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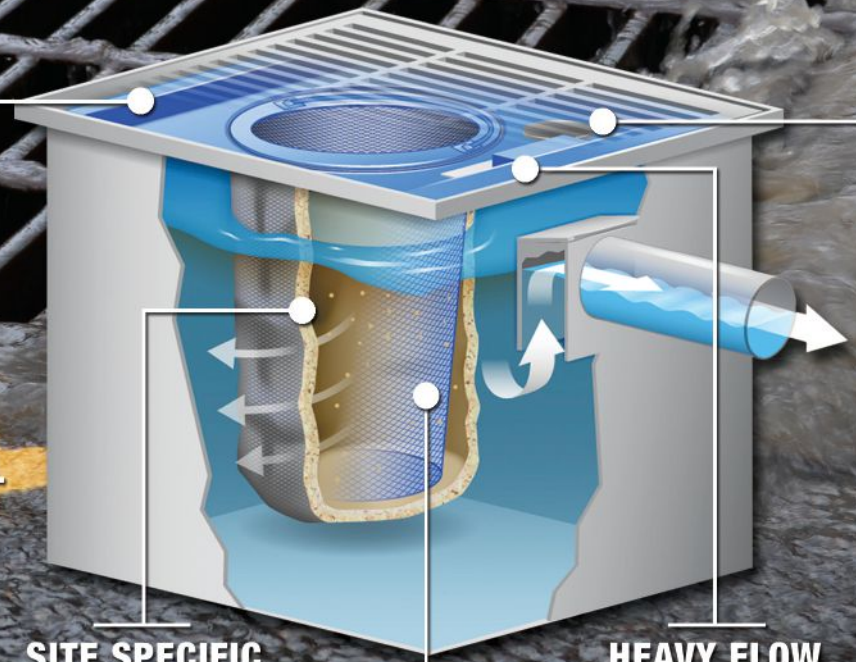

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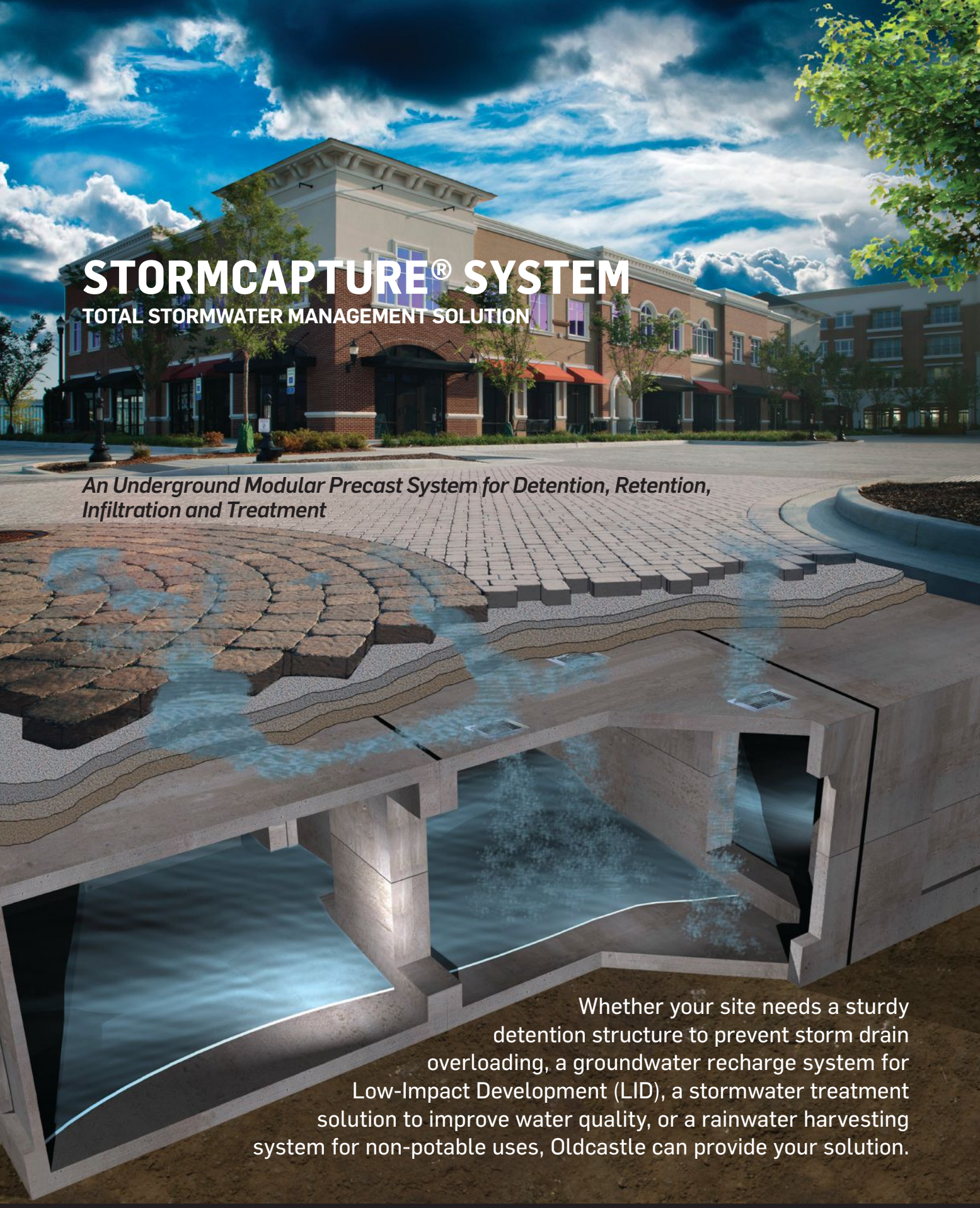

