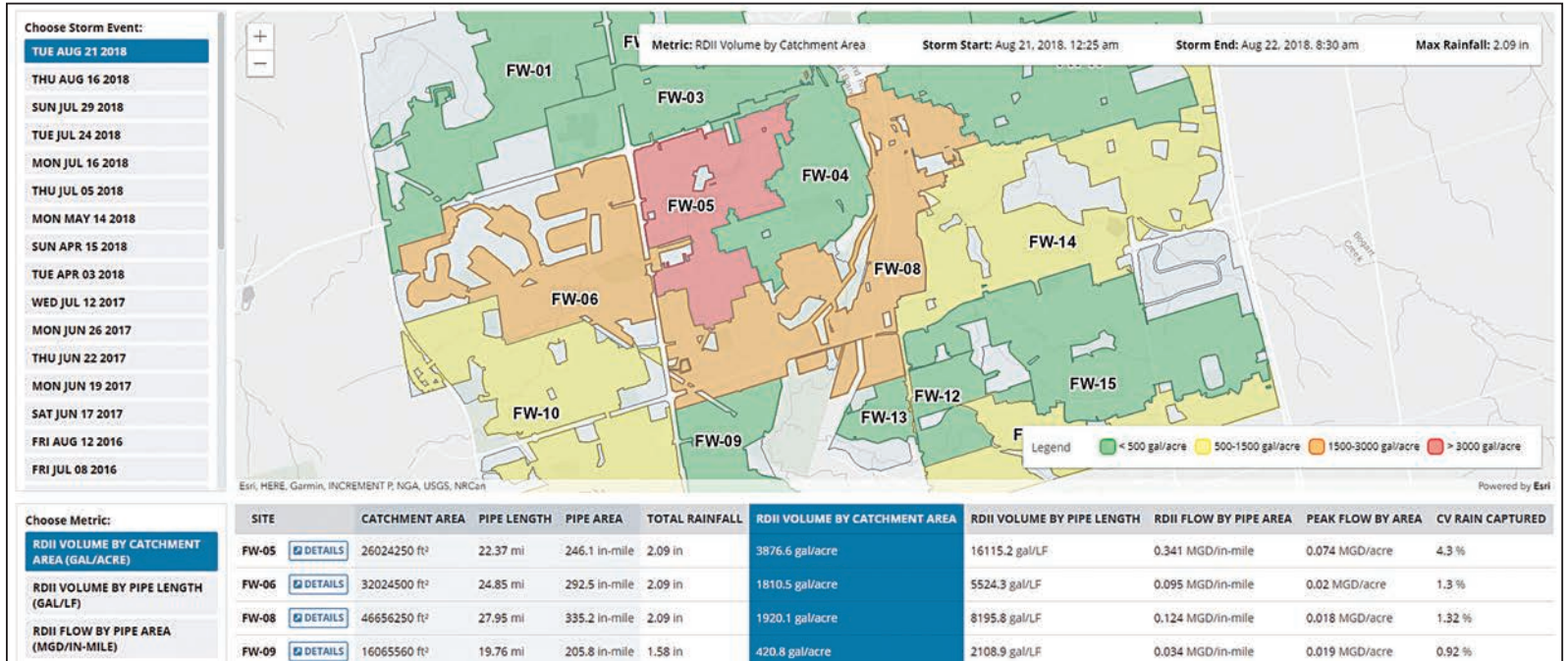
and Farmington before discharging treated effluent into the Connecticut River. While the Mattabassett District brings a large part of the Hartford region under one umbrella for water and sewer services, in the town of Berlin, the Berlin Water Control Commission is just one of three agencies serving the public.

Berlin's interceptor project was funded through the Connecticut Department of Energy and Environmental Protection, which provided a 20-year loan at 2% interest, as well as a \$20,000 grant to help pay engineering costs.

Cardinal Engineering Associates of nearby Meriden handled the I&I study and the design for the relining of the interceptor. The contractor for the project was Michels, which has two Connecticut offices.

Jarema says that despite the weather that pushed the relining into colder weather, the results were good and the project "wound up well within budget."

Although a neighboring utility had recently run into problems with the curing of its relined interceptor project, Jarema says the process went smoothly for Michels' crews in Berlin. The manager cites the engineers' decision to specify hot-water curing rather than steam deserves some of the credit because it gave the new linings more time to cure. **I&I**



Infinitii I&I is a web-based software tool that can help pinpoint areas for immediate investigation after a storm event and provide insight into historical trends that can indicate areas of aging infrastructure in need of upgrade.

