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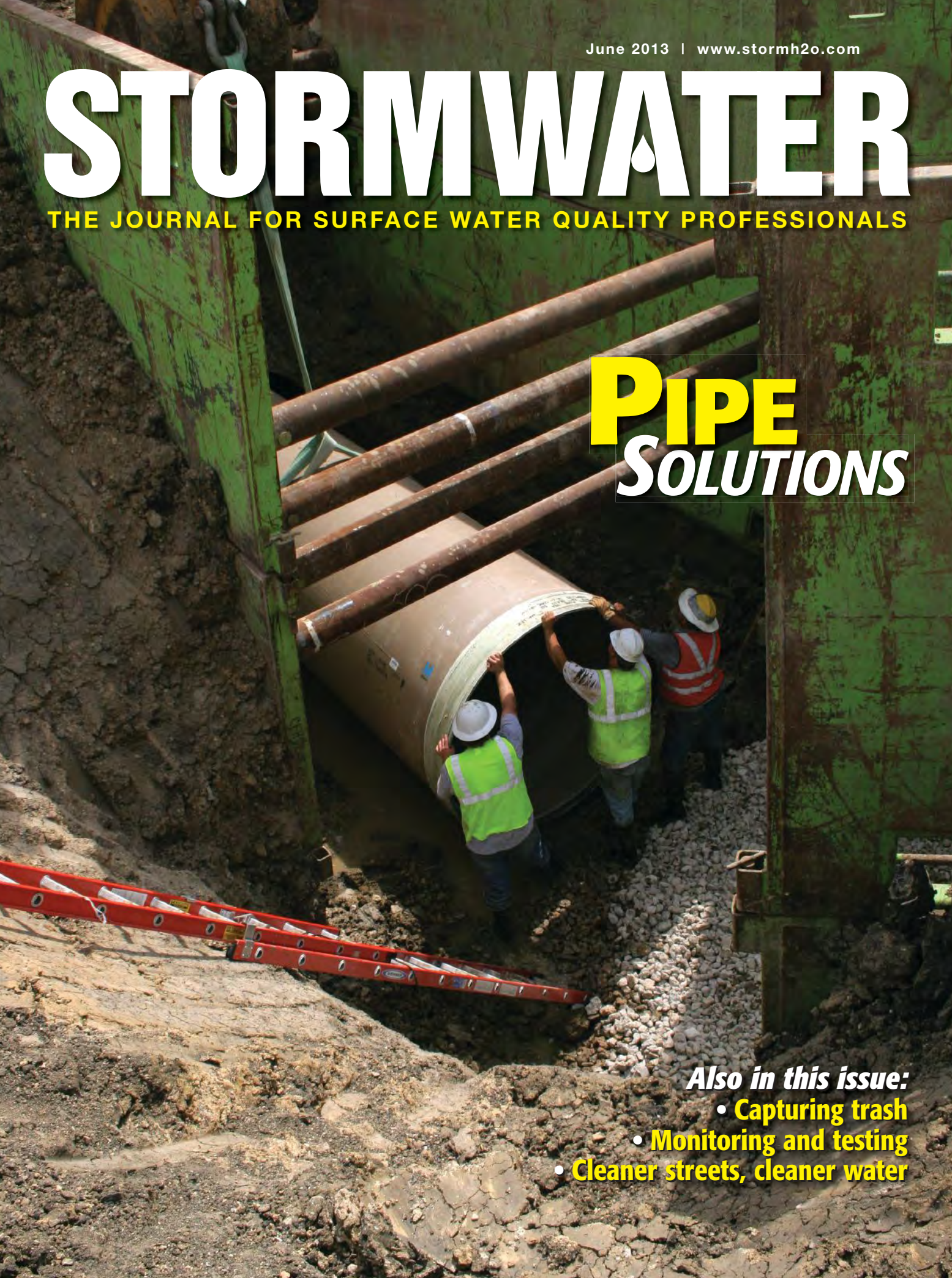

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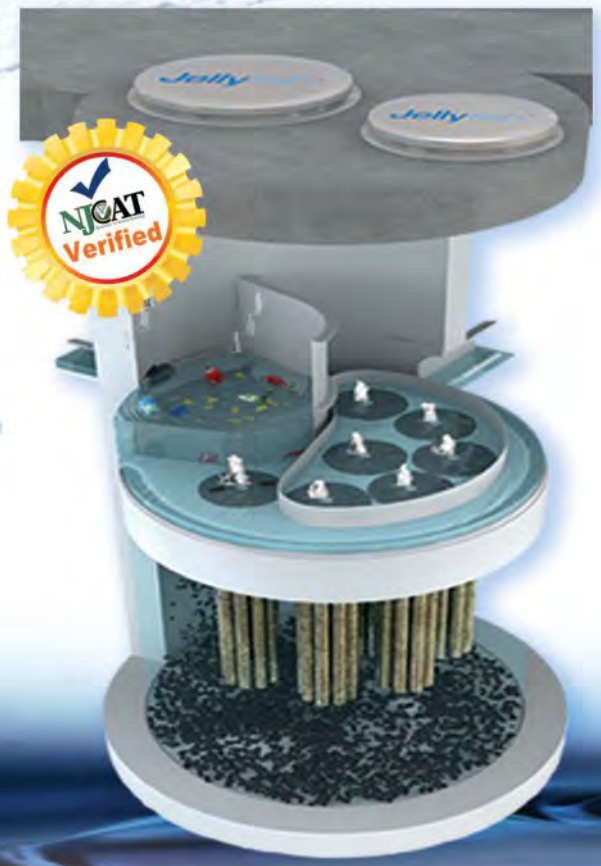

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A National Report Card for Streams

BY JANICE KASPERSEN

As stormwater professionals, much of our work is focused on local water bodies: how our programs are affecting, for better or worse, the nutrient levels in a local lake, or the number of days the local beach is closed because of high indicator bacteria counts. In areas that have total maximum daily loads in place for a large body of water—the Chesapeake Bay, for example—we're also concerned with the efforts of those closely surrounding us.

Every so often, though, it's useful to step back and look at the bigger picture. How are the nation's waters doing collectively? Are our policies and practices producing the results we want?

EPA's National Rivers and Streams Assessment, released in March, lets us do just that. The data are from a survey conducted in 2008 and 2009, the most recent nationwide information available; more than 2,000 sites across the country were sampled. The news isn't particularly good: Overall, the report shows 55%, or about 659,788 of the 1,193,775 stream miles sampled, are in "poor condition" to support aquatic life. But the more detailed information the report contains provides useful clues as to what we're getting right, and what needs work.

High nutrient levels are most pervasive problem. According to the survey, 27% of streams have excessive levels of nitrogen and 40% have excessive phosphorus. Major sources of nutrients are fertilizers from landscaping, golf courses, and agriculture. While golf courses and landscaping in urban and suburban areas must be in compliance with the Clean Water Act, agriculture is exempt and so will likely remain a major source of water pollution until that is addressed.

Nearly a quarter of streams and rivers, roughly 271,000 miles, suffer from "decreased vegetation cover and increased human disturbance," a broad category that leads to several different problems—making streams more likely to erode, allowing more pollutants to reach the streams, and increasing water temperature. The good news here, though, is that the national Construction General Permit released in February 2012 begins to address this problem. It requires a 50-foot natural buffer between construction activity and surface waters. In cases where that isn't possible because of a narrow right of way, it calls for added erosion and sediment control measures to achieve a reduction in sediment load similar to that of a 50-foot buffer. Although the national CGP applies directly only in the states that don't have their own CGP, most states look to it when revising and updating their own, so these provisions are likely to be widely incorporated.

Other findings from the survey: about 9% of streams and rivers have high levels of bacteria, and in 13,000 miles of rivers—a little over 1%—fish show excessively high levels of mercury. Atmospheric deposition of combusted coal is the only source of mercury in most watersheds, and burning coal is the primary mechanism for getting it into the atmosphere. And 15% (177,493 miles) of streams suffer from excessive streambed sediments—a respectable number, when you consider that just a few years ago EPA ranked sediment as the number one surface water pollutant.

You can find a copy of EPA's draft report, including results for different geographical areas, at **www.epa.gov/aquaticsurveys**.

that's a lot of green

DC Water will award more than $1 million for design and construction projects that green the District of Columbia.

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Separators for ***State-of-the-Art*** Pollutant Removal

BY STEVE GOLDBERG

Protecting Lake Lewisville

Rural Texas contains a number of what are termed "farm to market" roads, or "FM" for short. FM 720 is one of those roads, located in Denton County, just northeast of Ft. Worth. The Texas Department of Transportation (TxDOT) is in the process of upgrading the roadway because of population growth in the area.

"They're expanding FM 720 from two to four lanes. Where the road crosses Lake Lewisville, there is an existing double-lane bridge over the lake, and TxDOT has proposed a second bridge, another two-lane bridge, that will sit alongside it," says David Rubenkoenig of building materials company Cemex Inc.

"They're installing Stormceptor units, from Rinker Materials, along the bridge. Instead of having one big header pipe, they're putting six units on either side, east and west. It's a Corps of Engineers lake, so they had to obtain Corps approval. Having been in the Corps of Engineers myself, many years ago, I can tell you that they're not that easy to get along with. We didn't even like ourselves," he jokes.

"There are actually a total of 58 Stormceptor products on the road widening project, but 12 of those are the bridge units. The remaining 46 cover the full spectrum of every Stormceptor model that is built, starting with the 450i up to and including the STC 16000, which is their largest unit.

"The existing bridge has six units, and on the new bridge there will be another six Stormceptor units. These units sit atop the bridge bent cap. You have the piers coming up, and the horizontal bent cap, and then there are the beams that sit on the bent cap, and the Stormceptor sits in the smaller spaces on the bent cap, between the tresses on the outer edges of the bridges. It is Stormceptor model STC 450i."

He explains that the tresses are about 5 feet, 3 inches apart. "Those units are modified so that there's just enough space between the tresses for the Stormceptor. It's a 48-inch inside diameter with a five-inch wall, so it's just under 60 inches. It's a squeeze,

but it fits right in," he says.

"There are grated inlets on the top of the bridge, at the curb inlets, and they have some piping that goes into the unit, and then out of the unit, so that this treated water goes right into the Lake Lewisville.

"The Stormceptor treatment devices remove 70% or better of the TSS [total suspended solids] and capture the TPH, or total petroleum hydrocarbons. They will catch and retain the oils that wash off the roadway surface. Once that water is treated and leaves the unit, it's allowed to go right into the lake, via a downpipe."

Because both the existing bridge and the new bridge are essentially the same design, the same Stormceptor configuration will be used for both sites.

Rubenkoenig notes that these units are sized to be cleaned out about once annually, although if there is a spill, he advises cleaning the system immediately.

He adds that the units are designed to deal with a variety of materials. "Any time you drive on a street where it hasn't rained in a while, there are oily substances that drip off vehicles and accumulate over time. When the rain comes along, that sheen comes to the top and makes the street slippery. Whatever has accumulated between rainfall events is washed off with that first flush. The first flush gets most of the pollutants.

"The primary concern is the total petroleum hydrocarbons—greases, oils, drippings off of vehicles, and the like. Basically, anything that is lighter than the trash. It floats, we trap that in the lower chamber. It's trapped by the intermediate insert in the Stormceptor. Then you can pop it out."

Although the Stormceptor units are essentially standalone devices, Rubenkoenig notes, "They do have a grill on these curb inlets. They're about 3 or 4 feet in length, and each bridge has at least six of these, so each of these two-lane bridges has six sub-drainage areas, and each of those drainage areas empty into these grated grills.

"The grates on these grills help stop the trash from going down into the unit. The Stormceptor would actually take the trash, but if it can't get to the unit, that's better. It's easier to take care of the trash from the top."

Koalas in New York

Orchard Park, NY, a well-to-do suburb of Buffalo, boasts Ralph Wilson Stadium, home of the NFL Buffalo Bills. It is also home to the Orchard Park Central School District, which consists of four elementary schools, a middle school, and a high school.

The school district recently decided to build an additional bus garage, which necessitated the installation of stormwater controls. The district contracted with M/E Engineering for the project.

For its existing bus garage, the school district had used an earlier product from Buffalo-based Environment 21, manufacturer of a variety of stormwater products. The company's Dino Pezzimenti was asked to make a

recommendation for the new garage.

"I recommended the ESK Koala and sent the engineer all the information required. He contacted the New York State DEC [Department of Environmental Conservation] for their approval because he liked the product."

After receiving approval from the DEC, the engineer specified use of the ESK Koala, and the contractor purchased the product.

According to Pezzimenti, two of the units were installed late in the summer of 2012. "The main thing is that they needed something that met EPA requirements, and this product will do that easily," he says. "The EPA requirements are 15 parts per million [ppm] for 20-micron and larger oil droplets. That's the release limit. Our unit was independently tested even better than that, down to around 2.5 ppm for oil droplets that size. But we market it at five ppm, as a safety factor."

Primarily, the district was concerned with minimizing release of hydrocarbons from the site, in particular oil and liquefied greases. Pezzimenti explains why he considered the ESK Koala unit ideal for this project. "This product is a high-efficiency oil/water separator. It achieves the same or better release levels as other oil/water separators, but it's a lot more compact and a lot less expensive. So instead of having to purchase a system with tube separators or lamella plates that get very expensive, or similar products that use the open-cell polyurethane as ESK does that are in huge stainless steel boxes and require a larger vault or manhole, this product does the same thing, but at less cost."

He adds that, in contrast to some systems that are large and bulky, this system is compact and relatively easy to maneuver. "All of them have to go into a concrete structure, but if you discount that, one person could lift it and put it into the manhole. The total system probably weighs less than 50 pounds for this size unit. It will treat up to a couple hundred gallons a minute.

"These units are sized. We have larger models that will treat up to almost 5,000 gallons per minute, at that same release limit. Those are larger and would take probably two or three people to install."

Pezzimenti notes that these units are not part of a treatment train, but are standalone products. "But there should be a grit chamber in front of them, to get any grit out," he says. "With this project, the stormwater, post-treatment, goes to a detention basin, but in some projects it is then directly released into the environment."

Regarding maintenance, he advises, "At least initially, every month or so, the media should be pulled out. It's very easy—there is a bale on top, and you reach down and pull it up. You inspect the media, hose it off if required, then put it back. When the oil level reaches a high enough point, it needs to be pumped out.

They should pump out the entire unit, including any grit or sludge on the bottom, and hydrobrush it a little bit. Make sure it's clean, then put the media back in. The whole process takes probably less than an hour.

"The school district can do this themselves—at least, other than the pump-out and disposal," he adds. "That they would have to contract out to a vendor who has a pumper truck and can properly dispose of the hydrocarbons. But as far as the general maintenance and inspection, the bus garage personnel can do that. This media, if it's taken care of, and if the maintenance is done correctly, will last five years easily."