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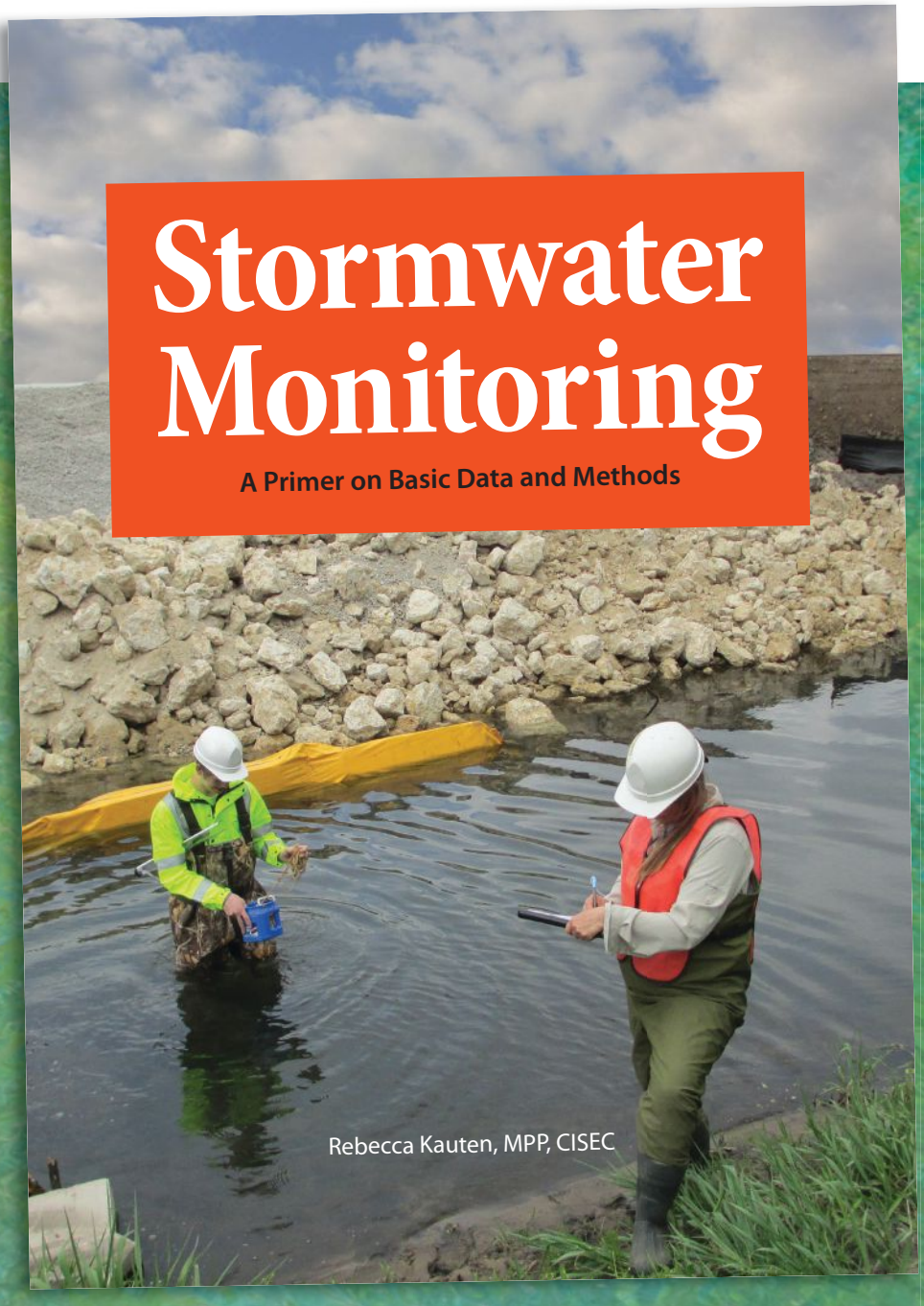

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Breaking the Plastic Habit

By Janice Kaspersen

There's a designated day, week, or month for just about everything you can imagine, and a few things you've probably never thought of, spurred by creative marketers everywhere. Some are serious, some are silly, and all of them promote awareness of a product, industry, company, profession, or cause. We have National Save for Retirement Week (the third full week of October), Spinach and Squash Month (November), Return Borrowed Books Week (March 4–10 this year), National Cheer Up the Lonely Day (July 11), National Zoo Keeper Week (third week in July), Responsible Dog Ownership Day (third Saturday in September), National Start Seeing Monarchs Day (first Saturday in May, and that's butterflies, not royalty), International Surfing Day (June 20), National Garage Sale Day (second Saturday in August), and National Leave the Office Early Day (June 2, unless it falls on a weekend, in which case it's the closest working day).

Getty Images

Now there's a new one: the fourth Friday in February shall henceforth be National Skip the Straw Day. Started by a group called The Coral Keepers, it's intended to make people aware of how much plastic—especially single-use plastic items like drinking straws—ends up in the waterways and ultimately in the oceans. You've probably heard some of the statistics: Americans use (and discard) 500 million straws a day. Half the plastic items produced worldwide—some 150 million tons a year—are made to be used only once. In the near future, the pieces of plastic in the ocean are expected to outnumber and outweigh the fish.

The paper straw was invented in 1888, and now it seems we can't live without them. For those who still want or need to use drinking straws, Skip the Straw Day's founders suggest returning to the original paper ones, which are at least biodegradable, or perhaps bamboo straws, which are both reusable and biodegradable, or permanent ones made of glass or stainless steel that you can carry around and use indefinitely. But as with all the other designated days and weeks and months, this one is part of a larger conversation, and it's not just about straws. Many cities, states, and countries have already banned single-use plastic bags, and now others (Seattle, Glasgow) are placing full or partial bans on straws as well. The European Union wants to ban *all* single-use plastic items in all of its member countries by 2030. The economic implications of that—for manufacturers, restaurants, and retailers—would be far-reaching.

I've mentioned the straw issue in a couple of blogs on the *Stormwater* website, and several of you have joined in the conversation online. Some don't think a ban is the answer, or argue that such things shouldn't be regulated. Some of you favor fees for plastic products, such as those already charged for bags in some areas, or refundable deposits like those on recyclable cans and bottles.

There seems to be general approval, though, of public education and awareness campaigns like this one. Looking at your own experience with other types of stormwater education, and at other campaigns you've been involved with or exposed to—"No dumping to the storm drain," "Reduce, reuse, recycle," and so on—how effective do you think this effort is likely to be? What else would you suggest?

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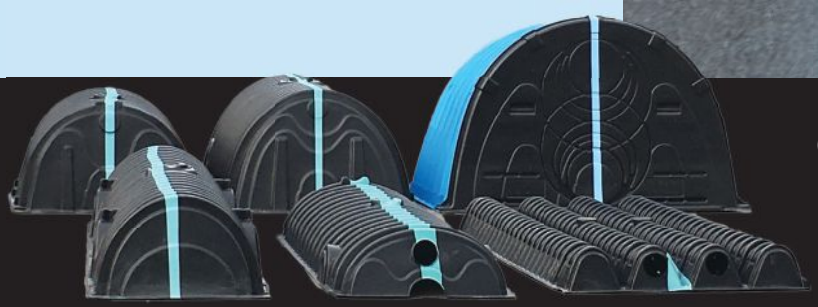

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Permeable Pavements Go Mainstream

Permeable materials are becoming more common for both new installations and retrofits.