IMMEDIATE ANALYSIS

Software tool provides real-time data on wet-weather response of sewer systems

By Kimberly Bruce and Mike McDonald

Extreme weather has caused \$3 billion in flood damage in the Midwestern U.S. alone so far in 2019, putting significant stress on sewer systems.

A combination of fluctuating and extreme wet-weather patterns and aging infrastructure is causing problems with wastewater collections systems across North America like never before. As hundred- and even thousand-year storm events increase in frequency, a holistic understanding of systems and their capacity is needed to plan proactively and ensure property and assets are protected.

FlowWorks Inc. (Carl Data Solutions) Infinitii I&I is a tool for the wastewater management industry that uses machine learning, advanced analytics and statistical analysis to provide ongoing, real-time data on the wet-weather response of sewer systems. Using automated tools that are built on proven methods of storm event and inflow-and-infiltration analysis, this web-based software provides timesaving calculations that can help pinpoint areas for immediate investigation after a storm event and provide insight into historical trends that can indicate areas of aging infrastructure in need of upgrade.

Each automated feature of this software allows users to convert their projects and studies into a manual form that allows the data to be manipulated and exported to a CSV file.

“I&I management is an important long-term initiative that should be continually supported by reliable and timely monitoring data.”

Dave Matsubara

PILOT STUDIES

Currently, there are seven municipalities across Canada and the U.S. piloting FlowWorks Infinitii I&I. In March, the city of North Vancouver, British Columbia, became the latest municipal partner to pilot this software.

“I&I management is an important long-term initiative that should be continually supported by reliable and timely monitoring data,” says Dave Matsubara, the city of North Vancouver’s infrastructure engineer. “Having real-time I&I analysis updates will be valuable for us as a small municipality. Our current team can evaluate our infrastructure and further characterize storm events that are driving I&I so we can target potential problems and prioritize new projects.”

(continued)

Infinitii I&I is designed to work on a real-time monitoring platform that provides web-based GIS maps of the locations of sensors and devices, and access to their data. The FlowWorks platform connects to any sensor or data source and provides tools for historical, real-time and predictive analysis of environmental data. This platform has been used by dozens of North American municipalities over the past 12 years to provide immediately accessible data in a variety of intuitive graphical representations.

INPUT SOURCES

A network of sensors that include flow monitoring devices and rain gauges are needed to provide the data for the I&I analysis. I&I quantification begins with accurate, reliable and repeatable sewer flow data. "Flow data" is defined as continuously recorded, electronic, time-series sewer flow. A pilot project can be initiated with three months to a year of monitoring data, but large amounts of historical data can be accommodated and actually enhance the performance of the software's machine-learning-enabled features.

The dashboard provides a color-coded map view of the different catchments being monitored. A catchment has at least one flow device and rain gauge associated with it. Its size is defined by the municipality's operations team. Thresholds then can be set to indicate when there is an I&I event, and the area will be colored green, yellow, orange or red with increasing severity.

The Storm Event Finder feature uses the amount and duration of rainfall to automatically define the date and time of a significant storm event. Machine learning is built using linear regression models to help define the 15 most significant storm events. Time parameters can be set to specify periods of time, such as seasons, where significant storm events relative to that time can be found. This enables fast identification of storms for I&I studies and is useful for engineers who must study a variety of storms to ensure accuracy in their studies and reports.

COMPARING VARIABLES

Regression is a method of modeling a target value based on independent predictors. This method is mostly used for forecasting and finding out cause-and-effect relationships between variables. Regression techniques