Installation seems fairly straightforward. "To install it in a manhole, you have to lower it down into the manhole, mark the two holes that have to be drilled to support the outlet pipe, pull it out, drill them, put the anchors in, and bolt it in. It's the same with the inlet pipe," he says. "The whole unit, with the manhole, is dropped into the excavation, and they use rubber couplings to couple it together. The whole evolution to install it into a manhole might take up to a couple hours. It could be installed in the morning, delivered to the site, and all hooked up in less than a day."

Pezzimenti does have a word of advice to installers of the product. "The only thing we have to caution the contractors about is that there is an automatic shutoff valve, a safety oil spill protector, and this is tied in place, in a closed position, for shipping. If the contractor doesn't pull that loose, it's not going to work."

Reducing Nitrogen Levels in Bonita Springs

Together with the Florida Department of Environmental Protection (FDEP) and other agencies and stakeholders, the city of Bonita Springs, FL, participated in the development of the West Coast Basin Management Action Plan in December 2012. The goal is to achieve pollutant load reductions and thereby improve the water quality of the local ecosystem. The community, located about 100 miles west of Miami and 30 miles south of Ft. Myers, has developed a stormwater master plan including a number of stormwater-related projects.

"At this point, most if not all of our stormwater projects revolve around the removal of nitrogen and phosphorus from the water," explains David Liccardi, senior project manager with the city. "With the completion of that action plan, the FDEP has recently set standards for removal of nitrogen, and the city of Bonita Springs was provided with removal allocations to remove 'X' number of pounds of nitrogen per year, in order to reduce nitrogen levels in the Imperial River.

"The nitrogen comes from a number of sources. A good part of it comes from fertilization—fertilizers being used by commercial operations and homeowners. It also results from a breakdown of biomass that is collected in stormwater systems. For example, when you cut your lawn, grass clip-

pings may get into the curb line, and if not removed those clippings get transported during a rain event into the storm inlet. They then break down into various nutrients, including nitrogen.

"So there are a few things that contribute to increased nitrogen levels and degradation of water quality. Those things are what we're trying to get a handle on by intercepting the stormwater before it actually outfalls to a receiving water body.

"In the case of the Imperial River, which is designated an OFW—outstanding Florida water—it is critical that we maintain and manage those loadings to the river. Of course, the denser your population, the more potential there is for an increase in nitrogen levels. The city of Bonita Springs is committed to supporting the necessary approvals and funding in order to plan for and implement the management actions and projects needed to improve overall water quality in the river.

He says the Felts Avenue project is the first in a series of projects to assist with nitrogen reduction. The city purchased four adjacent lots, approximately 1.2 acres total, and removed the buildings.

"We then built a pond as a dry retention area. The pond itself is about 0.75 acre of treatment. This project receives runoff from an approximate 36.5-acre drainage basin, so it covers quite an area. It's mostly residential, but there is some commercial presence."

Liccardi says the system was outfitted with a Suntree Technologies Nutrient Separating Baffle Box with a SkimBoss diversion weir. "The way this works," he says, "is that we have a mainline water conveyance, a grass-lined swale, which receives stormwater runoff from the surrounding properties. Runoff is collected in the swale and then moves northward.

"At a point about a block just south of the Imperial River, this stormwater is intercepted by the Suntree baffle box. The box is designed for pre-treatment of the stormwater, and it's calculated to remove approximately 15.5% of phosphorus and about 19% of nitrogen. So this serves as part of a treatment train before the stormwater is released into an adjacent dry retention area.

"The retention pond can accommodate stormwater up to a depth of approximately a foot and a half," he continues. "Then, rather than any of this water being discharged into the river, it is retained in the basin and allowed to percolate into the soil, which allows for the removal of nutrients."

According to Suntree, the SkimBoss diversion weir is hydro-variant, which means that the hydrology of the treatment system will vary depending on the elevation of the hydraulic grade line within the treatment system. This enables the stormwater to be treated to a high level during almost every rain event. However, when the heaviest rain events occur, the hydrology

of the treatment system will automatically adjust to allow flow to bypass and convey maximum flows without flooding upstream. The SkimBoss diversion weir has the potential to convey many times the flow rate of a static weir.

"It's a pretty efficient system. The resultant post-treatment loads are approximately 27.6 kilograms of nitrogen annually, and about 4.5 kilograms of phosphorus annually. We have a removal rate of about 70% for nitrogen, and about 65 to 70% for phosphorus. Previously, there was no stormwater treatment, so this is a dramatic improvement.

"These are the types of projects that we are engaged in and that we are pursuing. We have a number of projects listed in our stormwater master plan, and all of them are similar in nature. There is a water-quality component attached to them and they are designed to make sure that we achieve nitrogen reduction. We'll be working on these projects over the next several years," he says.

Liccardi explains how the city came to use the Suntree baffle box.

"We had a design company, Agnoli, Barber, & Brundage, professional engineers, and one of the services they provide is the design of stormwater systems. They survey different products, and they research them to make sure that you're going to get the best product for the best cost to achieve your goal. Suntree is a well-known company in terms of these types of products.

"The design company looked at specifically what they were trying to accomplish in terms of reduction rates, and they compared what we needed to accomplish against the specifications for the Suntree system. As it turned out, the Nutrient Separating Baffle Box exceeded what we were trying to accomplish. That was how the selection was made."

He reiterates how the Nutrient Separating Baffle Box is part of a three-step treatment train. "The first thing you have is sheet flow and runoff from impervious surfaces, such as sidewalks and asphalt roadways. The first part of the treatment train is a swale system that's vegetated. The swale system picks up that stormwater and conveys it. While traveling through the swale system, some of that water percolates into the ground, and some of the nitrogen is absorbed by the plants.

"The second part of the treatment train is the baffle box. Water enters into the baffle box, and it has a separator basket that catches all kinds of solids and debris. There are leaves, branches, grass clippings, and litter. Those are removed in the interior of the box and kept separate from the stormwater.

"Once you move on from the baffle box, the third level of treatment in the treatment train is the detention area itself," he says. "This is where the stormwater stays for a period of time. Over so many hours, it is allowed to percolate into the ground where nutrients are separated from the water. So we essentially have three levels of treatment.

"Every quarter we open up the unit, and we have a vacuum truck come in. They open the baskets and remove all of the debris. On the bottom of the system, they vacuum out all of the sediment and clean out the bottom pit of the box, so when they're done, it's clean—then you start all over again.

"It's not a very complicated system, but it really is effective. I think there is a huge advantage to having these types of fixtures in addition to swales and ponds. These are a real asset, and they significantly help with our goal of reducing nitrogen levels and improving overall water quality."

Mall Expansion Triggers Stormwater Requirement

Quaker Bridge Mall, located in Lawrence Township, Mercer County, is one of the largest shopping malls in New Jersey. In 2010, the mall's owners received approval from Lawrence Township to build a proposed

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600,000-square-foot expansion. In 2012, renovations to the mall began.

"Once they do an expansion in New Jersey, covering a certain area of disturbance, it triggers a requirement for stormwater quality," explains Michael Creeden, a representative for Imbrium Systems. "It's a New Jersey DEP requirement. Depending on how big an area they disturb, this dictates whether they use a hydrodynamic separator with a 50% removal, or a filtering device—in this case the Jellyfish Filter—to remove 80% TSS."

Creeden says he was contacted by the design engineer for the project and asked if he had a system that would suit their needs. At the time, the membrane-based Jellyfish filter from Imbrium Systems had recently come to market, and Creeden recommended two of their models for the mall expansion.

"The first one was set to treat a drainage area of 0.265 acre. The second one was for an area of 0.451 acre," says Creeden.

"That was specified back in January 2012. But as of July 2012, Jellyfish was given an upgrade in its New Jersey certification, which allows it to treat a much bigger area based on TARP [Technology Acceptance and Reciprocity Partnership] field-testing-certified performance. So even though those Jellyfish units were specified for the given treatment area, in fact they can treat a much larger area.

"The New Jersey DEP gave a final certification after review for the Jellyfish," he says. "They upgraded the area of treatment, I believe, from 0.17 acre per cartridge under the old regulation to 0.66 acre per standard-length cartridge with the new regulation."

According to Creeden, the Jellyfish units can be configured a number of ways.

"The nomenclature for the Jellyfish is what dictates the number of cartridges," he says. "For example, the first model on the project was the JF8-7-2. The first number after the 'JF' (in this case, 8) dictates what size diameter the unit is. The second number indicates the number of high-flow cartridges. The final number, 2, is what we call the drain-down cartridges. So in total, this unit has nine cartridges.

"The second model was a JF10-11-2, with a larger diameter and additional cartridges."

Creeden explains that there are also a variety of installation options. "We have different ways of setting them up. It could be done as a catch basin, which would take surface water on the side of the road; the water would fall into a chamber that would go under a weir, and then flow up through our filters. The filters are upflow filters, and water actually flows from underneath up through the membrane filter, comes out on top, and exits the system.

"In a manhole, we can configure it in two different ways. We can actually inlet below a separation deck, where the filters are contained, and water flows up through the filters and out, or we can come in above the deck, which is a traditional method for a manhole. Water would then drop down below the deck in a certain area, go through the filters, and come back up and exit out from another area. For our mall installation here, we had the manhole setup."

He notes that the Jellyfish filter is intended to capture TSS, such as clay particles, sand particles, and gravel, as well as separate oil and grease. It also removes high levels of phosphorus, nitrogen, and heavy metals.

The units are designed to be maintained annually. "Once a year you may need a vacuum truck to come in and vacuum out the sediment," he says. "The system also has a passive backwash capability after each peak of the storm flow. These membrane-based cartridges are unique in that they can be manually backwashed, or rinsed, and reused as needed. Prior to doing that, an inspection would be conducted to make sure the system is working correctly.

"In the first year of installation, though, we recommend that you check it every six months," he adds. "This way, you'll get an idea of how the system is working in your area and how much of a sediment load your area has, and you'll get a good gauge as to when maintenance will be required.

"We were trying to estimate a lifespan on the filters, but we haven't been able to do so yet, because we haven't had to replace any. We've been estimating a three- to five-year lifespan, but so far across North America the membrane-based Jellyfish Filter cartridges appear to be lasting longer than that."

Steve Goldberg writes on issues related to stormwater and the environment.

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Data *Goldmines*

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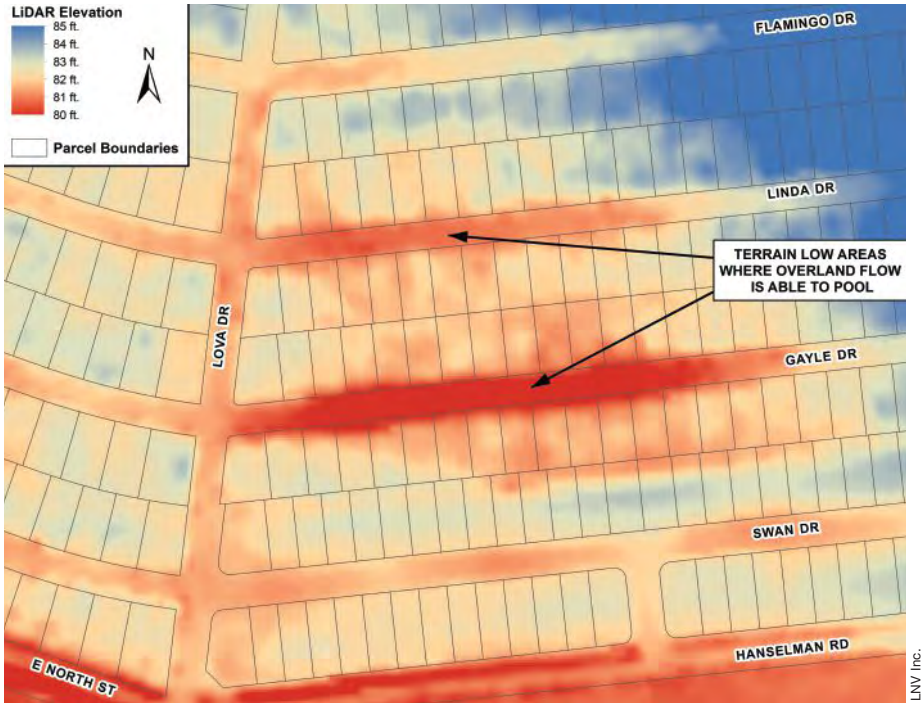
BY DON TALEND

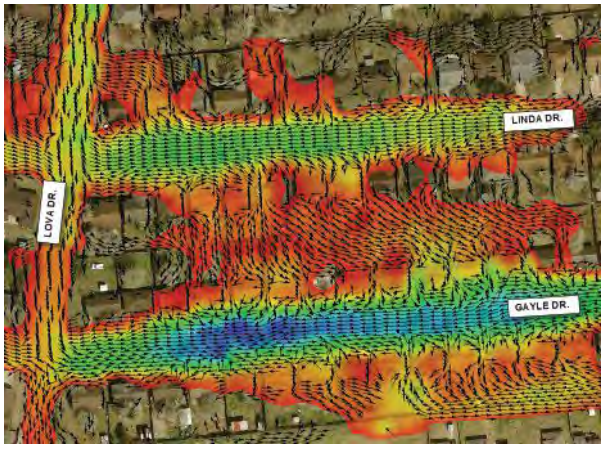


LNV Inc.

Persistent localized flooding problems in parts of Victoria, TX—located near the Gulf Coast—have prompted the city to use documented residential flooding complaints to identify and prioritize areas in need of in-depth evaluation. To optimize capital spending, the city is not merely using anecdotal flooding evidence to guess at how to possibly resize parts of its drainage infrastructure. Rather, sophisticated modeling efforts were undertaken to assist in identifying causes of the localized urban flooding and to support detailed recommendations for storm drainage system upgrades in locations where they are needed most.

This is one example of how stormwater managers are using robust information systems to analyze the true impacts of storm flows on their storm sewer systems. The decision support provided by these information systems is saving, or has the potential to save, millions of dollars.

Starting in late 2011, the City of Victoria hired LNV Inc.—a Corpus Christi, TX-based multidisciplinary engineering and architectural firm offering drainage and flood control among a range of other services in the civil, structural, transportation, environmental, architectural, surveying, and design/build specialties—to conduct an investigative hydrologic and hydraulic study of the existing storm sewer system within the Mayfair Terrace subdivision in Victoria County.



LNV Inc.