BY ROBERTA BAXTER

Permeable products have gone mainstream as cities struggle to manage stormwater and create aesthetically pleasing spaces. As more project designers and owners understand the value of permeable products, the industry has responded by providing a variety of types and designs. The products are available in a mixture of colors and sizes, so there will likely be one that fits a specific project.

Permeable products are being included in new construction as well as retrofits of older spaces. The projects in this article range from refurbishing an older schoolyard, to rebuilding a community space for exercise or shopping, to new construction in a space-constrained environment.

Space Saving in Portland

On many projects, space for stormwater systems is very limited. When an apartment building in Portland, ME, was built on a small lot, the parking lot and driveway had to be constructed in an extremely tight area. Another complication was the location of the property at the headwaters of the Capisic Brook, an urban impaired stream. The City of Portland is actively working to clean up this stream to improve overall water quality in the watershed. The adjacent wetlands meant that the site could not have untreated stormwater rushing off the parking lot and driveway.

"Urban infill development begs for space-efficient innovative solutions," says Robert Woodman, senior environmental engineer and green infrastructure specialist with ACF Environmental. "When you look for function, features, and meeting rigorous state stormwater standards, innovative and

creative design, paired with quality installation, are essential." ACF supplied the R-Tank modules and the PaveDrain blocks used in this project, as well as design support to the engineer during the permitting process and construction support and oversight.

Ransom Consulting and Mitchell & Associates were tasked to plan for stormwater management on this site. Peters Construction was the site contractor for the 72 Bishop Street project, and Great Falls Construction was the general contractor.

The south side of the area has a large block retaining wall, which had to be protected so that it would not be undermined by runoff. It provides the grade change needed from the parking lot to the wetlands below. A 30-mil PVC liner was wrapped around the wall to protect its integrity and stability.

An R-Tank subsurface storage system was placed underground at the location. It provides 4,600 cubic feet of storage, enough capacity to capture runoff from a major storm, and allows controlled release of the water through an outlet control structure. This meets the channel protection requirements to ensure no impact on the nearby brook. The R-Tank system was chosen because it has 95% void space and a reduced footprint compared to other systems. The tank has enough capacity to handle two-year, 10-year, and 25-year storms.

An 18-inch sand filter course was placed between the R-Tank and the PaveDrain blocks, ensuring water-quality treatment to meet Maine Department of Environmental Protection standards.

PaveDrain is an articulated concrete block paving system. The blocks are not permeable in themselves. However, each weighs almost 50 pounds, so once the blocks are in place they are stable and the joints remain open to allow water infiltration.

Each block interlocks with six others and an arched space on the block bottom provides room to store water so that it can be released gradually. About an inch of rainfall can be captured this way. The joints are open so that water will drain evenly from the paved surface. Approximately 2,400 square feet of the PaveDrain system was installed at 72 Bishop Street, curving around the outside edge of the property.

The installation had to be closely coordinated to allow the correct placement of each layer: base stone to tank, sand filter to stone, stone to pavers. A variety of fabric types, 30-mil liner, and geogrid were placed. Small areas of soft soils were found, leading to a need to over-excavate and place granular material in those spots.

Maureen McGlone of Ransom Consulting notes that although the pavers used are more costly than asphalt paving, other factors must be considered. With the space limitations and the stormwater runoff requirements both for quality and quantity, the elements

of design needed to save space and money. "There were other 'soft costs' associated with the less-expensive options, which compromise the overall design—maybe that means eliminating parking, or reducing the footprint or number of units in the structure, which impacts the development viability on a larger scale," she says.

Several other stormwater management options were included in the project. Roofline drip edge treatment and internal cartridge filters for roof drains helped ensure that stormwater was treated effectively onsite.

Maintenance will include periodic vacuuming to remove accumulated sediment from the open joint system. In winter, the surface can be plowed, lightly sanded, and salted as needed. The blocks were sprayed with a sealer after installation to repel salt damage on the block surface.

McGlone said that the project was so successful that her company has designed others in the Portland area using similar methods, especially in areas that are already heavily developed.

Washington Lane

The City of Kirkland, WA, needed to upgrade a two-block long retail area. Park Lane had tree roots breaking through sidewalks, and a failing water main was causing water to flow into Lake Washington. The city decided to create a *woonerf*; the name comes from a Dutch term meaning "living street." In this design, pedestrians and vehicles share the right of way.

Paul MacInnis

Parrish Medical Center in Titusville, FL

The project was taken on by Cascade Design Collaborative, landscape architects, and Perteet Engineers for utility and engineering design. Grants were obtained from the Washington State Department of Ecology and the Transportation Alternatives Program. With added money from the city, the project totaled $3 million.

After the water main was replaced, pavers were installed. The products chosen were Eco-Priora and Hollandstone, both manufactured by Unilock. The blocks were supplied by Mutual Materials of Bellevue, WA.

Eco-Priora pavers are installed with a 7-millimeter gap between the pavers. Spacer bars help installers maintain a uniform gap, which is filled with fine stone chip that allows water to percolate into the sub-base and soil. The pavers are available in a variety of colors and sizes.

Hollandstone is an interlocking concrete paver. For this project, 19,000 square feet of Hollandstone and 7,000 square feet of Eco-Priora were installed. Both types of pavers were 8 centimeters thick, giving a smooth finish to the surface. Using the two kinds of pavers, project designers were able to create an interesting color design, as well as incorporate stormwater management.

The 60-foot right of way has no curbs. It weaves along for the two blocks. Parking bays are included, as well as street furniture, bicycle parking, and art plinths for art displays. The non-permeable interlocking concrete Hollandstone pavers were used for the streets and sidewalks and Eco-Priora pavers were installed for the angled parking.

The plaza-style design slows traffic and allows easy interaction between vehicles and pedestrians. Bollards can be used to block the street for special occasions, permitting only pedestrian access. Bioretention planters and trees provide vegetation and additional stormwater management. They also give the public a chance to see water infiltration in action.