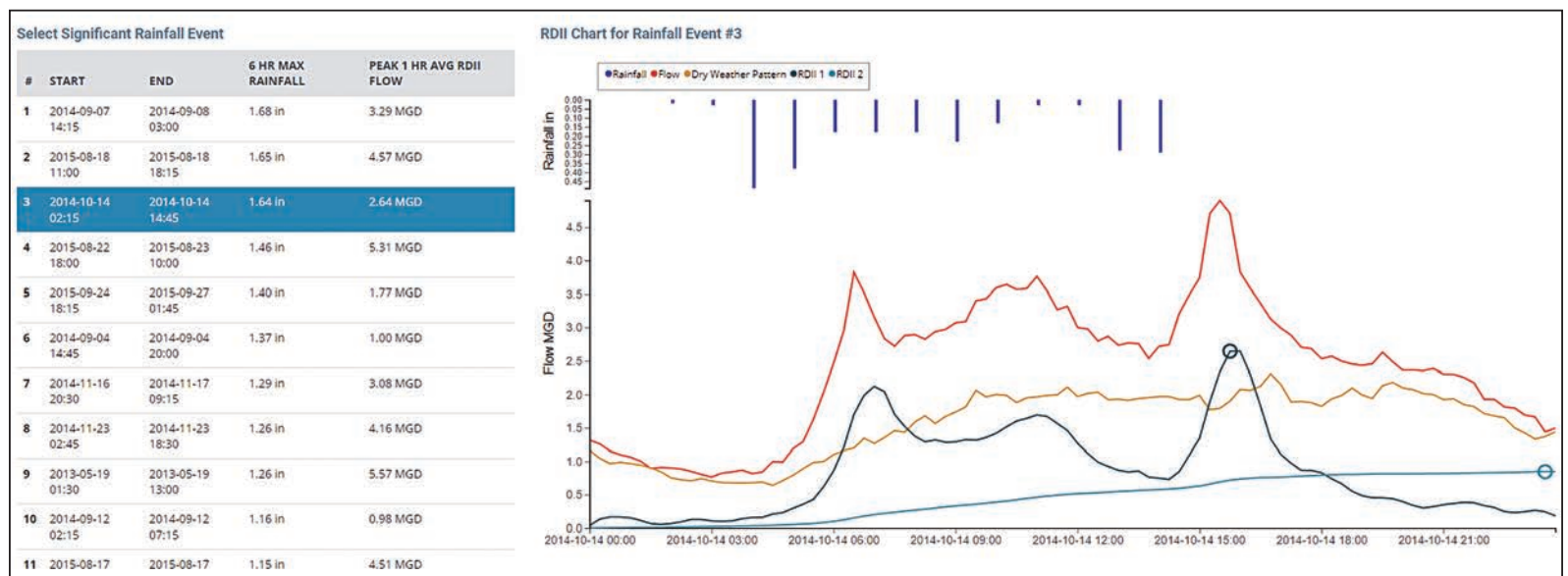
mostly differ based on the number of independent variables and the type of relationship between the independent and dependent variables. Linear regression is a type of regression analysis where there is a linear relationship between the independent (x) and dependent (y) variables.

The Dry Weather Pattern Finder feature predefines an optimized pattern to use when studying a specific storm event. When a project is exported, users can define the dry-weather-pattern parameters and the system will fetch the data. It also allows users to quickly build their own dry-weather patterns. Select several dry days and the system will average them out to determine the pattern for a single dry day.

Infinitii I&I uses the I&I Envelope Method for analysis in the application since it is relatively easy to apply to collected data and provides a means of normalizing I&I results. It is an economical and practical method of standardizing I&I analysis. This graphical method is based on a summary of rainfall and sewer flow data from flow monitoring. By plotting these results, a



Real-time I&I analysis updates can help utilities evaluate their infrastructure and further characterize storm events that are driving I&I.



The real-time monitoring platform provides web-based GIS maps of the locations of sensors and devices, and access to their data.



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With Infnitii I&I, utilities can immediately see where and how I&I was a factor during storm events without having to crunch numbers to understand the significance.

relationship between rainfall and rainfall dependent I&I can be developed. The purpose of the I&I Envelope Method is to use a collection of recorded storm events to create a correlation between the amount of rain that falls in a catchment and the amount of I&I that shows up at the flow monitoring site.

The FlowWorks RDII features automatically generate a Correlation Graph for a selected catchment site. For each catchment, you choose the Flow Channel, Dry Weather Pattern, Rainfall Site or Storm Event Group RDII Charts/Correlation Graphs. The user can toggle between Correlation Graph view and

RDII Chart view at any time. As with all Infnitii I&I analysis features, data can be exported to view all values associated with each chart, graph and calculation. In future iterations, features like Catchment Age Relationship Analysis could be developed into the Infnitii I&I tool.

Alan Tse, M.Eng., P.Eng., from the consulting firm Kerr Wood Leidal has over eight years' experience running a variety of I&I studies. Tse reviewed the Infnitii I&I tool and says he found it very useful after a significant storm event, especially when flooding occurred. "After any flooding event, the question anyone asks is, 'Why did it happen?' With Infnitii I&I, you get a preliminary idea of when, where and how I&I was a factor. And there are already numbers and data to work with instead of rushing to crunch numbers to understand the significance of the storm event in relation to the sanitary system."

**"After any flooding
event, the question
anyone asks is,
'Why did it happen?'"**

Alan Tse

Infnitii I&I helps save engineers and operations departments hours of preliminary work, providing insights any time, so that municipalities don't need to wait years between their I&I studies and can have a more forward-facing approach to infrastructure planning. As technologies like Infnitii I&I help to improve the efficiency of sewer systems and affordability of real-time monitoring, municipalities and consulting engineers will continue to gain more value from their growing infrastructure monitoring networks and environmental data. **I&I**



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