Top: ArcGIS depiction of LiDAR elevation data
Bottom: Results provided by xpStorm 2D for the 25-year storm event

The basic pre-processing workflow for this project used a geographic information system (GIS) and included data collection, data integration and analysis, and model building. From there, LNV used XP Solution's xpStorm computer program with two-dimensional (2D) module to simulate one-dimensional (1D) and 2D hydraulic elements. The program assisted the engineers in identifying areas of street and structure flooding and allowed them to compare these areas against flooding complaints from residents.

The data collected during the ground survey included inlet location, type, and size; manhole location; and storm sewer size, type, and depth. Other ground survey data collected were topographic shots of an outfall ditch and culverts, curb shots, and approximate road centerline shots. In all, approximately 2,300 survey shots were acquired during this portion of the data collection. The survey data would be a significant source of data used to build the storm drainage network and outfall ditch within the hydraulic model. LNV also acquired 1/9 arc-second (about a 3-meter resolution) Light Detection and Ranging (LiDAR) elevation data from the US Geological Survey (USGS), which was used to simulate the ground terrain within the hydraulic model.

From there, LNV used computer

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modeling to identify areas of street and structure flooding and compare them against flooding complaints to determine precisely where modifications to the local storm sewer system were necessary.

In some cases, LNV used the field survey data for modeling because those data were more accurate than the as-built surveys or the old design plans of the subdivision, recalls Jeremy George, P.E., CFM, project engineer with LNV. "In other cases, the field survey data had gaps, perhaps due to lack of access or a hidden manhole, and the historical design plans came in handy to fill in the gaps," he says. If LNV had had an unlimited budget to work with, it could have conducted an even more thorough field survey of the storm sewer system, George adds. However, the resolution of the USGS 1/9 arc-second LiDAR data was high enough for the purposes of this study and using it saved the city money, he says.

An area east of Lova Drive, a north-south street nearly bisecting the subdivision located east of downtown, is particularly flood prone. After performing an inspection of the LiDAR elevation data, LNV discovered high points on a couple of the streets forming a "bowl" that collects stormwater runoff. This was the main area of focus as LNV developed the hydraulic model to determine the impacts of flooding on the city's storm sewer system.

All storm sewer systems and drainage channels were modeled as 1D elements, and all overland flooding was modeled on a 2D grid surface consisting of 6-foot cells. The cell size was deemed an acceptable compromise between acquiring adequate resolution for 2D mapping and reasonable simulation run times and result file sizes. The 1D elements were linked to the 2D grid surface so that stormwater runoff could be transferred between the 1D and 2D domains, as allowed hydraulically by the model.

"Using our experience, we felt that having a 2D modeling component was necessary to accurately determine the complex property and street flooding extents and complex flow patterns, so we decided to use xpStorm," says George. "It was important for us to use a modeling program with the capability of being heavily GIS-integrated, because we were going to build and lay out this system in GIS and directly import it into the program, something xpStorm is capable of doing." He adds that LNV wanted to include residential structure footprints and variable 2D roughness values in the model to reflect the impact on the storm sewer system as stormwater surged either through or around these map features representing buildings.

Using a "Rainfall Area" feature in xpStorm 2D, engineers distributed the rainfall excess over the Mayfair Terrace subdivision drainage area. The rainfall runoff that entered into the hydraulic analysis flowed throughout the 2D grid surface, eventually finding natural paths to the storm sewer inlets. Any runoff in excess of the capacity of the inlets remained on the 2D grid

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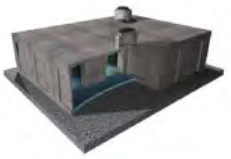

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surface as inlet bypass flow or pooled in low areas. The rainfall feature—one that LNV does not always use—helped LNV identify where water would naturally flow, based on the topography and the capacity of the storm sewer system. The engineers felt that the application of the design storms using the rainfall feature was the best way to simulate the dynamic overland flow patterns, letting the hydraulic model sort out how the storm runoff reached the storm sewer inlets.

In terms of data volume and analysis time, this project was a significant undertaking. According to George, the model included nearly 440,000 2D grid cells, running the storm simulations took eight to 10 hours, and the entire project consumed about 95 gigabytes of data, 80 gigabytes of which was made up of the xpStorm2D model files and results. Although using the rainfall feature made for a more comprehensive analysis and increased computation time, the investment of time paid off in terms of identifying the relative impacts of storm events, George contends.

The 25-year storm event was primarily used to analyze the storm sewer system and surface flooding for comparison with proposed condition scenarios. The modeling results confirmed that the storm sewer systems throughout much of Mayfair Terrace are considerably undersized and that an obvious low area exists within the subdivision, supporting the engineers' pre-project suppositions. Additionally, it appears that several of the residential lots separating the streets are slightly lower in elevation, allowing storm runoff to flow from one street to another through the residential properties.

LNV then analyzed several potential improvements to the storm sewer system. Flood depth reduction percentages were calculated for five- and 25-year storm events at a sampling of 19 hydraulic model nodes located along Lova Drive and within the problem area east of Lova Drive. The 19 depth-reduction percentages for each storm event were averaged to determine the overall effectiveness of the improvements.

"Typically, you'll have a one-dimensional hydraulic scenario where, if you know where the water is going, you can generally say you're pretty sure you know the flow patterns," says George. But there are other situations in which stormwater might flow in several directions, he adds.

"That's when a two-dimensional or integrated one-dimensional-two-dimensional—what we call a 1D-2D model—is very beneficial," he says. "There's a definitive advantage to an integrated 1D-2D model in these types of cases, because the flow patterns around houses can be modeled and identified, and you can tweak or fine-tune your model accordingly."

George recalls that LNV initially identified about 15 proposed improvement scenarios that varied in terms of degrees of effectiveness and cost. The options included any or a combination of three main modi-

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fications: upsizing a portion of the existing storm sewer system, adding an earthen trapezoidal channel to serve as a new relief route to the outfall ditch, and adding an additional storm sewer line to serve as a new relief route to the existing outfall ditch. In March 2012, LNV presented the city with the four best options.

For example, option 1 includes a combination of upsizing a portion of the existing storm sewer system and adding an earthen trapezoidal channel to serve as a new relief route to the outfall ditch. Option 4 includes upsizing a portion of the existing storm sewer system along the east side of Lova Drive only. Option 1 is the most expensive at nearly $3.9 million but offers the greatest effectiveness for reducing five- and 25-year storm event flood depths in the focus areas. Option 4 is the least expensive at less than $1.9 million but also the least effective for reducing five- and 25-year storm event flood depths in the focus areas.

After subsequently meeting with city staff to discuss the findings of the study, LNV provided four more improvement scenarios in June 2012. For example, option 6 is a variation of option 4 and includes removing the existing storm sewer systems on the east and west sides of Lova Drive and replacing them with a single, combined, and significantly larger storm sewer system. This option has the possibility of numerous and significant utility adjustments at an estimated cost of $1.25 million. This cost could be reduced if utility conflicts were investigated and found to be a less significant obstacle than previously thought. A cost reduction of just 15% would move option 6 from the third most cost-effective option to the most cost-effective option.

As of early 2013, LNV had not heard from the city about the eight improvement scenarios that LNV provided. Regardless of what improvements, if any, are made, LNV learned some valuable lessons in terms of modeling flood-prone areas—and can include another large-scale urban flood modeling study to its resume.

"First, we learned that just because you think you know how a complex system is supposed to perform doesn't mean that's how it's actually performing," says George. "We found that this software really helped unveil flow patterns that we suspected at the outset of the project, but the software really confirmed these flow patterns visually once we saw the model.

"We also found that clear project goals are important," he continues. "In engineering, often there are numerous ways to solve the problem. We had to weigh a lot of different things: Are we providing maximum benefit per dollar of construction cost? Are any improvement options less desirable or off the table completely?"

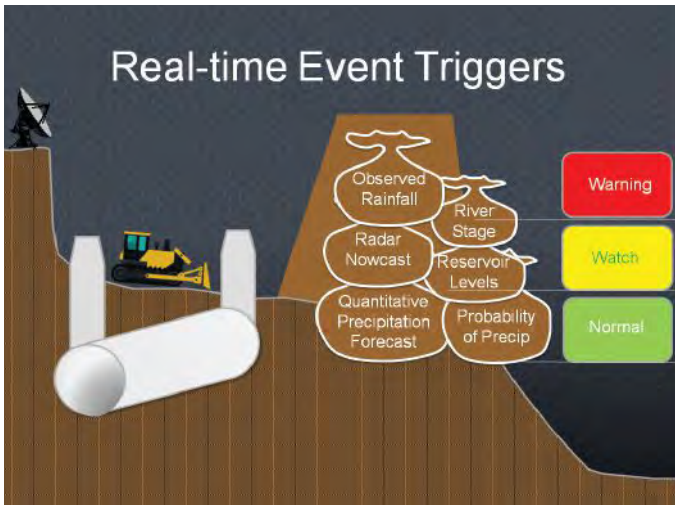
The xpStorm 2D computer program that LNV used provided a great deal of flexibility and capability. Using it, the engineers ran dozens of variations and combinations of storm events and determined which modifications would be the most effective at meeting project goals while providing the optimum balance of cost and benefit. In fact, the number of

scenarios became overwhelming and potential scope creep became an issue, George recalls. "You need to stay close to your goals and take a step back every once in a while to look at the big picture," he says.

Critical Pipe Repair, Accurate Weather Reports

Sometimes, when considering the benefits that an information system provides in stormwater management, you're trying to prevent catastrophes. Such is the case as the Espey Consultants Inc., dba RPS Espey (RPSE)—part of RPS Group, an international consultancy providing the development and management of the built and natural environment among other services—designed the rehabilitation of a roughly three and a half-mile stretch of deteriorating sewer pipeline in Irving, TX. The location of the work in the floodplain creates the potential for catastrophic stormwater flows during the construction process, making accurate weather forecasting critical.

The Trinity River Authority (TRA)—a conservation and reclamation district that provides water and wastewater treatment for municipalities within the nearly 18,000-square-mile Trinity River basin—is overseeing the $16 million rehabilitation of 17,200 feet of 96-inch sewer pipelines in Irving. In April 2012, general contractor Insituform Technologies was given a notice to proceed with construction to rehabilitate the pipeline, with completion scheduled for spring 2014. As of January 2013, the project was about 60% complete.



Vieux & Associates

The level of flood control reservoirs and the likelihood of rainfall, or a combination of the two, can trigger a demobilization of pipe rehabilitation work along a flood-prone stretch of the Trinity River. A dedicated information system sends alerts to the construction team when triggers are activated.

Insituform is repairing unlined reinforced concrete pipe originally installed in 1984. A 1990 evaluation and a 2008 internal inspection identified the need to rehabilitate the pipeline, which was experiencing accelerated corrosion from hydrogen sulfide in the wastewater. On two occasions, sections of the pipeline actually collapsed due to a loss of

design strength, and the rehabilitation is intended to restore the life of the pipe walls and prevent further incidents. TRA named the rehabilitation project CAC-11 for Critical area of concern, segment 11.

The project is challenging, to say the least. The river has historically experienced regular cycles of out of-bank-condition within the 100-year floodplain of the Elm Fork of the Trinity River where the pipeline is being repaired. The work itself involves use of a cured-in-place pipe (CIPP); it is one of the largest CIPP projects in the nation. Accessing 10 manholes along the "critical area of concern," Insituform is inserting a CIPP liner about half the distance to the next manhole. The liner is filled with water that is heated, pressurizing and hardening a resin that produces a rigid pipe lining.

Once started, the lining process cannot be interrupted for about five days. The timing for starting the lining process must be coordinated with avoiding an overbank condition by the adjacent river, and the duration of the lining curing must be leveraged with the monitoring of the river levels. Vacating the project area necessitates sufficient time for Insituform to seal the system from river flows swollen by stormwater flows and to remove equipment from the area. Not sealing the system would turn the project area into a giant "draining bathtub," with stormwater flowing into a 96-inch-diameter pipe and possibly overwhelming the TRA's wastewater treatment system downstream.

"I've actually flown over the river in years past when we had a situation where a manhole had been blown out due to high flows, and literally looking down in this wide floodplain and seeing a whirlpool and knowing that's the location of the manhole—that's a situation and it's scary," says Wayne Hunter, P.E., project manager and Dallas/Fort Worth Area Branch manager with RPSE. "If a weather event would occur within those five days once the liner is partially inserted or partially cured, it would have to be removed and reinstalled, and that would involve major costs to the contractor. They're relying on understanding what the risks are before he starts the process. They know that once they start, they can't stop."

To manage the project's risk, RPSE developed a three-point plan that has been implemented since the project started. An evacuation plan requires Insituform to seal the pipeline from stormwater flows and demobilize within 24 hours. Additionally, RPSE would provide a weather monitoring system. Finally, the levels of the river immediately upstream of the site and three flood control reservoirs, located immediately downstream of the project and operated by the US Army Corps of Engineers, would be monitored.

A major planning variable is the presence of the reservoirs. RPSE must put together a risk profile consisting of both the reservoir levels and the long-range weather forecast. Hunter points out that the best approach to managing risk in this situation is to set a risk threshold, above which relining work is delayed.

Vieux & Associates, a Norman, OK-based engineering

technology firm specializing in water information software, products, and services, is providing near-real-time decision support to the RPSE via a sophisticated rainfall monitoring system that integrates multiple feeds of rain gauge data and radar data that are used in a display and notification system. A high chance of precipitation, a high reservoir level, or a combination of the two could exceed the risk threshold and trigger an alert that is sent to the project team, indicating that work should be halted on a given day.

"Everyone gets regular e-mail warnings," says Hunter. "Since construction began, we have experienced three instances of predicted out-of-bank conditions, two of which resulted in periods of out-of-bank floodplain inundation. In these instances, the contractor necessarily has to reschedule all of his activities and postpone things that it planned." For example, Insituform typically has numerous large trucks onsite for processing the pipe liner and resin, including a boiler that heats a large volume of water. When the risk threshold is exceeded, any plans to begin processing the repair materials must be postponed and the vehicles must be removed from the scene.

Hunter points out that when the purpose of an information system is to prevent catastrophes, one does not know how effective it is unless a catastrophe occurs. He adds that 2012 was a dry year, although 2013 could be much wetter—and more challenging. "The reservoirs upstream are not utilizing all of their flood storage," he notes. "As a result, when it rains, the peak effects that we might normally see from the very large upstream watershed are reduced by the flood control reservoirs. If we continue to have wet weather, that could change."

The cost savings of preventing a catastrophe are pretty easy to calculate, Hunter says. Dividing the $16 million project cost by 20—or 10 pipeline segments marked by manholes and one repair section on either side of each manhole—yields a cost of about $800,000. Halting work and evacuating ahead of a flood would save the cost of replacing that section, Hunter contends.