Eastern States Paving Inc. in Portland, OR, was the masonry contractor for the project. Dave Carlton of Eastern States Paving says a six-person crew installed the pavers. Access to existing businesses had to remain open throughout the construction. The company has worked on similar projects throughout the US.

Park Lane has 23 shops and cafes and overall is an inviting community space. Events are planned for this renovated space. In October 2017, the Park Lane project was awarded the Great Streets Award by the American Planning Association.

Education and Environment

A renovation project in West Philadelphia illustrates the need for better stormwater management. Many older cities, including Philadelphia, have combined sewer systems, mixing stormwater runoff with septic sewer flows, all of it passing through wastewater treatment plants. As the cities expand, more impervious surface is added, leading to increased runoff. More people in the municipality also produce more sewage. The increases can overload the treatment plants and cause combined sewer overflows, in which untreated effluent is released into nearby waterways.

Lea Elementary School in Philadelphia is more than 100 years old. The area is highly urbanized, so the school is surrounded by pavement, apartments, and commercial buildings. The site was covered in asphalt that needed to be replaced, and the community chose to use a durable, permeable surface that would have the added advantage of decreasing stormwater runoff.

The final plan was drawn up by designer Sara Schuh of SALT Design Studio in Bala Cynwyd, PA. Thomas Johnston, landscape architect and principal of ThinkGreen LLC, also worked on the planning and construction.

The project was fairly low budget but received a grant from Philadelphia Water Department, as the city is trying to foster these types of projects. Schools and the community are raising money for similar projects.

The goal was to make the area around the school accessible and interesting to the students and for it to handle runoff not only from the schoolyard but also from the street. Products from Pine Hall Brick Company of Winston-Salem, NC, were chosen.

Pine Hall Brick Company manufactures permeable clay pavers, as well as other types of pavers; it is the largest

One goal of the project is educating students at the school, giving them a chance to observe and learn about plants native to the area.

manufacturer of clay pavers in the US. The pavers used for this project are rated for pedestrian and light vehicular traffic. They are slip resistant and skid resistant, even in wet weather.

The installation started with a storage basin sized to handle runoff from the site and the street. Geotextile fabric was added over the subgrade to keep sediment out of the rock layer. Construction continued with a sub-based course of large crushed stone, 2 1/2- to 3-inch size. On top of that, a base course of small- to medium-sized crush stone, 1/2 to 1 inch in diameter, was placed, followed by a bedding course of open-graded washed aggregate. The pavers were set on top of this layer.

The permeable clay brick pavers have spacers, or nubs, on the sides to ensure a gap of 1/4 inch between the pavers. Open-graded aggregate was used to fill the joints, allowing stormwater to infiltrate into the lower courses through the joints. The water is stored in the voids between the stones and then passes on down. The pavers were placed in a crosshatch pattern. The pavers chosen were a rosy red color, an attractive contrast to the dark brick of the school building.

The planners of the Lea School project did not stop with permeable pavers. They added rain gardens with native plants, including cool- and warm-weather grasses, flowering perennials, and edible shrubs and fruit-bearing plants. A variety of switchgrass was planted in some areas because it has thick biomass that does an excellent job of capturing sediment and pollutants. Schuh says one goal of the project is educating students at the school, giving them a chance to observe and learn about plants native to the area. For example, many of them thought that the grasses died when they went dormant. Students have also learned about pollinators and why they are important. The Philadelphia Orchard Project cooperated with the planting and volunteers from the school also joined in.

Johnston says one of the project's challenges involved scheduling. School officials had hoped to complete the project in the summer when school was not in session. However, a number of things happened to push the timing back, so construction was carried out while students were at school. The top priority was making sure that everyone was safe, so extra fencing was used and the crews were reminded to be extra vigilant while they were working.

The school will handle maintenance of the new pavers and the rain gardens. The permeable paving should not have sand or rock salt applied. Since water drains into the joints, icing should be minimal. The area can be shoveled with plastic or rubber blades, or a snowblower with plastic implements can be used. The joints should be vacuumed periodically.

Schuh notes that it is extremely

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Parrish Medical Center in Titusville, FL

important in designing a site to know how it will be used. She is using the knowledge gained from this project on the design of a second school project, incorporating input from teachers and administrators as well as observations about how students use the space.

Trail Building

The CEO of the new Parrish Medical Center in Titusville, FL, wanted to encourage employees and the community to exercise and be active to improve health. Next door to the new building was the location of the original hospital, which had been torn down once the new facility was built. A park was created on the 5-acre lot with a trail and exercise stations. In the center is a small stage of concrete pavers, used for hospital celebrations and as a platform for the hospital's 30-foot Christmas tree each year. Park vegetation includes a small area of low-maintenance lawn, as well as live oak and citrus trees. Existing oak trees on the site were preserved.

Site runoff drains to an existing stormwater pond on the northeast side, and the trail also drains to a large Brevard County stormwater park to the northeast. The system drains into Indian River Lagoon, which has been impaired by pollutants in the past and is now being cleaned up. This project fosters that goal.

The designer, Kathleen Burson, ASLA, owner of Indian River Garden Company LLC, explains that the medical center wanted the park trails to look as natural as possible, with full accessibility for a future nearby rehabilitation facility. The trail needed a non-slip surface that would provide good wheelchair access.

Gravelpave2, a porous gravel paver material manufactured by Invisible Structures Inc., was used for the trail. Gravelpave2 consists of a ring-and-grid structure with a geotextile fabric backing; once the system is in place, the rings are filled with aggregate. Gravelpave2 comes in rolls and is installed and anchored over a base course of gravel up to 12 inches deep, depending on the load that the site will carry.

Once the Gravelpave2 grid and aggregate are in place, the aggregate is smoothed with power broom, blades, or shovels. The gravel can be compacted with a small roller. For the trail, borders were constructed of brick, accenting the gravel path.

Burson designed the project and oversaw the construction. The contractor was Rush Construction Inc. of Titusville. Burson says exercise stations were clustered, rather than spread along the trail. Many park users have commented that the gravel is easy on jogging feet. The area remains a focal point for employees of the hospital and the surrounding medical buildings, as well as the community.

The hospital CEO is pleased with how the project turned out and how it is holding up in the few years since its construction. Even with heavy jogging and walking traffic, the trail is in good condition, and no weeds have sprung up.