"Now that we have had the opportunity to use this tool, there's no question that it gives us and the contractor a significant value in terms of making better decisions as to how projects get done," says Hunter. "So without our having to dictate to a contractor its means and methods, which we try not to do, we give the contractor additional intelligence with these data that allows better-informed decisions, and we'd like to think that better protects our clients."

Complex Network Requires Solid Data

Hamilton, ON, Canada, has one of the largest combined sewer overflow (CSO) systems on the Great Lakes. The system has existed in one form or another for 150 years; it's an ideal candidate for a monitoring tool to ensure that it has sufficient capacity for inflows and keeps up with growth. Additionally, the Canadian Council of Ministers of the Environment requires the capture and treatment of all dry-weather flow plus 90% of volume resulting from wet-weather flow above the dry-weather flow, for a seven-month period starting within 15 days of April 1 every year.

Capturing these flows has a beneficial impact on Hamilton Harbor, an International Joint Commission Area of Concern for pollution on the Great Lakes, as attempts are made to de-list the harbor.

The idea of an information system for monitoring is not new to the city, which first implemented a MIKE URBAN water modeling system from DHI Software with about 4,000 links and nodes back in 2004; this is known as the "trunk system." It just so happened that for the next five years, Hamilton was hit with many extreme storms that caused flooding in the lower part of the city. Although the city did not model 100% of the CSO system at that time, it did model the system serving this entire area that was subject to chronic flooding, or about 25% of Hamilton, with an "all pipes model" in MIKE URBAN. The real-time monitoring and control implementation was part of an initiative to assess flood risks and develop remedial capital measures such as new pipes, storm release sewers, and other infrastructure to address the problem.

From 2009 to 2011, the all pipes model was developed for about $930,000 to monitor "pretty much every hydraulically relevant pipe in the city," according to Chris Gainham, senior project manager in the city's Water and Wastewater Planning area. The city also updated the trunk model by recalibrating it and replacing a one-hour rainfall time series that represented the average year with a five-minute rainfall time series to better represent CSOs in the system. Last but not least, Hamilton undertook a large CSO quality characterization program to better monitor chemical loadings in the harbor. Stantec Consulting—a company providing planning, engineering, architecture, surveying, and project management services—and BPR CSO—a hydraulic modeling and urban infrastructure consulting firm—assisted the city in implementing the systems.

The MIKE URBAN platform integrates GIS into water modeling, allowing monitoring of either combined or separate sewer systems, or stormwater drainage systems, including 2D overland flow. Users can edit network data in GIS and run simulations of collection systems and water distribution systems. The system is modular and available in different sizes.

The growth of the system was part of a 30-year plan for the city, according to Udo Ehrenberg, manager of infrastructure and source water planning for Hamilton. "We needed a computer model that would allow us to set the impact of the various scenarios on the collection system," he says. "In essence, it was a planning process that was the catalyst for the current effort in terms of modeling," he says, adding that the city has actually had a computer model in place since the early 1990s. As technology has evolved and Hamilton's need for dynamic modeling has grown, the city chose to update the model first implemented in 2004.

The all pipes model uses the city's existing GIS system, which displays the plan view. However, a great deal of data mining was required to build a robust database, Gainham recalls. This entailed cataloguing thousands of drawings of the system. "Where we didn't have drawings, we went out in the field and did things like crack manholes, perform entries, and confirm the dimensions of significant infrastructure here in the city," he says. Part of developing the model was undertaking a large flow-monitoring project and a rainfall monitoring project to calibrate the model for quality assurance/quality control purposes, Gainham says.

Increasing the complexity of a storm sewer or CSO system necessitates major capital improvements, making a modeling system like Hamilton's practically a necessity, Ehrenberg says. "A robust computer modeling application allows you to run extensive time series, allows you to have a backward look at how the system performed in the past, and a forward look in terms of simulating a what-if scenario to assess what infrastructure will provide you with the best results in terms of reaching the objectives you're after," he notes.

The Hamilton Water and Wastewater Planning staff runs reports in its

information system to determine what capital improvements should be made, with a particular focus on the area covered by the all pipes model. The reports include general capacity assessments under dry-weather flow and projecting for growth. The projections help the staff to determine how vulnerable certain areas of the city would be in wet weather if more land is developed there. The assessments also provide insight into how much performance the city can get out of its existing infrastructure—and if it will get a commensurate reduction in CSO volume with increased system utilization.

Using the data, the city can identify opportunities for increasing the level of service in some areas, such as building new infrastructure or increasing pipe diameter. The staff makes risk assessments and identifies emergency scenarios; in the event that major infrastructure is out of service or has a diminished service level, the model provides insight into allowable response times. "Our system is very complex, so it's very difficult for one person to sit down and look at the system and make a judgment call," says Gainham. "You really need a model to assist you with that—it's a powerful tool for that."

Ehrenberg notes that using the all pipes model, in particular, has allowed the city to optimize its capital improvements in the flood-prone area of town. "We focused on the solutions that provided the most benefits, both locally where the flooding was happening and where a solution might provide an overall benefit to the network," he says. "We have improved the level of service in that area, making good infrastructure decisions, and there has been less flooding since we implemented some of the solutions." The next initiative using the model will be gaining a detailed understanding of the performance of the city's entire network, Ehrenberg says.

Gainham indicates that the city's two models reveal significantly different data, underscoring the importance of accurate data inputs. "The all pipes model was built well," he says. "We are of the understanding that development of the model never really stops; we're constantly tweaking it."

"I don't think you can underestimate the level of effort that goes into getting quality data," adds Ehrenberg. "With a network as old as Hamilton's, we had old or missing information, so when we structured our work plan, we allowed for field verification. It is critical that you allow for fieldwork to allow for narratives and understanding the actual performance of your infrastructure in the field, especially when you have complex control structures with flow diversions. With a complex network, you have to be prepared to go out there and do some validation."

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Real-Time Flow Dynamics Analysis

One software program is available that performs advanced rainfall and stormwater flow analyses in real time, and the data can be imported into modeling programs to give public works staff a clear picture of storm sewer system capacity versus the infrastructure and terrain that the system services. From there, users can set up historical rainfall thresholds to trigger alarms for emergency measures to be taken if necessary.

FlowWorks is an integrated, affordable, real-time Web-based data collection system combined with engineering analysis tools. In June 2009, a revised version of the program was launched under the name of FlowWorks and included the first web-based tools to perform mathematical calculations on real-time data; these tools would eventually form the basis of the FlowWorks Advanced Calculation Engine (FACE). Stormwater managers can obtain data from any meter, rain gauge, or Supervisory Control and Data Acquisition (SCADA) system; import it into FlowWorks; perform real-time analysis with the FACE tool; and export the data into a modeling program for further analysis.

The program, built around rainfall tools, also monitors stormwater flows with the capability of monitoring multiple meters. This allows analysis of rapid, radical changes in the depth of stormwater flow levels. In addition, the program allows flow velocity calculations so that the timing of impacts on a storm sewer system can be determined.

Using historical data, public works managers can figure out whether storm sewer pipelines need to be enlarged, for example. It is possible to conduct an Intensity-Duration-Frequency (IDF) analysis of rainfall. The user can identify the maximum amount of rainfall in a 15-minute time period—rainfall intensity—in a given month, for example. Using this IDF analysis, public works staff can make real-time emergency decisions to react to major rainfall events.

Significant rainfall events are illustrated with FlowWorks' Rainfall Isohyetal Mapping tool. This tool relies on custom ArcGIS server geoprocessing tools to show rainfall totals in the form of contour maps and reveal values spread over a geographic area. The user can specify the time period of interest, and specify all or any specific rainfall stations to quickly generate the corresponding rainfall surface with contours. Using the program, stormwater managers can determine how many feet of water a downstream storm interceptor will receive, based on a given number of inches of rain.

The city of Seattle, WA, obtains data from 35 depth-only and area velocity meters in pipes and ponds and analyzes the data in FlowWorks. The data are used to analyze the hydraulics of a previously unmonitored problematic drainage system in an area of the city that is characterized by stagnant to fast flows. The city reaps the benefits of flexible flow monitoring and moves the locations to identify drainage properties throughout the system.

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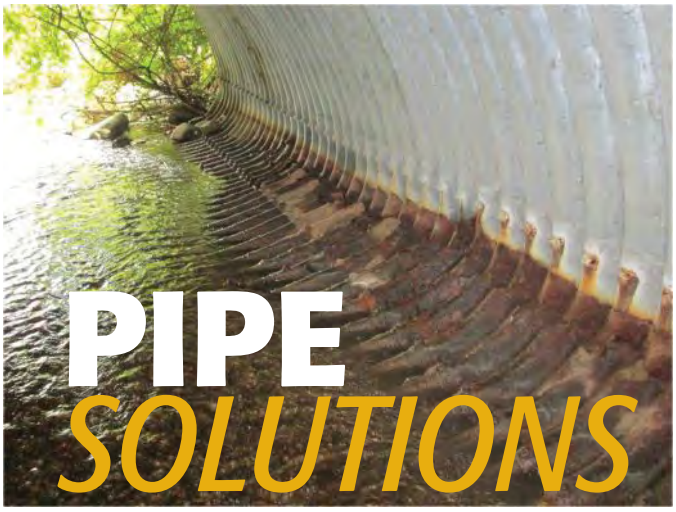

PIPE *SOLUTIONS*

Faster repair, replacement, and rehab techniques

BY CAROL BRZOZOWSKI

Damaged pipes pose a host of problems, from significant maintenance costs to environmental threats. Many communities throughout North America have been mitigating those problems in such a way that minimizes costs, traffic interruption, and maximizes on the longevity of newer materials and repair methods.

Stoney Creek

In Oakland Township, MI, a pipe arch culvert that allowed Stoney Creek to pass underneath Stoney Creek Road had corrosion and was exhibiting various signs of distress due to its age.

"We had a fairly quick turnaround time to be able to utilize funding for the project," notes Jeff O'Brien, a design engineer for the Road Commission for Oakland County. The project was federally funded as a surface transportation maintenance project. "That eliminated our ability to acquire any additional necessary rights of way for a complete replacement."

Additionally, Stoney Creek Road is the only paved east-west road in the area and as such is a heavily used corridor.

"We did not want to close the road for replacement," points out O'Brien. "There is also a golf course immediately adjacent to that particular structure, and that would have involved business interruption."

The choice was to use CentriPipe by AP/M Permaform. CentriPipe is centrifugally cast concrete pipe and is a trenchless approach for corrosion protection and structural renewal of storm and sanitary sewer pipe between 30 inches to 120 inches in diameter.

After an engineer's inspection and determination as to how the pipe should be mediated, the pipe's interior is scoured by CentriPipe's high-pressure spin washer, and any repairs needed to be done prior to spin-casting are executed.

Top left, bottom left: Deteriorated pipe at Stoney Creek before rehabilitation

Top right, bottom right: After pipe rehab

AP/M's self-consolidating PL-12,000 mortar is pumped into the damaged inverts, which seals the bottom of the pipe, fills inverts, and makes a new structural base to keep water from leaking in or out. PL-12,000 leaves a new pipe floor that may be flat or contoured to the radius to enable flows. CentriPipe's high-speed spin caster is placed in the center of the pipe at its far end.

Next, PL-8000 concrete is centrifugally cast evenly around the interior of the pipe; the application head is retracted by a computer-controlled motor at the properly calculated speed to ensure an even thickness.

"It was cost-effective," says O'Brien of the choice. "On other types of roadways, it may not have been quite as cost effective. It was a fairly large pipe arch. There was quite a bit of lining material that was required in order to meet the structural requirements of the culvert."

The bottom of the structure was a 4-inch liner that tapered to a 2-inch liner at the top, O'Brien says.

Essentially, the Oakland County Road Commission chose CentriPipe because of hydraulics, he notes. "The culvert was a bit deformed. Michigan Department of Environmental Quality essentially allows us to line it with a push-type liner. If we were to go to any other push-type liner, by the time we tried to push another liner through that structure, we wouldn't be able to get the hydraulics to work. In terms of meeting the environmental requirements, this was a good fit."

Repairing a Culvert

In 2010, the North Carolina Department of Transportation (NCDOT) used Hobas Pipe to meet the many challenges in rehabilitating an aging culvert along the seacoast near Nags Head.

The existing culvert was leaking, causing sand to migrate into the pipe and undermining the sand dunes above. The line, which outfalls directly into the Atlantic Ocean, was corroded by a severe environment.

NCDOT sought a corrosion-resistant and leak-free replacement pipe. The pipe also had to resist abrasion, as sand and gravel often works its way into storm sewers.

To meet those criteria, NCDOT chose a 30-inch nominal Hobas pipe with an outside diameter of 32 inches to slipline the existing 36-inch-diameter concrete line, which ran from NC 12 to the beach. The job was performed in-house by NCDOT crews.

John Abel, NCDOT division bridge manager, says the existing pipe had separated so badly that it was a challenge to keep the sand from filtering back into it while the work was underway. The crew tried to work when the tide was outgoing so the water would help push the sand from NC 12 to the ocean.

Working within a narrow easement adjacent to local businesses, the NCDOT crew excavated an installation shaft and removed the top of the existing concrete pipe. Following that, 20-foot segments of Hobas pipe were then

placed one at a time into the sewer and pushed toward the ocean outfall, extending 670 feet.

Bridge Work

Oldcastle Precast was chosen for a project for the Pennsylvania Department of Transportation's Mohnton Borough Bridge, which crosses over a tributary of Wyomissing Creek in Berks County, PA.

The replacement project focused on existing two-span steel pipe culverts conveying a tributary of Wyomissing Creek with a single-barrel 90-inch pipe culvert. The roadway over the culvert will have two 11-foot lanes and 4-foot shoulders.

Oldcastle Precast designed, engineered, and shipped 120 linear feet of 5,000-psi reinforced concrete pipe (RCP) culvert comprising 90-inch RCP culvert and 66-inch RCP. While Oldcastle Precast had extensive experience with manufacturing the 66-inch and 90-inch RCP culvert, the company needed to create a new joint for the 90-inch RCP culvert.

Near Nags Head, NC, seawater and sand had corroded an aging culvert.

Hobas Pipe USA

In collaboration with engineers from CC Johnson & Malhotra, the company designed and engineered a new 90-inch baffle for the 90-inch RCP culvert.

Shelter Solutions provided the precasting for the $968,000 project. JD Eckman of Atglen, PA, served as the general contractor and project manager/engineer.

New Glasgow CSOs

Addressing combined sewer overflows (CSO) has been a priority for many cities throughout North America.

"In the past, rainwater flowed into the sanitary sewer system and was then treated. Extra stormwater would, during times of a heavy rain, create an overflow. This combined sewer overflow generally discharged into a nearby water body. With the latest EPA Phase II requirements in the United States and similar regulations approved by the Canadian Council of Ministers of the Environment in 2009, controlling and managing storm water runoff is imperative, not only for the welfare of people, but also to meet these new

governmental standards," points out Tony Radoszewski, executive director of the Plastics Pipe Institute (PPI).

New Glasgow, Nova Scotia—a municipality of fewer than 10,000 people—has been engaged in a CSO reduction program and as such needs to improve its infrastructure. One area being upgraded is a tidal estuary for salt and freshwater and is the centerpiece of the town's revitalization of the East River of Pictou riverfront.

A few years ago, New Glasgow was pounded by several 100-year storms, flooding its downtown area. Flow volume from even smaller storms would overload the treatment plant.

The improvement program in early 2011 called for the installation of new storm sewers for 12 streets and upgrading of 12 pumping stations to help remove stormwater from the sewer system and help the East River Environmental Control Centre operate more efficiently.

Bob Funke, P.Eng., then the town's chief engineer, led a task force that pinpointed two distinct areas where constructing a trunk sewer line would cause positive CSO reduction. The line extends from the downtown area to the river and intercepts a secondary sewer causing flooding in another part of town.

Corrugated high-density polyethylene (HDPE) pipe was chosen and sized—740 meters (2,400 feet) of 900-millimeter (36-inch)-diameter pipe was used.

The pipe used was double-walled —smooth on the inside, ribbed on the outside—corrugated HDPE pipe. Called Solflo Max, it was manufactured by PPI member company Soleno at the McAdam, New Brunswick (Canada) plant. It meets ASTM standards for F405 and F667 and complies with Canadian Standards Association, CAN/CSA B182.6.

"Looking at the water volumes and the various friction loss with the various pipes led us to using HDPE pipe which enabled us to save a diameter or two by using it instead of concrete," says Funke. "The HDPE pipe has very favorable Manning's rating, which means a better friction loss."

That was a critical factor, given the deep cuts of between 12 to 15 feet and in some cases, slopes of less than 1%.

"When you are designing a sewer separation project to be installed in tight quarters, you have to look at the smallest diameter pipe that can deliver the largest volume of water," says Funke. "If you can take a half-size off that, six inches means a lot to the construction crew."

Contractor Dan Tupper of Tupper Excavating echoes that. "When you're 15 feet in the ground between sewers and water mains, and underneath high voltage lines and all the fiber optic conduits we have today, digging in and around those areas in very tight real estate, you want the smallest pipe possible," he says. "The HDPE pipe made it pretty simple for us. The ability to thread this pipe through very difficult areas was key."

Tupper Excavating had to bury the pipe as quickly as possible in the McLean Street section of New Glasgow with its tidal area of 4- to 5-foot tides.

"When you're down in the ground six to eight feet and you have to deal with four to five feet of tide, you get into a mess," he says. "For about 1,000 feet we were fighting tidal water, and in a few situations we were down in 10 to 12 feet of water."

The crew constructed a dam. "We could only hold back about five feet of water," says Tupper. "Once the tide got over that level and the water started squirting around the ground, we had to abandon until the next tide, which was 12 hours later. Still, we were able to move safely and quickly getting in two or three lengths a day. We found it easy to use the HDPE pipe and didn't have any problem with it. Plus it's tough and it's versatile."

Funke says his municipality has become more confident in using plastic pipe ever since it entered the market in Nova Scotia as a culvert pipe and became a standard replacement for metal culvert pipe.

He favors it for its light weight and ease of installation in its 20-foot lengths, as well as helping the municipality achieve a desired flow rate through a smaller-diameter pipe.

Radoszewski points out that HDPE pipe is inert to the problems of pressure and the impact of acids in the rain and

water, as well as saltwater, chemicals, pH, and acidity. It's a critical consideration for any project near water, he adds.

Fewer joints reduce the chance of leaks in pipe that is already watertight, he adds.

Working on the Railroad

In summer 2011, a 99-year-old poured-in-place box culvert in Durham, NH, needed repair. A times when the groundwater level was high, water could be seen pouring out of cracks in the original culvert, which measured 6 feet wide and 8 feet tall at the top of the arch.

The culvert ran under an active railroad track and a paved remediated area through a brownfield site. Repairs had to be done in a way to prevent contamination from entering the pipe and to avoid interfering with the flow of a nearby creek, while still being able to withstand the weight of the Amtrak passenger and freight trains passing overhead.

Dave Cedarholm, P.E., town engineer for the Durham Department of Public Works, says EPA and the state both expressed concerns that contamination from the parking lot area above could potentially seep into the creek; they wanted the culvert sealed. However, there were questions about the longevity of merely sealing it.

The preferred solution: sliplining with 180 feet of 60-inch-diameter Advanced Drainage Systems (ADS) SaniTiTe HP triple-wall pipe to prevent contaminants from migrating into the creek. Manufactured with a specially formulated polypropylene resin, SaniTiTe HP pipe in 30- to 60-inch diameters meets ASTM F2764 and AASHTO MP21-11 standards for polypropylene pipe in surface and subsurface drainage applications. Its triple-wall profile is designed with a smooth interior and exterior wall design supported by a corrugated structural core to provide high pipe stiffness and greater beam strength to minimize deflection and enhance performance. The SaniTiTe HP pipe has an extended inline bell and spigot joint design with pre-installed dual gaskets designed for maximum joint integrity.

Durham had received a brownfield cleanup grant to address tetrachloroethene (PCE) contamination in the soil and groundwater on the site near the University of New Hampshire. A company once distributed dry cleaning supplies and chemicals at the site, and the contamination resulted from spills and leaks from storage facilities and railroad tanker cars.

A hydraulic analysis was conducted for the pipe project to calculate the effects of a 100-year flood. Durham city officials did not want to choose a pipe material that would reduce the culvert's capacity. The smooth-lined SaniTiTe HP pipe offered additional capacity.

Weight was also a major factor in pipe choice. Cedarholm says there were concerns during the design phase that the existing, damaged culvert would not withstand the weight above it. He says the ADS SaniTiTe HP product line provided the needed performance at the desired price point.

The joints had to satisfy a sanitary condition akin to those

of a sanitary sewer. The security of the joints also was an important factor in the final installation steps.

Time constraints were another challenge: there was a small time frame in which to complete the installation work with respect to the University of New Hampshire school schedule.

Another consideration was that the pipe had to be managed with a reasonably sized excavator in a narrow area. Cedarholm notes that some pipe materials, such as steel reinforced pipe, would require a crane to lift each section, creating installation challenges at that site.

The Ted Berry Company of Livermore, ME, provided contracting services, putting rails on the base of the culvert used to slide the pipe in and allow water to flow underneath the pipe as the bulkhead was being constructed. The upstream end was lower than expected; adjustments were made to the slope of the pipe to create a more consistent flow line.

With the rail system, Ted Berry workers corrected the pitch by raising the inlet end by 8 to 10 inches. They shot the invert and slipped in the new pipe. The job was completed by a crew of four in a few hours.

The crew also used grout to fill in cracks in the walls of the old culvert and the space between the SaniTiTe HP pipe and the surface of the old box culvert. The grout was used to penetrate through any of the old joints to help fill soil voids around the pipe and increase the loading ability by filling in annular space between the pipe and the inside surface of the old culvert. The headwall also was repaired, with a masonry company hired to make it look aesthetically pleasing.

Although the original construction costs were $180,000, the total costs were $101,000 due to the pipe selection and the project being treated as a design-build endeavor. The majority of the project was financed with a Brownfield grant, and Durham provided a 25% match.

State Route 145

Abel Recon, an infrastructure rehabilitation contractor in Mountville, PA, serves as a one-stop shop for sanitary and storm sewer infrastructure trenchless rehabilitation, including design, installation, grouting, and root control.

The company started off using a spray-applied, cured-in-place polyurethane lining system for structural rehabilitation and also as a corrosion-barrier management and protection for sanitary and storm sewer structures. In 2007, Abel Recon began using a relining process from Reline America —its Blue-Tek cured-in-place pipe (CIPP) liner. Blue-Tek uses an ultraviolet curing system to line pipes 6 inches to 54 inches in diameter.

One such project, in June 2012, involved relining a 36-inch corrugated metal pipe that ran underneath Pennsylvania State Route 145 for the Pennsylvania Department of Transportation.

"It was a decent-sized length of 36-inch pipe, and it was an interesting project where the Pennsylvania Department of Transportation [PennDOT] could not dig and replace

Relining with Blue-Tek ultraviolet curing system

the pipe," notes Scot Snyder, business development manager with Abel Recon.

"They had to use a trenchless lining for all practical purposes because of the busy route. It was what they termed as a safety project—there was an urgency to getting it done. We were able to get it done quickly with trenchless technologies as opposed to an open-cut dig and replacement of that storm sewer pipe, which would have to shut down that State Route 145 for days and days, possibly weeks. We did not to shut it down at all with the Reline America's Blue-Tek CIPP."

Cost savings comes into play as well, he adds. With today's economic environment mandating budget cuts, "PennDOT would be foolish not to consider the trenchless technologies just because of the cost savings," says Snyder. "And the inconvenience of shutting a roadway down makes today's trenchless technologies more ideal.

"There are situations where if there is no roadway to shut down and no traffic, CIPP may not be the way to go."

Snyder says cleaning the pipe was one of the biggest challenges of the

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Abel Recon

job. "When you rehabilitate a storm sewer pipe in situ or from the inside, storm pipes tend to have a lot more large debris," he says. "We've seen anything from large rocks and rubble to tree limbs and bricks to bicycle parts to parts of a tricycle. We saw a Big Wheel on one project. One of the obstacles was to get that pipe cleaned and prepped."

Another challenge was having to work through the night due to traffic control constraints that PennDOT had on State Route 145.

Snyder says as far as CIPP products go, he finds Blue-Tek more environmentally friendly than traditional older processes "because all of the fiberglass resin is impregnated versus saturated with polyester resin.

"All of that resin is contained with an outer film and an inner film, whereas the old processes were not contained —that resin was just pushed into the environment without any outer film to contain it. With Blue-Tek, there is zero resin migration or contamination in the environment," he says.

Flood Abatement in Columbus

At the site of the Chattahoochee River —which borders downtown Columbus, GA, on the west and south—and Weracoba Creek, which borders the east, surcharging of combined sewers and flooding of the downtown core by Weracoba Creek was historically hazardous.

Donna Newman, city engineer for Columbus, had been planning long-term storm drainage solutions for downtown Columbus for more than a decade.

One plan element, developed jointly by the city and Jacobs Engineering, was a two-phase abatement project of a combined sanitary and stormwater system. Both phases would utilize precast concrete boxes (PCB) for sections of the flood abatement storm sewer system. PCB sewers were chosen for what Newman and Jacobs believed would be the best long-term solution based on hydraulic capacity and minimal disruption to historic downtown Columbus.

Precast boxes for the storm sewer were the preferred solution to the need for quick construction with limited disruption to the area's businesses, allowing residents to return to the downtown area more rapidly.

Foley Products supplied precast concrete boxes for the second phase, which began in March 2011. This phase included 8,350 feet of PCB ranging in size from 8 by 6 feet to 14 by 12 feet.

All sections required a troughed invert. In addition to the precast boxes, Foley supplied 6,064 feet of 15-inch- to 72-inch-diameter reinforced concrete pipe.

Foley's design team, headed by Chris Davidson and Bob Palmer, P.E., accommodated a design that was both efficient and cost effective, considering site limitations affecting the contractor's onsite equipment. The small construction work area determined the size of installation equipment. Product was scheduled for just-in-time delivery.

Andy Hedrick, project manager with Reynolds Inc., says Foley Products worked diligently to meet all of the material requirements for the flood abatement project, delivering consistent products of superior quality. Foley modified the boxes by reducing the wall thickness from 16 to 33%, decreasing the average weight of each box by 25% and removing more than 5,000 tons from standard designs.

The weight reduction allowed the contractor to set a majority of the boxes with existing equipment already onsite. A unique set of lifting pins was designed for unloading the 14-foot by 12-foot boxes safely and efficiently.

Carol Brzozowski specializes in topics related to stormwater and technology.

TOOLS OF THE TRADE

Monitoring and testing stormwater

BY MARGARET BURANEN

Having reliable water-quality and -quantity data makes stormwater management much more effective. Technological advances in monitoring and collecting tools have made possible real-time data that can be custom-programmed for the site.

Civil & Environmental Consultants

A Green Roof in Pennsylvania

In southwestern Pennsylvania, an average rainstorm can produce 2 inches of rain in a 24-hour period. Even 2 inches of rain falling on a roof can result in runoff of more than 600 gallons of water. As little as 1/10 inch of rain can cause combined sewers to overflow.

Like many cities and counties, Allegheny County (Pittsburgh) needs a wastewater system upgrade to solve the problem of extensive combined sewer overflows (CSOs). And just as with other municipalities, it doesn't have the funds to pay for it.

One lower-cost solution is to reduce stormwater runoff so that its smaller volume will decrease the chances of CSOs happening. Toward that objective, Allegheny County officials decided to install a green roof in an urban location as a demonstration project.

The green roof above the Allegheny County Office Building is Pittsburgh's first green roof on a public building. It was built in 2010 for $621,400, using federal stimulus funds. Half of the existing roof remains as it was, to serve as a comparison.

Cuddy Roofing of Pittsburgh installed the green roof. Eisler Landscapes of Prospect, PA, did the landscaping. Civil & Environmental Consultants (CEC) of Pittsburgh has an ongoing stormwater monitoring project on the green roof.

Monitors on both halves of the roof collect data regarding temperature, humidity, and rainfall. As a public education feature, the data are available online so that anyone can track the performance of the green roof compared to its adjacent normal roof. Monitoring the green roof's success in reducing runoff is critical to the project's ultimate goal of encouraging the installation of other green roofs to lessen runoff. "We can't talk about the benefits of a green roof without monitoring it," says Darla Cravotta, special

projects coordinator with Allegheny County.

CEC project manager and soil scientist John Buck is monitoring the green roof for six years, using eight HOBO U3O weather stations. Onset Corp of Bourne, MA, manufactures these instruments. These U30 weather stations have about 90 separate sensors to track soil temperature, soil moisture, runoff duration, wind speed, wind direction, air temperature, relative humidity, and solar radiation.

In 2005, Buck used Onset data loggers to track data for an alternative soil cap study at a solid waste disposal site. The advances in technology in just a few years are interesting.

"We created a 900-MHz network that relayed data and e-mailed me three times a day," he says. "When you consider the dependence of that system on the computer at the site, and the power outages, Windows updates, and the fact that the computer hated zero-degree weather, you've got a lot of variables. The U30 cut out the intermediate computer and 900-MHz radios and simplified the system."