*Author **Roberta Baxter** specializes in science and technology topics.*

Breaking Down the Walls

A new age in rainwater harvesting

BY DAVID C. RICHARDSON

The Roman Empire was known for many remarkable engineering achievements, including roads that straddled continents and aqueducts capable of conveying life-sustaining water into ever-growing cities at the heart of the empire. Researchers tracing the history of Roman influence in Great Britain, however, long wondered how one critical, remote outpost in the northern part of the country could have maintained itself and persisted for decades without a source of water. With no streams or springs within its walls and no connection to aqueducts, Hadrian's Fort, at a strategic point on the monumental Roman defensive barrier known as Hadrian's Wall, held a garrison of up to 800 troops. According to a recent study, the stonework fortress happens to be situated in a location that precludes access to springs and waterways, and the area's topography, although advantageous in military terms, made the prospect of supplying it via aqueduct impracticable. Yet the fortress is believed to have housed and sustained a mighty force, sent to the region to pacify the locals and protect Roman colonists seeking to turn the plains of England into an extension of Caesar's realm.

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Here researchers recently have uncovered evidence believed to be the ruins of a massive rainwater harvesting system. They believe the rooftops of each of the key buildings in the fortress were designed to capture and collect rainfall. Nearby were also found a number of stone-lined tanks, each capable of storing 2 cubic meters of water. The researchers believe that between two and six of these tanks would have been associated with each of the major buildings of the fort. Estimating the rainfall totals for the Roman era, they surmise the system could have provided the 800 soldiers manning the fort with 10 liters of water per capita per day during their deployment. According to Peter Beaumont, the author of the study, the success of the ancient system helps make a strong case for increasing the use of rain harvesting systems in the present day.

The Roman system took a tremendous amount of foresight and drive. Roman officials would have had a keen awareness of the need for a water source fitting with military strategy, and it helped sustain an empire. The average American today, fortunately, doesn't have to manage water based on an emperor's dreams of conquest. However, water is just as critical a resource for our society, and many experts say the task of ensuring sustainable water sources is overlooked by too many.

"Most Americans feel we have an endless source of water, but we don't," says Mike Ruck, co-owner of Rainwater Solutions of Raleigh, NC. Tapping new sources of water requires careful planning, even if the source is ubiquitous like rainwater.

An Era of Complexity

Ruck says that a system for harvesting rainwater from a rooftop for potable use can become quite complex. Every detail of the path the water takes must be considered as critical to the system's performance, starting with the roofing material itself. He outlines a simplified sketch of a potable rooftop rainwater harvesting system. "When you talk about potable rainwater, you have to design the whole system taking into account where that rain hits first. What's the roofing material? A smooth surface like a baked painted metal roof is the best. The slicker the surface, the better, because not as many contaminants are going to settle on that roof." Next in line in Ruck's hypothetical simplified system would be flush diverters, designed to channel away the most contaminated water released during the first flush of a rainstorm; collection begins only after this water has been directed away from the potable system. Once collection begins, he recommends filtration down to 280 microns to remove particulates.

Equally important to ensure quality is an efficient storage system. He recommends designing that system to keep the water in the tank as calm as possible to avoid agitating any sediment that may get past the filter system and settle at the bottom of the tank. To avoid disturbing sediment, he explains, the rainwater storage tank must be filled via a calming inlet so that "the water is not just dumped into the tank as it falls, but is rather piped to the very bottom of the tank and then enters through a turned-up pipe so that it doesn't stir the sediment in the bottom."

He adds, "When extracting water from the tank, you draw from the top of the water column with a floating extractor, and then it goes through a series of filters and then through a UV sterilization procedure. Finally, you have that water tested, and you're good to go as long as that test comes back saying it's safe to drink."

Rome's best engineers would never have imagined the need for such sophistication, and it is unknown to what standards they aspired to satisfy the thirst of their legions. It's possible they believed what doesn't kill you makes you stronger. That philosophy, of course, won't do in today's world. However, rainwater harvesting can deliver practical value even when it

is not held to potable standards. In fact, the work Ruck's firm specializes in, "focusing on community rain barrel programs," targets a hunger for knowledge rather than the thirst for conquest. In community rain barrel programs, he says, "The rain barrel is used as an educational tool helping meet the MS4 requirement that cities have to educate their citizens on stormwater and water quality."

Mike and Lynn Ruck have deep family roots in harvested rainwater, having fallen in love with a rain barrel early in their partnership. "My grandfather had a rain barrel, and it's been passed down through my family. It was first built for my grandmother down in Texas," he says. "When my father gave it to us, my wife said, 'Great, that is so cool.' I was skeptical at first."

It didn't take long for him to change his perspective. "We were newlyweds; we had just bought our first house and we were really into gardening, so I thought, 'Wow, a free source of water—this is great.' That was in the early nineties. By the late 1990s, we were making rain barrels for friends and selling them locally and eventually turned our hobby into a full-time business.

"We focus on non-potable uses of rainwater—uses of water that don't have to have a high degree of cleaning or a high level of purity for the water. Plants don't mind the extra bits of organic material in the water that obviously the city would take out to make sure we don't get sick drinking the water."

He adds, "There are two drivers for rainwater harvesting—either drought or flooding—and on the flooding side you have water-quality concerns."

A Garden Attraction

Ruck says his company has completed rainwater harvesting systems ranging in size from a 13,000-gallon catchment, built to serve a greenhouse and small farm, to individual rain barrels providing water for homeowners' backyard gardens. He said the payback for a system depends on the scale of the project. He estimates that the 13,000-gallon system he installed for the greenhouse and several plots of cropland allows the farmer to avoid the expense of a municipal water connection for crop irrigation and has likely paid back twice its cost in the 10 years since it was installed.

> Large numbers of people making optimal use of rain barrels can make a difference by reducing peak flows.

For homeowners, it's not so much the monetary savings that make rain barrels attractive. He notes that the economic return is not particularly dramatic. According to Ruck, a typical homeowner using water collected in 55-gallon rain barrels and a rainwater collection system to water the grass "would be looking at 10 to 12 years before they see that breakeven point." For that reason, he says, "We see it not so much as a payback but as a way to protect their landscape investment."

Dana Nichols, manager of the Conservation Department at San Antonio Water and Sewer (SAWS), says that in San Antonio the issue with water is not so much one of scarcity but of timing. With homeowners seeking ways to irrigate lawns and flowerbeds during the particularly dry months of July and August, residents have fallen in love with rain barrel distribution programs promoted by SAWS, and her agency has had tremendous success distributing rain barrels to local citizens. The focal point of her agency's work over the past 20 years has been conservation. "The first ten years we spent converting 300,000 toilets to low-flow models by turn-keying every hotel and school restroom with pre-1992 fixtures," she says.