The U30s are weatherproof and transmit the data via WiFi to Onset's Web server. Buck planned to use WiFi communications for all eight weather stations, but WiFi would not transmit through the roof. He put two Ethernet-enabled U30s inside the building. An access point on the roof allows the other six WiFi devices there to communicate. Buck is using Onset's HOBOlink Web server as a data repository and a way to monitor the system remotely, sensor by sensor.

The stations will also be used to detect humidity spikes in several roof areas. Because the 1923 building already had a history of roof leaks, there was understandable worry by Allegheny County officials that the situation that could be made worse by putting structures up there.

To prevent leaks, Buck started by installing a completely updated roof membrane. "That roof membrane can last two, three, even four times as long as a conventional roof," he explains. Then he put in place not one, but two, means of detecting any possible leaks. Both measures will operate quickly if need arises.

An electric field vector map on a wire trace goes around the entire roof, on top of the membrane. The wire grid can energize it and thus detect the location of a leak down to within 1 square foot.

The county's data center is located right beneath the green roof. The system was already planned to track moisture levels. To allay fears of a leak right over such a critical area, Buck added temperature sensors on the ceiling above and below both the green and regular roofs. Tracking that relationship of temperature and humidity provides an extra safety net. If preset limits are reached —which could suggest a possible roof leak—the station will automatically send Buck a text message alert.

"We'll get a message before the water starts dripping," he says. "That wasn't a primary objective of the project,

but it is a benefit."

The roof was designed to capture 1 inch of rain after the plants had fully matured. Buck says it is performing even better than planned. "In some months the green roof has achieved 100% stormwater abatement. It has exceeded my expectations," he says.

The summer temperature of the green roof is 40 to 50 degrees cooler than the control roof, thereby decreasing the "urban heat island" effect. Two engineering students from Carnegie Mellon University studied the temperature differences between the roofs. The green roof has resulted in about a 75% reduction in heat infiltration into the building. In winter, the green roof has reduced heat loss by about 12%.

The electric bill for the building in 2010 was about $92,000 less than before the green roof was installed. Municipal officials were delighted and expect to add more green roofs as funding allows.

Flow Studies: Detective Work

Scott Teter, field operations manager for Instrulogic in Round Hill, VA, relies on Stingray portable level velocity monitors from Greyline Instruments of Massena, NY, for conducting flow studies.

"I did a flow study for the Berkeley County Public Service Sewer District in West Virginia to monitor sewer flow coming out of an industry plant," he says. The company's owners were sure the excessively high sewer use bill they had received was incorrect. They complained to the sewer district, which called in Teter.

"We monitored it for a month. It turned out that an employee had left a valve open, and the water was coming from their chillers," explains Teter.

"These data loggers log level velocity and temperature," he says. "I use a five-minute interval. Direct from a pump station you might set it down to a two-minute interval. You can set the Greyline down to 30-second intervals if you need to."

For another West Virginia job, in Harrisville, Teter used six Greyline Stingrays to monitor inflow through sewer pipes. He installed the meters, trained an engineering firm's employee to collect the data, then went back and removed the instruments from the upstream/invert pipes.

The sewer district needed the information "to figure out what sections of the sewer system had the most problems so they could figure out where to spend the money for sewer rehabilitation, to get the biggest bang for their buck," explains Teter.

Reflecting on the use of meters in stormwater work, Teter says, "A lot of manufacturers of instruments want to get everything wireless so people don't have to go any distance [to see data], and that's a good thing. But," he adds, "somebody needs to be going out to check that sensor and be sure nothing is hung up on it, to be sure it's clean. It's important to check sensors on a weekly basis."

That checking "takes time and it takes manpower, but if you want good results, it's a must," he states.

Capturing Data in an Arid Climate

Since 1994, Larry Walker Associates (LWA) of Davis, CA, has been the primary firm responsible for stormwater monitoring in Sacramento and Sacramento County, CA. LWA uses both its own employees and municipal workers, depending on the project.

The work involves monitoring 10 urban tributaries, three long-term discharge characterization sites, bioassessment monitoring, and coordination of river monitoring activities.

LWA also assists with National Pollutant Discharge Elimination System (NPDES) studies, permit issues, and water-quality objectives.

The firm's biggest challenge is "the complexity of the monitoring program," says Brian Laurenson, vice president. "You can't really schedule stormwater monitoring. In an arid climate like ours, you don't have that many chances to do live storm monitoring."

He estimates, "Sacramento has monitored only 50 to 55 wet weather events over the past 20 years. As we get more probes, we get more robust data sets."

Rainfall in Sacramento averages only 18 to 19 inches annually, but "even smaller streams can rise four, five, six, seven, eight feet in a few hours. You have to balance onsite monitoring and collection with safety [of workers]," explains Laurenson. But "with sensor technology advancements, we don't have to use as many crews. We can save field time."

LWA has had automatic sampling at sites for 20 years, "but in the last five years it's gotten less expensive and easier to deploy," says Laurenson.

"We're moving more and more toward using automated equipment and having continuous sensors at our sites," says Jeff Walker, LWA's chief engineer.

Walker relies on In-Situ's RDO Pro optical dissolved oxygen meter. "I'm happy with this sensor. It gives good performance," he says. "Oxygen levels can change a lot in a day. We collect data every five minutes."

He finds that the new technology of the last five years "performs significantly better" than that of older oxygen sensors.

Laurenson agrees. "The older type with membranes were hard to keep calibrated."

Walker likes to customize the company's equipment. "In-Situ is the only manufacturer where you can buy just the sensor and hook it to your other equipment. We can get a lot of data at an acceptable cost."

Cleveland Metroparks

Cleveland's Metroparks are at the receiving end of heavy runoff from surrounding communities. The parks have become catch basins for stormwater, which is impacting aquatic habitat, eroding hundreds of miles of riverbanks, and flushing sediment into Lake Erie.

Increased stormwater runoff resulting from urban development has had a negative effect on the parks system and overall watershed health. The unnaturally high flow rates overwhelm headwater streams, which serve as tributaries

for larger streams and rivers.

Under normal circumstances, headwaters moderate flow from heavy rains, process nutrients, and reduce sediment. They also provide habitat for unique native flora and fauna in the water and in surrounding riparian habitats. With heavier runoff, however, they are subject to channelization, culverting, and pollution. Additionally, streambed scouring destroys the habitat used by many native species.

As a stream becomes urbanized, flashy water causes scouring of substrate, removing the interstitial spaces within where invertebrates live. Sensitive species, such as stoneflies, mayflies, and caddisflies, which require undisturbed habitats to survive, begin to disappear.

Within the Rocky River watershed, Cleveland Metroparks staff have been studying vulnerable headwater streams affected by the runoff and the effectiveness of small wetlands for water storage and water-quality improvement. The Metroparks system contains 900 separate headwaters. The complete census has been done; in subsequent years, subsets will be sampled.

"Our director of natural resources, John Mack, came from the Ohio EPA, where he had done a wealth of wetland monitoring. He really understands the need to gather baseline monitoring data," says Jennifer Grieser, senior natural resources manager for Metroparks. "In his first year here, he set up a number of monitoring projects. A USEPA grant paid for the bulk of the monitoring equipment. Our first project was to monitor wetlands around our administration building in Rocky River Reservation [a 2,600-acre park]."

Cleveland Metroparks

Cleveland State University stream ecology class visiting a monitoring station

That monitoring project ended in mid-2010, but monitoring of other wetlands within the park system continues. Some of these are constructed wetlands, the result of mitigation for projects that removed wetlands elsewhere.

"In our Lake-to-Lake area, we have the largest remaining wetlands complex in Cuyahoga County. We're using Isco flow meters, a couple of US Geological Survey monitor gauges, a couple of water-quality sondes from Fondriest," says Grieser.

The monitoring of wetlands and headwaters is all a part of Metroparks "taking an ecosystem approach," says Grieser. "We're reaching out to communities, businesses, entities adjacent to us."

Cooperation and interest from Metroparks' neighbors is likely to be stronger because the Northeast Ohio Regional Sewer District has "just unveiled a regional stormwater program with a stormwater utility fee to anyone with impervious surface," says Grieser. The new program includes most of Cuyahoga County (Cleveland) and parts of Summit and Medina Counties. A consent decree from EPA requires $42 million of new grey and green infrastructure.

Another Metroparks stormwater project is adjacent to the 500-acre West Creek Preserve. Each residential street there has outfalls that become feeder streams carrying runoff to West Creek as it enters park land.

Residents on some of these streets have installed rain gardens and rain barrels. Bioswales now run along the

right of way. Two streets have no stormwater measures and are the controls. Isco 2150 Area Velocity Flow Meters have been installed on streets in both categories.

"They're super-durable and super-reliant," says Grieser. "The sonde meters have to be calibrated every so often. They take a lot because they have moving sensors."

Metroparks' Lake-to-Lake area used to be called Podunk Swamp. Grieser says this is another section that will benefit from improved stormwater management, such as adding deep-rooted native plants. "We're trying to improve it for songbirds and migrating waterfowl," she says.

And the area along Sheldon Road is plagued with chronic flooding after heavy storms because it is in a low elevation. Stormwater improvement in the surrounding area should stop the road closures that happen now.

Unlike previous studies, the current and recently finished monitoring projects done by Metroparks researchers collect real-time flow and water-quality data. The emerging hydrologic patterns of stormwater quality and quantity are much more precise. Instead of the daily or monthly samples and level measurements used in existing research, the continuous monitoring network provides data every 15 minutes. Being able to turn up the unexpected is one of the key advantages to having the continuous, real-time data.

"With the flow meters, we're getting actual quantities of water. That level of detail allows us to find stuff that we couldn't before," says John Mack. "We sometimes don't know what we're going to find, because no one has ever been able to collect this kind of data."

He adds, "The ultimate goal is to do urban watershed restoration using real short-interval data to track performance. We're trying to figure out how to use the equipment and work out the kinks before using it on a larger scale."

Mack believes that one of the key solutions to the region's stormwater problem is use of smaller wetlands that are hydrologically isolated, which are highly effective at water removal.

In a previous study he conducted while working for the Ohio EPA, Mack and colleagues found that small isolated wetlands were capable of removing three to four times the amount of water compared to riverine wetlands. The isolated wetlands can retain water until it is removed through transpiration and evaporation, whereas water can move out of riverine wetlands before this occurs.

Metroparks' monitoring work on wetlands is in essence a follow-up to the investigation he conducted with EPA, Mack says. The new level of detail afforded by digital monitoring systems, he notes, marks a giant leap in ecological studies.

"This is happening all through ecology," he says, citing what many are calling the "digital revolution" in the field. "Ecologists are suddenly able to ask questions they never could have asked before."

For related articles:
www.stormh2o.com/water-quality-monitoring

Monitoring on the Golf Course

About half of the world's 35,000 golf courses are located in the United States. Most of them have at least one stream, either to enhance the natural setting or to present a challenge to play, as a water hazard. Courses also use their streams for irrigating the greens and fairways.

Common golf course practices or design features that could alter a stream's aquatic ecosystem include the entry of pesticides and fertilizers into the stream via runoff or groundwater flow, reconfiguration, and channelization of streams,

Stream water temperature is an extremely important water-quality parameter. It significantly impacts the health of stream ecosystems, and that of the aquatic species within and other wildlife nearby. It also affects microbial activity and various components of water quality.

To assess the effects of some golf courses on the temperatures of the streams flowing through them, the National Science Foundation sponsored an undergraduate research project. The study was directed by Furman University.

Now a geologist with Aerostar in Jacksonville, FL, Kevin Ashman was a student at Georgia Southern University when he participated in this research project. The project assessed the impact of five 18-hole golf courses in Green-

ville, SC, on stream water temperature. The courses all had continuous, tributary, and lake-free reaches that passed through their grounds.

The student researchers installed HOBO Water Temperature Pro v2 Data Loggers from Onset at points where the streams entered and exited the golf courses. The loggers have an accuracy of ±0.2°C from 0° to 50°C and a resolution of 0.02°C at 25°C.

"Setting up the loggers was easy, and it was easy to pull off the data," says Ashman. "They worked wonderfully."

The students used zip ties to attach sensors to cinder blocks or a piece of rebar driven into the stream bottom. Conscious efforts were made to locate the upstream and downstream sensors in similar conditions of water flow and depth, shade, and surrounding area.

"We wanted our data to be consistent, so we put our sensors in the centers of the streams. Water's stagnant at the stream edges, so it gets warmer there," explains Ashman.

At least one readjustment had to be made. "In one stream, the high-flow conditions kept the sensor held down," says Ashman.

The sensors measured stream water temperature at five-minute intervals from July 1 through October 31, 2008. The data were offloaded monthly.

In addition to stream temperature, stream discharge was manually measured using a current meter under baseflow conditions at the downstream logger location in August 2008.

Sites downstream of the courses exhibited elevated stream water temperatures (on the order of 3–4°C during the afternoon hours) and increased diurnal temperature ranges (1–4°C larger) compared to their upstream counterparts.

The students concluded that temperature differences between the upstream and downstream sites were primarily due to the lack of riparian cover. The magnitude of the temperature differences among the courses was largely a function of stream discharge. Smaller streams were affected much more.