"We tried helping for-profit businesses with cisterns and potable water capture, but it's tough to make them work well. There are too many moving parts," says Nichols. "Sometimes you get a situation where a new owner doesn't want to pick up all the upkeep of a system that was installed by a previous owner."

She says she was at first skeptical about the prospect of success for a rain barrel program in San Antonio, "but

because we have been in water conservation for 20 years, we get a good uptake for our projects." In association with nonprofit partners, SAWS completed what Nichols believes has been the largest one-day rain barrel distribution project in the US during the fall of 2017, distributing 6,000 rain barrels provided by RainHarvest among 3,000 households in the agency's service area.

Ruck says the barrels protect the environment while serving as a visceral visual educational tool that demonstrates the value of capturing water: "The homeowner can understand how much water is coming off that roof." He says that a 1-inch rainfall on a 1,000-square-foot impervious roof yields 600 gallons—more than 10 times what a barrel holds—yet Ruck believes when people see how quickly the barrel fills, they can understand firsthand the impact their actions have on the environment.

Make, Take, Buy, Borrow, or Deal

Nichols notes that there are many ways to implement rain barrel initiatives. These include providing subsidies for purchase, free distribution, and make-and-take programs. Each has its own advantages and drawbacks.

Although a single rain barrel might not have a big effect on water quality, large numbers of people making optimal use of rain barrels can make a difference by reducing peak flows. A survey performed in the Chesapeake Bay watershed indicated that 80% of residents could install a rain barrel but only 14% have actually done so. More importantly, only 10% have the barrel connected and keep it drained between storms.

The survey also revealed that although only a small percentage of watershed residents are civically engaged in environmental issues, that could expand to 43% who could see themselves doing so.

"We believe when people are running a make-and-take program, the interest drops off quickly," says Lynn Ruck. Another disadvantage is that the demographic interested in a make-and-take program may be limited to do-it-yourself clientele confident in their handyman skills, leaving out the majority of homeowners. "Our goal is to make it easy," she says.

The SAWS rain barrel program was supported by a $162,000 subsidy, and the city sold 6,000 rain barrels to the public. According to EPA, one rain barrel can save 1,300 gallons of water per year; 6,000 barrels amount to 7.8 million gallons of the scarce resource that the water department doesn't have to supply.

Mike Ruck has some tips for implementing non-potable use systems. "One of the biggest challenges is filtration from asphalt shingled roofs," he notes. "Composite roofs are like a big chunk of sandpaper, and the rougher surface, the more contaminants it can hold—whether its animal waste from birds, or pollen, or if you live on a dirt road and

there's a lot of dust. We advise that if you're going to be watering edibles that you do not harvest off a roof unless it's less than a year old. If it's older than that, we recommend watering the area around the plants and not the edible parts of the plant itself. Let the ground act as the filter to take out any of those contaminants."

Bigger Than a Barrel

Although rain barrels require minimal technical skill to implement effectively, they do require some level of commitment. To be most effective, they must be drawn down after each storm so they're ready to capture water from the next one. Ruck says that although rain barrels are great in the spring, in August when insects may become a problem they require a little more attention. While there is no guarantee that rain barrel owners will make the best use of them, some programs such as the one in Santa Monica, CA, provide support for users. Santa Monica's program requires recipients of rain barrel rebates to make a written commitment to operate and maintain their barrels for a specific period of time after installation. Surveys indicate that 85% of the people who bought the product were still using it.

Industrial-size rain water collection container

iStock/wyndy25

Neal Shapiro, watershed and urban runoff coordinator for Santa Monica, says for the homeowner a rain barrel is often just a first introduction to the idea of harvesting precipitation for use. He says aside from making sure there is adequate funding—in Santa Monica's case from a stormwater parcel fee—a few helpful questions should be asked when deciding how to structure a rain barrel program, such as "Do you want to give out rain barrels or make the customers buy them and install themselves?" Santa Monica opted for a more streamlined approach. "By offering a retail rebate program, we don't have to pick out a vendor or organize distribution; the customer takes care of that. People apply for a rebate and buy the model of their choice," says Shapiro. "They submit an online application stating that they intend to use and maintain it for at least three years. A general issue we have is when someone is selling their home or moving and wants to know what they should do with their old barrel. We collect them and find new homes for them."

In addition to a robust homeowner rain barrel distribution program, Santa Monica has initiated some larger-scale rainwater harvesting projects. "Southern California has an ongoing and critical need for alternate water resources," says Shapiro. Efforts include a project to install rainwater-fed flush toilets at a branch of the

public library, a 55,000-gallon storage unit at Los Amigos storm drain to be used for park irrigation, and an offsite stormwater collection and harvesting system.

Although water is harvested from winter snows on the Sierra Nevada, Shapiro says, "It's just not sustainable to continue intensifying the use of imported water. You're taking water from other regions. Rainwater harvesting is a way to reduce our dependence on imported water. In California, if you can use local water you can avoid the huge expense of pumping large volumes of water over the mountains." Harvesting local water for use becomes even more sensible when factoring in not just the infrastructure and operating costs of importing water, but also the tremendous energy expenditure and the attendant greenhouse gas emissions generated by the pumps. Sourcing water locally mitigates environmental harm on a broader scale.

Santa Monica has set a goal of water self-sufficiency by 2020, and Shapiro is at the center of that effort. He observes that although there are distinctions between stormwater and rainwater, the dividing line is somewhat arbitrary and might serve to confuse matters and place practitioners in silos isolated from counterparts doing closely related work. For instance, the American Rainwater Catchment Systems Association takes the position that what lands on a roof and is collected before it reaches the ground is rainwater, and what lands on grade is classified as stormwater. While Shapiro concedes that roofs can generally be expected to be cleaner than impervious surfaces on grade, such as roads, he says there are exceptions, such as old decaying rooftops and rooftops used for parking. He believes more precise language would help make regulations and implementation projects uniform, clear, and comprehensible, and that clear and consistent terminology would encourage rather than discourage people from getting involved.

"The definition that I promote is what lands on your parcel and stays there is your water—rainwater. If it leaves your property, it is stormwater," says Shapiro. For the municipality, "The more you keep on people's property, the less you have to deal with and treat."