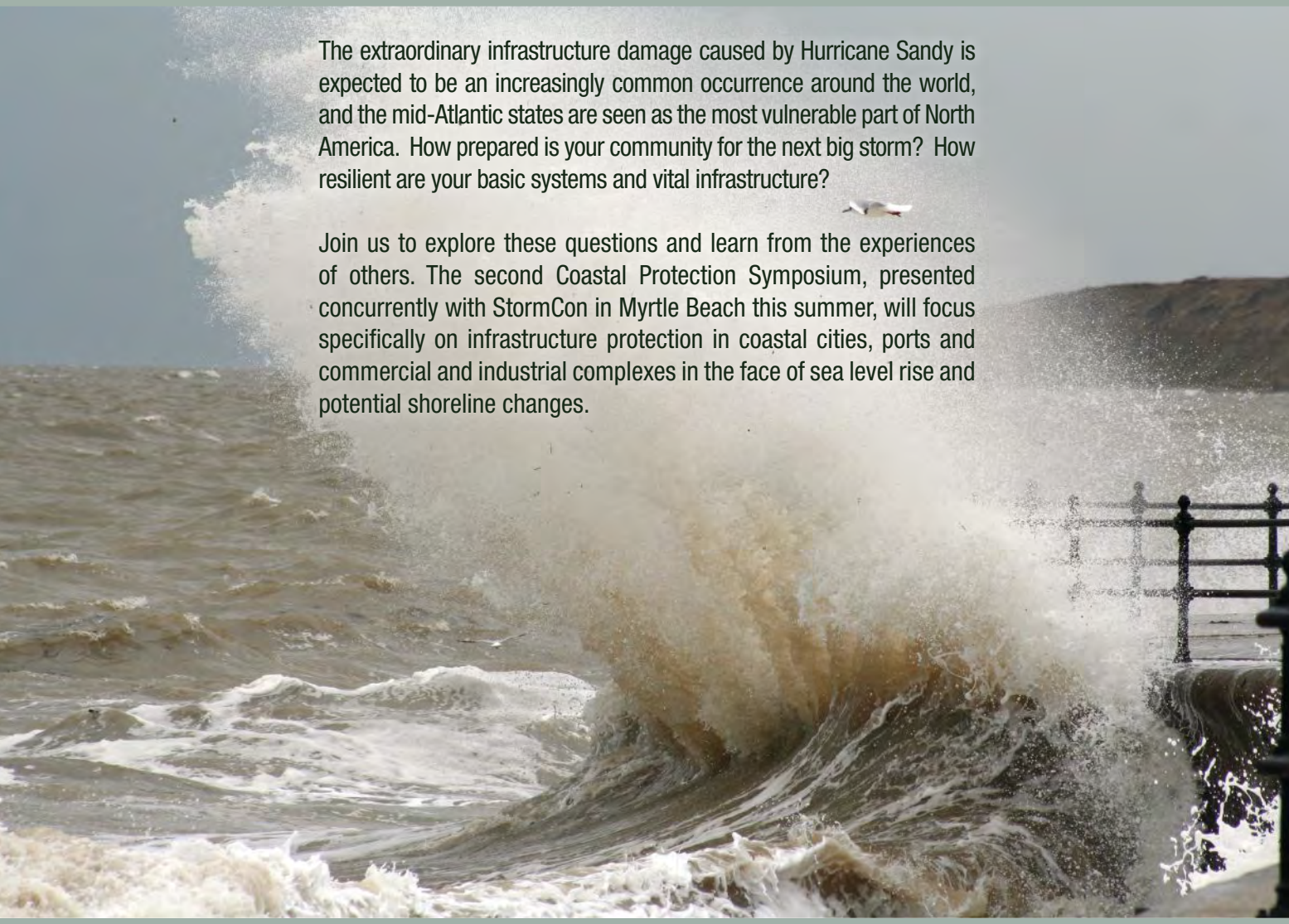
The study's authors suggest that new golf course guidelines recommend or require sizable vegetated buffers along streambanks. The resulting shade over the streams would help protect aquatic species and ecosystems by keeping water temperatures consistently lower. Vegetated buffers provide habitat for wildlife. They would also help filter and reduce nutrient loads carried into the streams from runoff.

Given these real-world, real-time examples of monitoring and metering to improve stormwater management, it's likely that both the precision and capabilities of the tools will increase.

Margaret Buranen *writes from Lexington, KY, on business and the environment for several national publications.*

COASTAL PROTECTION SYMPOSIUM

WHO'S NEXT?



The extraordinary infrastructure damage caused by Hurricane Sandy is expected to be an increasingly common occurrence around the world, and the mid-Atlantic states are seen as the most vulnerable part of North America. How prepared is your community for the next big storm? How resilient are your basic systems and vital infrastructure?

Join us to explore these questions and learn from the experiences of others. The second Coastal Protection Symposium, presented concurrently with StormCon in Myrtle Beach this summer, will focus specifically on infrastructure protection in coastal cities, ports and commercial and industrial complexes in the face of sea level rise and potential shoreline changes.

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Kathy Keating

CLEANER STREETS, CLEANER WATER

Street cleaning is more than "picking up trash"; it may be the first, and least costly, defense against water pollution.

BY JANIS KEATING

Ask the average citizen about "street sweeping," and chances are she'll say, "It cleans up the trash people toss out of their cars." This is, of course, true, and what most people notice. Minutes after Los Angeles' 2013 Golden Dragon Parade ended, pedestrians quickly returned to Chinatown's sidewalks as street cleaners whisked along the parade route, collecting the numerous piles of paper confetti and Mylar streamers shot from and to the crowds.

However, street sweeping does much more, and not only citizens, but also their municipalities, need to realize what's actually on the streets, and what that debris can do to local waterways, and, perhaps, residents' health.

Roger Sutherland, P.E., principal water resources engineer with AMEC Environment and Infrastructure in Portland, OR, who's slated to give a talk on street cleaning at StormCon 2013 in August, points out that "aesthetic" definition is causing problems for America's cities as well as its rivers and streams. "What I call 'street dirt' is composed of heavy metals and other pollutants —items that may be killing fish when they get into waterways via stormwater runoff. Ironically, some cities are trying to solve the problem by using media filters for stormwater treatment, when effective street cleaning could lessen much of that problem at about one-fourth the cost, based on a pound of sediment removed from the stormwater."

To Sweep, Perchance to Clean?

To begin with, Sutherland thinks a simple name change would offer a better understanding of what the process entails. "I prefer to call it street cleaning. The connotation of 'sweeping' is 'sweeping under the carpet.' 'Cleaning' is something useful—a job well done."

Street "sweeping" has likely been performed for centuries—of course, before the advent of automobiles, much of that cleaning entailed horse manure. However, the cleaning vehicles we see today had their start around the turn of the 20th century. Many cities across America purchased them, but their effectiveness was somewhat limited.

"I can't tell you how many American cities sweep and how many don't," says Sutherland. "It's a situation where a number of communities swept streets for years and years. As far back as 1969, 'street dirt,' the material accumulating mainly in the gutters, was identified as a source of water contamination. In 1972, in the first USEPA publication ever on stormwater [Sartor and Boyd 1972], street dirt was named as the *primary* source of contamination, in terms of mass."

The contamination was identified, so

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one would think street sweeping was desperately needed. "And yet," he says, "what happened was, EPA did a study of the effectiveness of best management practices needed to remove stormwater that involved 30 American cities—the Nationwide Urban Runoff Program, between 1980 and 1982, at a cost of about $30 million. EPA looked at studies and technology, and concluded sweeping was 'ineffective in the ability to reduce pollutant concentrations found in stormwater.' This was a death knoll for street sweeping for America.

Stewart-Amos

The Starfire S-4 mechanical broom street sweeper by Stewart-Amos Sweeper Co. is mounted on a highly maneuverable, fuel efficient, non-CDL chassis.

"If a community was trying to cut costs, street sweeping was one of the first items to go," he continues. "EPA's evaluation was correct when it was made; 1980 machines were not very effective at picking up sediment, especially the finer material that contains a higher proportion of the contaminates. But now we have really lost sight of how smart people, mechanical engineers, have improved the technology in street sweeping."

Street Tech: The Next Generation

Sutherland gives an overview of street cleaners on the market today. "Mechanical machines, which use a main broom and conveyor belt to pick up material—the only ones being used at the time of that 1980s EPA study—have been around at least 100 years. Their design hasn't changed that much, although impressive improvements have been made, such as the broom design and speed, and the conveyor belt speed and alignment, which carries particulates to the hopper. The mechanical machines are still the most popular—perhaps 90% of those in operation? During my next webinar I'll have to ask the attendees for a 'show of hands' on the type of machines they use.

"There are also regenerative air street cleaners. In one motion, the machine blows air down on the pavement to dislodge material, and then the air is immediately vacuumed into the hopper," he adds. "Some of these machines can stir up lots of dust, because most do not filter the return airflow.

"Vacuum machines are just that, and they can be very effective. Manufacturers have strived to increase the fan speed and create a greater vacuum. But sediment in the return airflow limits their ability to do just that. Perhaps Dyson should be working on this?" jokes Sutherland.

"All of these machines can, and some have been designed to, capture fugitive dust and basically filter it in some way," he says. "Each of the major manufacturers has one or more sweeper models that do just that. In fact, I believe that only these machines should be viewed as 'high-efficiency cleaners,' a term I coined in 1997. Certainly, all street cleaners are more efficient than what was tested in the 1980s. Some can actually change the color of the pavement, and there's no dust."

Picking up the contaminants is, after all, the objective. "If you're just 'sweeping,' you're blowing it away," he says. "True, that contaminated material has less chance to get into stormwater, because you've blown it onto nearby grassy areas, where it can infiltrate through the soil. Of course, though, this irritates people, and it looks awful, going

down the street in a cloud of dust—and it's not good for anyone breathing in that stuff."

Beautiful Downtown Burbank —and Glendale

In Burbank and Glendale, CA, Sutherland's firm and Larry Walker Associates of Santa Monica, CA, have been studying the potential effectiveness of enhanced street cleaning programs in removing heavy metals from stormwater runoff. "We're getting down to the heart of the issue. Are cities cleaning streets merely for the cosmetic or aesthetic value, or to reduce the concentration of contaminants found in the runoff? Our work is a quest to get them to recognize the pollution-reduction benefits of street cleaning. And these two cities sweep a lot—I don't know many in southern California that don't have a program. However, some don't understand the value of that program; even though they sweep, the focus is on aesthetics. If one concentrates too much on the 'big stuff,' everything else will suffer; you may not be picking up the contamination material."

Studies such as this are being driven by total maximum daily loads (TMDLs) for various waterways. "Heavy metals —cadmium, copper, lead, zinc—are specific pollutants of interest in Burbank and Glendale, since they're included as part of the Los Angeles River TMDL," says Sutherland. "The study we did was just the first step; maybe next year they will move to the next step.

"We put together a street dirt sampling program that monitored the accumulated material both before and after sweeping, for three separate sweeping events, spread over a three-month period in late winter and early spring," he adds. "Interestingly, to my knowledge, this is the first time anyone had sampled street dirt in southern California. We need to learn more about street dirt—its accumulation over time, its particle size distribution—but most importantly, we need to learn more about the pollutants that are in it, and their association with these particle size groups. If we focus on the pollutants by particle size group, we can understand how effective the different cleaning processes are."

Using Google Earth and Street View, Sutherland's team selected 10 different areas, five in each city. "We selected typical land-use areas: single-family residential, commercial, major arterials, and industrial areas. We started the data collection program, knowing the cities were not going to stop cleaning; one sweeps weekly, the other, every two weeks. So the data collection program was designed to determine the pickup effectiveness of these cleaning programs. Unfortunately, not being able to stop the cleaning program made it difficult to see much accumulation there would have been if cleaning had not occurred."

To find what's occurring in his field of study, Sutherland uses a Google alert feature which lets him know daily when the terms "street cleaning" and "street sweeping" appear in postings throughout the world. "There's a tremendous amount of chatter out

there—people are upset about sweeping. 'So I moved my car and they didn't sweep' is a recurring complaint. Perhaps people would be more compliant if they knew more about street cleaning, and how important it is in the battle to reduce pollutants in stormwater. Public education on this topic is needed."

Educating the public might be accomplished by shifting street cleaning's "image" from "a tidy city" to "averting health problems." Sutherland wonders, "Do we breathe any of this dust that's being swept up? Yes, street cleaning removes possible pollutants from stormwater, but it also could help keep them out of the airshed. Machines that embrace filtering airflow with pickup are particularly effective in reducing pollutants in the air, such as PM_{10} particulate matter. If you're filtering to about 2.5 microns, you're doing a good job. All major street sweeper manufacturers have a machine or two that have been fitted with this type of advanced technology. These are the true high-efficiency cleaners that every city should work towards obtaining."

Tymco

The Model 600 regenerative air sweeper from Tymco

Sometimes the street pavement can be part of the problem: "Want to improve water quality? Maintain the condition of street pavements to 'good' if at all possible, since 'poor' condition streets contribute to the pollutant load when the asphalt and concrete break down," he says.

Getting stuck in traffic behind a street cleaner will take less of one's time these days. "It had been thought that to be effective, street cleaners had to sweep fairly slow—five or six miles per hour. However, studies in Burbank, Glendale, and elsewhere have shown that today's cleaners can sweep at twice that speed—10 miles per hour or so—and do the job well. Of course, an experienced driver who wants to do a good job will slow down if he encounters an atypical, higher accumulation."

Water: Part of the Problem

Dry street cleaning captures the pollutants before rains can transport them someplace else, such as down a drain, which makes them even more of a hazard. "A few years ago, I read research, done in Hamilton, ON, in which the team went around the city, especially its industrial areas, and picked up street dirt [Irvine et al. 2009]," says Sutherland. "Their data went beyond the particle size distribution and chemical analysis, such as total pollutant mass, as I and others have done. They also looked at the bioavailability or solubility of the metals in much greater detail. They identified four different categories of metals' bioavailability, from 'readily available,' once the material is wetted, to 'potentially available,' under certain environmental conditions that may not often be met. As an example, copper's bottom line: The bioavailability of the accumulated street dirt ranged between 21% and 73%, depending upon land use and contact time. It's ironic—humans can drink a certain amount of cadmium, copper, zinc, and so on. If toxicity levels were based on *human* consumption, the levels would be higher, but these metals are very bad for fish, so toxicity levels are much lower."

When soluble metals do get into stormwater, is there any way to get them out? "For passive stormwater treatment, some argue the most effective way to reduce soluble metal

pollution is to use media filters with the appropriate media," he says. "However, that's very expensive—costing up to perhaps $20 per pound of sediment that contains metals removed from the stormwater. On the other hand, by street cleaning, I can pick up these metals and contain them for about three to five dollars per pound of sediment removed from the stormwater. That's why we need street cleaning—it's good for the environment, and better for municipal budgets."

Although the composition of street dirt is now better known, 30 years ago Sutherland confused labs with his samples. "When I first collected street dirt in the 1980s and got back the results, the testing lab asked 'What mine is that sample from?' When I told them the sample was southeast Portland street dirt, they said *'What?* We found almost every single metal known to man, except gold and silver.'" Sutherland chuckles, "Heck, if there *was* gold and silver in it, *everyone* would be cleaning the streets."

Yet, after 40 years of stormwater data collection, there's still not much known about the source of this road pollution "street dirt." "We still don't understand all of it, and most communities don't know anything about this material. Gary Minton, author of *Stormwater Treatment: Biological, Chemical, and Engineering Principles*, wrote an article calling stormwater sampling 'a fool's errand,' because you can take a grab sample of stormwater, but it tells you nothing about the pollution's source and what you can actually do about controlling those sources [Minton 2009]. We have asked 'How did these metals get into stormwater?' and the answer is 'Via the street dirt.' From some California work, we learned the street dirt was related to buying cheaper automobile brakes from Asia. No one seemed to care that these imported brakes were very high in copper, which is very toxic to fish and highly soluble. Just by stopping that purchasing practice we were able to reduce copper in street dirt, which in turn reduced the concentration of soluble copper in stormwater. Thankfully, lead is one of the least soluble metals in water, because when we had leaded gasoline, there was an order of magnitude higher concentration of lead in street dirt—and, as a result, in the stormwater. More studies on the original source of contaminants found in street dirt would be very helpful in identifying other 'common sense' sustainable practices that can be implemented.