He also says there are two kinds of water harvesting, but they should perhaps be given a more equal footing. "One is collecting precipitation for indirect passive use, like a rain garden, and the other type is a more direct or active mode—putting it in storage unit for potable or non-potable uses later on."

Codifying Challenges

Another challenge facing the market for rainwater harvesting is plumbing codes and tradespeople's lack of familiarity with newly developed water harvesting technologies.

> It's ironic, but it's time to consider intentionally mixing stormwater with wastewater.

According to Shapiro, some municipalities are not familiar with dual plumbing systems and the installation of dual plumbing and treatment systems for using rainwater. "It's a challenge for traditional building inspectors to accept them. They say, 'Show us an example where it's working,' and because it's new, it's hard to find examples. And when you do find one, the inspectors are quick to point out why that situation is an exception, such as a different climate. But our city wants to be a leader in this."

Henry Graumlich, manager of strategic planning for the Municipal Water District in Thousand Oaks, CA, says his region gets 15 inches of rain per year, but that it comes in brief bursts and varies so dramatically from year to year that on a practical level, "You never really get an average year. Some years there is lots of rain, and then there can be a couple of years in a row when there is very little rain."

In this climate, he says, the frequency with which contaminants mobilize is very variable, as is their concentration. "So it's very different from Ohio, where rainfall is distributed more evenly throughout the year and there is less variability from year to year."

Furthermore, he notes, California has just emerged from a five-year drought. On the positive side, the drought has inspired indoor conservation efforts, resulting in greater water efficiency and new initiatives, including water reuse and efficient fixtures and appliances. This has brought about a 30% reduction in wastewater flows. "It's not expected that these wastewater flows are going back up, and as low-flow fixtures become a part of mandated plumbing code, we'll probably see flows that go down even further," he says. In addition, new technologies will continue the trend toward lowering the wastewater volume that reaches the treatment plant.

However, that means there is unused capacity at treatment plants, and as the flows have decreased, the concentration of contaminants in those flows has increased. It's ironic, he says, but he thinks it's time to consider intentionally mixing stormwater with wastewater. This, of course, is contrary to the practice of trying to keep stormwater out of the sewer system in places prone to combined sewer overflows. He says managed rainwater harvesting presents an opportunity for wastewater agencies to work with stormwater agencies for the introduction of stormwater into wastewater collection and treatment systems. This, he says, could help accomplish a series of goals. It could keep treatment plants running at capacity, it could reduce the concentration of problematic contaminants in effluent, and it could significantly reduce the salt concentration in recycled water.

The goal would be to impound stormwater in a distributed fashion

throughout a watershed. Following a storm event, the water could be tested to ensure it wouldn't disrupt the wastewater treatment process and then could be introduced slowly into the wastewater system, thereby improving the quality of the wastewater effluent and the quality of the resulting recycled water that would be distributed as a product at the other end.

According to Graumlich, the most common deficiency of recycled water is high salt concentrations that limit its use for landscape irrigation and other sensitive uses. The addition of rainwater, which is relatively free of salts, to the recycled water production cycle would result in reduced sodium concentrations, making it a more attractive product. Since recycled water is a commodity that is metered and sold, Graumlich maintains that a program to mix rainwater with wastewater could create "a cash nexus to work out between the wastewater and stormwater agency to pay for projects."

There are issues to overcome, however. For instance, drinking water systems and wastewater systems have a long history of regulation and water-quality standards. "With stormwater, we're in the relative infancy of managing quality. Since stormwater is not confined to a pipe but is spread across the landscape, it's coming from diverse areas, and water-quality issues come to the fore as it is discharged from one body of water to another. That would be a concern for wastewater agencies having flows introduced into their systems."

Harvested Rainwater Top to Bottom

Eddie Van Giesen, national sales manager for Watts Water Technologies, believes in the fit-for-purpose design concept. From an engineering perspective, he says, whether water lands on the roof or on the pavement, "It's all stormwater, but we decided to make a distinction between water on roofs and water at grade. The distinction is important because those areas at grade are more likely to have contaminants than the roof." Nonetheless, he says, "It's not so much the presence of pollutants but the concentration of these things that matters."

He said building codes in Georgia, where Watts Water is headquartered, are gradually coming of age in the sphere of rainwater harvesting. "When I worked there, there was nothing in the plumbing code that allowed you to do it. Now you can do a rainwater system even for potable water."

Drought, he says, was the motivation. "Atlanta was a large metro area with a reservoir that was not big enough." He says when the drought came, there was a scramble to figure out what to do. "The state hashed out what would work in Georgia and eventually put together a manual" that encompassed rainwater harvesting, following in the footsteps of Hawaii and Texas, which had the first rainwater

harvesting manuals. These included guidelines that, when referenced by code, give them the force of law.

"We started to see flush toilets using rainwater, then saw other non-potable uses, and finally rainwater was allowed even in the sacred envelope of the building," says Van Giesen. "Most of the code is not prescriptive, telling people what they have to install, but rather it tells what the end quality needs to be."

He adds, "Different people do different things to the water; you have to rely on the people designing the system." He notes that parts sourced from unrelated vendors often don't fit together or interface properly into a functioning system. Furthermore, it is a relatively new discipline, and contractors are often learning on the fly. "The key is documentation; know what you are doing and don't piece the work out."

His company provides a top-to-bottom solution for rainwater harvesting, custom-designed for the client's requirements. The components include a pre-filter, a storage device, and a skid-mounted filtration system. "There can be relative degrees of sophistication of 800 moving parts. We manage all of that. We have the ability to send this information to the building automation system informing engineers when the tank is empty and full, usage rates, chlorine levels, UV intensity, pH, and turbidity," he says.

Most systems Watts Water designs for customers have a five- to 10-year return on investment. A recent project at the Rita Hollings Science Center at the College of Charleston in Charleston, SC, deployed a system with a 4,900-gallon rainwater capture tank in the basement as a component of the building's HVAC system for sensitive laboratory ventilation. According to the engineer on the project, using harvested rainwater provided one of the best options to achieve the goal of isolating the laboratory, with its potential for generating hazardous outputs in its ventilation gases, from the public.

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Harvested rainwater has many uses, and making optimal use of rainwater means finding the right partners. The challenge is getting people with different priorities to work together.

"Water suppliers have the least interest in stormwater when water is plentiful," says Graumlich. The irony is that when rainfall is scarce, there is little that harvesting and storage can do to change the balance sheet.