"Our own behaviors can have an impact," he continues. "Something as elemental as leaves, which are full of nutrients—communities that don't have an aggressive leaf pickup program are missing the boat. Since street dirt contains many toxic contaminants in high concentrations, we should be very focused: How can we get that stuff before the rain does, or even before the street dirt does?"

Areas that still think of street cleaning as "appearance" are likely wasting money. "The amount of effort some

spend sweeping downtown every day is ridiculous. For one thing, that's high labor costs—albeit deserved, as street cleaner operators should be well educated, because they're the first line of defense against stormwater pollution. There's no reason to street-clean with expensive machines every day; we monitored areas that were swept daily, and the amount of accumulation was under 100 pounds per curb mile, versus 300 to 600 pounds per curb mile everywhere else."

Town of Zebulon

The town uses its street sweeper to help spread the stormwater message.

Water: Part of the Solution?

What's on the horizon for street cleaning? "There's another technology I've teased people with—I'm amazed it doesn't yet exist here—called 'captive hydrology.' Their term, not mine," says Sutherland. "Think of it as a 'carpet cleaner for pavement,' a machine with both clean- and dirty-water tanks. Rotary arms with nozzles on the end blow water down on the pavement; the back end of the machine features a powerful vacuum and a squeegee that sucks up the water and the debris it contains. We used this technology as part of the work I did in Israel in 2000 through 2004; I'd never seen it before then. We were cleaning some paved areas outside a cement factory—phenomenal amounts of accumulated dust, until we cleaned. After delivering its passengers to a nearby attraction, a tour bus rolled up, and the driver asked, 'Is it OK to park on the clean, brand-new pavement?' This machine's power is remarkable; it can be used to scarify pavement, or remove paint. Right now, this technology is being used in the UK, Germany, Israel, and the Netherlands. However, it's expensive, and I was concerned that it didn't have a gutter broom, so accumulated street dirt, against a barrier like a curb, would be missed.

So I thought, wouldn't that be great if someone added gutter brooms, to throw the accumulated material into the machine's path? Well, last December, someone sent me a link for a Turkish manufacturer I didn't know that's essentially combined the pressure-washer technology with adjustable, responsive, dual gutter brooms."

Despite the costs, "pressure washing" streets might be a great solution—providing the water's removed—especially for a question that's yet to be answered: What are the health effects of street dirt pollutants once they become airborne? "That's a good question," Sutherland concludes. "How much illness, how many deaths a year could be linked to breathing street dust?"

Small Town, Big Ideas

The town of Zebulon, NC, population 4,500, might be small in size, but big on ideas for keeping streets and streams clean.

"For us, sweeping is a big part in meeting our stormwater management program goals," says director of public works Chris Ray. "We're trying to prevent debris and catch it before it enters the stormwater system. Along with our sweeping program, we and stormwater superintendent Tony Rose promote stormwater education: mainly, telling people to not put stuff into storm drains. We talk at schools and public events, such as Zebulon Festival on the Lawn and Zebulon Business Expo, on the importance of keeping debris or other foreign objects out of the storm drainage systems. Our in-person efforts are reinforced by the work done by our volunteer stormwater stenciling program."

To make street cleaning as effective as possible, Zebulon recently purchased a Schwarze A7000 street sweeper. "Buying this machine and putting the informative 'wrap' on it was a significant investment for our small town, considering our typical stormwater budget is $151,000 a year," says Ray. "It cost us $170,000 to purchase the sweeper, which includes highway use taxes and tags, and to install the vehicle wrap, which was designed by Looking Glass Communications and installed by Capital City Signs, both of Raleigh, NC. The wrap ties in with the brochures, fliers, and t-shirts we give to the public. Since the sweeper goes down roads at two to five miles per hour, it's like a moving billboard down the street."

A state program allowed Zebulon to get a good deal on the machine. "Price is always an issue; we 'piggybacked' a purchase from the city of Lexington. North Carolina has a purchasing listserv where you can post questions. Our staff learned Lexington had recently publicly bid for a street sweeper. We requested and reviewed its specifications and decided the specs met Zebulon's needs, and the price Lexington quoted was within our budget limitations. We advertised our bid process, and the vendor, Carolina Environmental Systems, extended us the same price as Lexington.

"Being in a small town requires wearing many different hats; developing bid purchases is time consuming," he continues. "If we find a town that's already done that, and it meets our requirements, then it's a winning solution to allow you accomplish the purchase and to invest your time in other tasks. We still bring in other vendors for demos and field testing to ensure the machine meets our needs. We review the ease of maintenance, and evaluate operator feedback on performance and ease of operation, as well as discuss with other owners their experience with the machine."

Because it benefitted more than one department, the Schwarze machine's cost was shared by Zebulon's streets and stormwater capital budgets. "Thirty-five percent of the total stormwater budget was the truck, with a goal of it giving us 12 to 15 years of service, with proper preventative maintenance," explains Ray. "Two town employees are assigned to the sweeper full-time, but all public works employees are trained

on it." The dedicated drivers become diagnosticians: "The crew that's on the sweeper all the time can tell by noise or vibration if something is wrong with it. They can stop and fix it before it suffers significant damage. We do most preventive maintenance on it here in our shop, run by our sanitation and fleet maintenance superintendent Dale Matthews. Major overhauls we have to outsource."

Ray says the city is pleased with the Schwarze machine. "We have found the machine is highly efficient on larger debris, but also on PM_{10} fines, which are known to contain a high percentage of heavy metals and other pollutants. The Schwarze A7000 can pick that up. We keep records on the amount of miles and debris picked up in a typical month. We then know that's not entering the stormwater system. The sweeper is proven to get the obvious debris on the street surface, plus the small particulates hidden within pavement cracks and voids. In our small town, we average collecting approximately 28 to 30 cubic yards of debris, or one-and-a-half tandem dump truck loads of debris per month. We feel this is significant."

The street sweeping schedule varies. "Residential areas are swept once a month," he explains. "Major thoroughfares are swept 26 times a year. The downtown area is cleaned weekly. Before we got the Schwarze A7000, we struggled in residential areas during autumn leaf fall, but this machine has no problem with them. We're responsible for 19 miles of the town's maintained streets, plus another six miles of NCDOT roadway in town, for an approximate total of 25 miles of street sweeping."

Zebulon citizens seem happy. "We've heard very positive remarks thus far," he says. "Sometimes, if residents haven't seen the sweeper in a while, they call and ask us to send it to their neighborhoods. This is the second sweeper we've had; the last one was bought in 1997. We're very impressed with the product performance, and have excellent past experience and service with Carolina Environmental Systems."

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Reader Profile

Brant D. Keller, Ph.D.

BY CAROL BRZOZOWSKI

Look for the pinnacle, and you'll see Brant D. Keller standing there. Keller has made it his life's mission to reach for the top, from earning Boy Scouting's highest rank of Eagle to earning a doctoral degree. Military awards and other honors are scattered throughout his resume. From those who have achieved much, much is expected. In Griffin, GA, Keller—who has been with the city since 1992—directs the public works and utilities department. His responsibilities include overseeing the stormwater utility in a highly urbanized area consisting of administration, operations and maintenance, environmental management, water, and wastewater for retail and wholesale operations—including two drinking water reservoir and water treatment facilities and four wastewater treatment facilities. He also manages that which sits under the umbrella of the public works department: cemeteries, parks, golf course, transportation, and traffic control.

What Led Him Into the Field of Stormwater Management

Keller's career path has taken him through the education, private and public sectors—from the local to the federal level—giving him a wide view of the working world. Working on construction projects led him back to local government and the chance to practice customer-focused "lean management" in the local government sector. A self-described conservationist, Keller says he enjoys that he works with a city commission whose members have a vision of environmental sustainability and "good stewardship of our resources." That visionary thinking led to the creation of Georgia's first stormwater utility, the first 100%-compliant FOG (fats, oils, and grease) program, the state's first mandatory recycling program, and the development of a regional drinking water supply system. "My board and our citizens have allowed my staff the opportunity to promote and build environmental awareness in the region," notes Keller.

Brant Keller speaks at a public outreach event, with help from a local mascot.

What He Likes About His Work

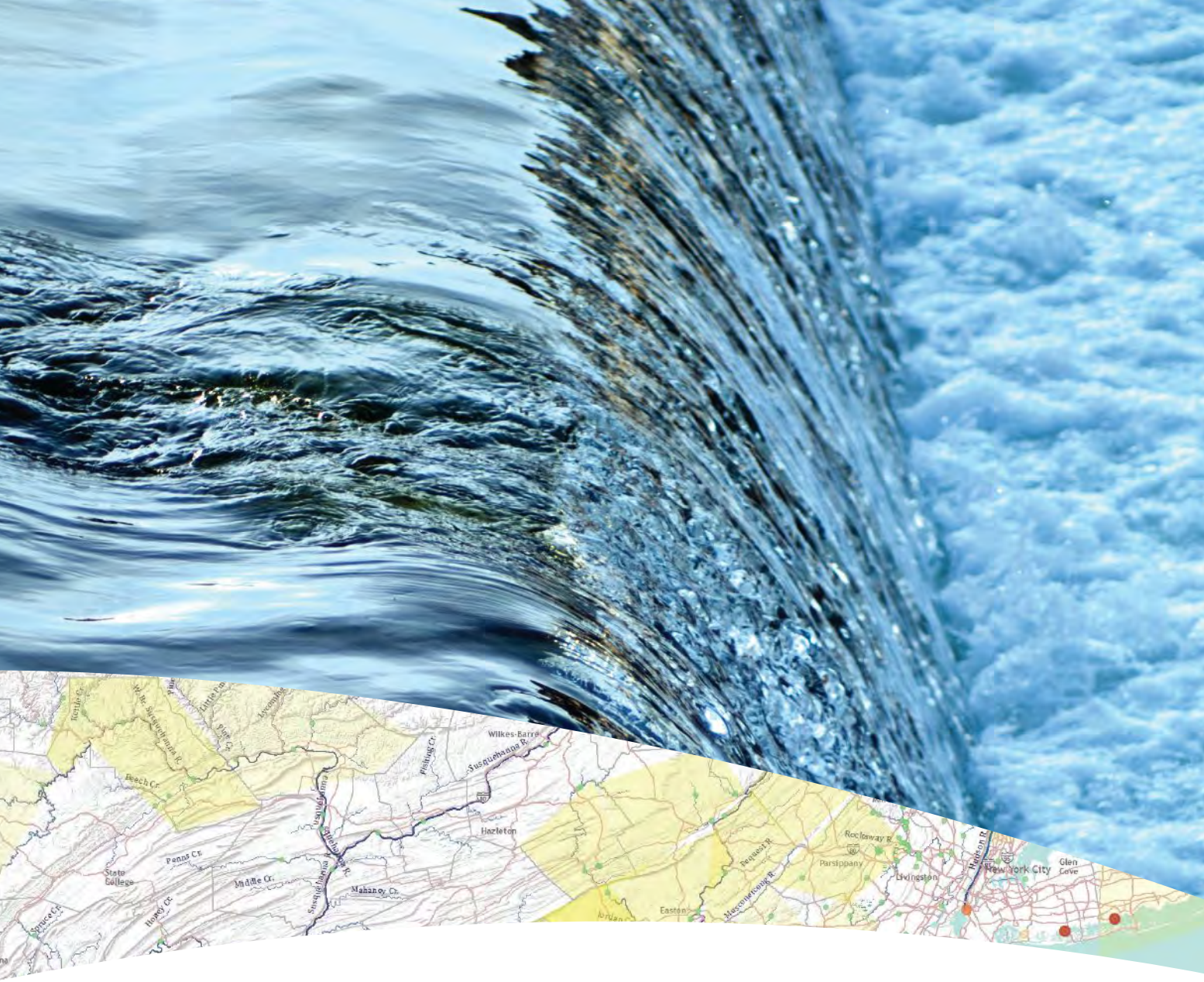
Keller enjoys working with the citizens, the city's elected officials, the city manager, and city staff on improving Griffin's health, welfare, and safety. That's due in part to the fact that for the past decade, city manager Kenny Smith has demonstrated forward thinking and has allowed his department to meet environmental challenges head-on. Keller is cognizant that there is not much more for which someone in his position could hope. He also welcomes the challenges of staying in the forefront of watershed management. To that end, each department has long-term master plans. "Currently, we are preparing lean documentation practices to ensure funding is available for future programs and projects," says Keller.

His Biggest Challenge and What He's Doing to Meet It

Griffin's road to a successful stormwater program has been paved with honors, awards, and achievements in categories such as "Gold," "Silver," Platinum," "Best of," and "Excellence in" from such groups as the Georgia Association of Water Professionals (GAWP), Georgia Water Wise Council, and the US Environmental Protection Agency. In 2012 alone, Griffin won first and second place honors for GIS maps from the Georgia Surveying and Mapping Society; Gold, Silver, and Platinum Awards from GAWP; the distinction of Outstanding Distribution Operations Medium System 2012 from GAWP; and the Georgia F.O.G. Alliance Program of the Year 2012.

One might wonder why Keller views that as his biggest challenge. But he says he fears he and his staff members may become complacent, adopting an "I have arrived" attitude. Addressing that fear means setting a higher bar and reviewing goals on an ongoing basis for continued improvement, Keller says. "Meeting minimum requirements is not acceptable. It's great to have master plans, but if they sit on the shelf, they do not do much good." Action plans require capital, and funding is an ongoing challenge. Aged culverts and bridges need replacing. Rehabilitation of water and wastewater systems is costly. Griffin has delineated all of its basins into sub-basins and designed retrofits of LID projects and proprietary BMPs at more than $40 million. "We are going to have to eat this elephant one bit at a time," notes Keller. "We are looking to partnering, being more efficient in what we do operationally, and analyzing our projects for long-term benefits. Public education and public engagement is critical to meeting our challenges. At the end of the day, we meet our challenges through proactive engagement with citizens, our commissioners, and staff."

Carol Brzozowski *specializes in topics related to stormwater and technology.*



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TARGETED POLLUTANT REMOVAL

Filtrexx® Treatment Train™ for Targeted Invisible Pollutants

EnviroSoxx® consist of sediment control devices with one or more natural additives used to remove invisible pollutants. The EnviroSoxx® product line includes BactoLoxx® for bacteria removal, MetalLoxx® for heavy metals removal, NutriLoxx® for nutrient removal, and PetroLoxx® for hydrocarbon removal, such as diesel, gasoline, and motor oil.

Contact us today to learn how to control your pollutants.

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