Dana Nichols of SAWS believes harvesting rainfall is an important part of an overall water conservation strategy. "Conservation should always be seen as a water source, even where you think you have an apparent source of abundant water."

*Writer **David C. Richardson** is a frequent contributor to Forester publications*

Asset Management

Telling a comprehensive story for stormwater management

BY UKI DELE

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Asset management (AM) is a popular management strategy for maintaining the level of service for water and wastewater systems. These systems have clearly defined services and objectives and have been tested and regulated for much longer than stormwater systems. Compared to wastewater, stormwater less frequently receives direct treatment to remove pollutants, making it challenging to meet numeric effluent limitations. The main obligation of most stormwater systems was once to collect rainfall runoff for reduction of flooding. Stormwater is typically not treated. However, with the increasing water-quality regulations, more obligations are being introduced for stormwater systems, including total maximum daily loads (TMDLs).

Asset management for stormwater systems is becoming increasingly essential for achieving water-quality objectives while continuing to provide flood protection. Asset management is a structured approach to optimizing the life cycle cost of asset ownership and focuses on providing reliable and dependable service to customers. The goal of an AM program is to meet customer needs and expected levels of service (LOS) through sound fiscal planning and improved infrastructure management.

With aging infrastructure, increasing water-quality regulations, and the multifaceted needs for surface water and stormwater management, there is an increasing need for a transparent, feasible, and proactive long-term management strategy for stormwater infrastructures. The city of Shoreline, WA, is using AM principles to manage the stormwater program, not only to exceed permit requirements but also to meet residents expectations for rates, flood protection, and environmental substantiality.

The city's AM program provides a long-term management strategy for the city surface water utility to manage the stormwater assets at the lowest life cycle cost while meeting the expected LOS. It provides a transparent way to

inform difficult investment decisions, educate residents and the city council about the system needs, and ensure proper allocation and acquisition of funding for construction, operations, and long-term maintenance of the stormwater system.

Background

The city of Shoreline is located in King County, WA, and is approximately 12 square miles. The city is bordered on the south by Seattle and on the west by Puget Sound, the second-largest estuary in the US after Chesapeake Bay.

The city has a surface water utility that serves more than 55,000 residents and 780 businesses. The utility operates and maintains a municipal separate storm sewer system (MS4) within seven drainage basins. In 2016, the city completed its first installment of drainage basin plans that began in 2009.

Through the basin plans, the city learned a great deal about the stormwater system and about residents' expectations and identified a growing list of activities and projects to address the needs of the system. To better manage and prioritize the list of activities identified, the city established an asset management framework as a strategy for long-term management of the system instead of merely reacting to the identified needs.

The asset management framework is the basis for the city's AM program and was developed in the 2018 Comprehensive Surface Water Master Plan. This plan includes a compilation of all the data and assessment from the completed basin plans and a long-term management strategy (enterprise strategy and risk mitigation) for meeting the established LOS. The master plan will guide utility activities for the next five to 10 years and includes policies, programs, a schedule for capital improvement projects, and a financial plan for long-term asset management.

> There is an increasing need for a transparent, feasible, and proactive long-term management strategy for stormwater infrastructures.

Stormwater System

The city's MS4 includes approximately 140 miles of stormwater pipe, 7,461 catch basins, more than 260 green stormwater infrastructures (bioretention, rain gardens, permeable pavements, etc.), and eight

pump stations. The MS4 has approximately 148 outfalls that discharge directly into creeks, lakes, ponds, and Puget Sound.

NPDES Permit

The utility also holds a National Pollutant Discharge and Elimination System (NPDES) Phase II municipal stormwater permit for Western Washington. This Phase II permit, administered by the Washington State Department of Ecology (DOE), allows the discharge of stormwater to waters of the state if the utility takes certain actions to minimize stormwater pollution in the discharge. These actions are specified in the Phase II permit, including specific requirements for operations and maintenance and documenting a stormwater management program.

Although the current Phase II permit does not explicitly require treatment for outfall and discharges, it does require compliance with any TMDLs established for water bodies that receive municipal stormwater runoff. However, none of the water bodies within the city has TMDL requirements.

Asset Management Framework

The city's AM program is based on an asset management framework with various elements including LOS, asset knowledge, risk mitigation, and enterprise strategy. Figure 1 outlines the various elements of the AM framework. The AM program helps the city maintain its mission of protecting public health and the environment by improving the knowledge and management of assets. Two basic concepts of asset management are to maximize the useful life of assets and to reduce life cycle costs. Measurement of asset performance and processes are key to sustaining the AM program.

One of the goals of the AM program is to ensure the delivery of prioritized activities (projects and programs) identified in the basin plans while managing the life cycle cost of assets and improving asset reliability.

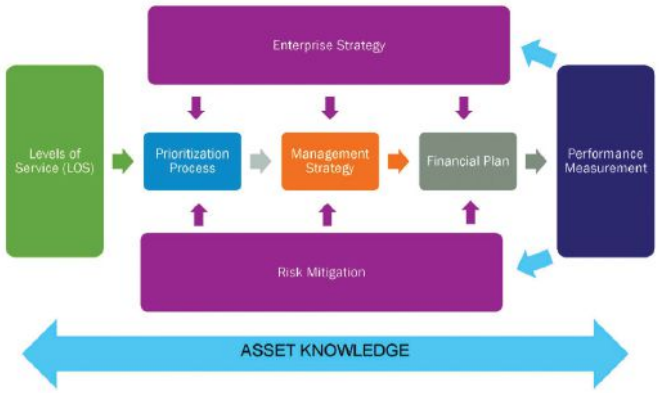

Figure 1. AM framework

The AM program requires an ongoing collaboration among the engineering, operations, maintenance, finance, and information technology groups.

Asset Knowledge

Asset knowledge is critical in telling a comprehensive story for stormwater management programs and achieving the AM program goals. The knowledge of the city's assets is captured in Cityworks, a computerized maintenance management system (CMMS) and geographic information system (GIS). The use of CMMS and GIS to capture this information allows the city to understand the assets from any level and performance across multiple queries.

The asset knowledge is also enhanced through strategic drainage basin planning. Drainage basin planning is an approach to stormwater management that provides detailed drainage assessment and identifies problems, system needs, and management activities to address the needs. Drainage basin plans can also provide better information on needs and activities to address the protection and restoration of the beneficial uses of our water bodies.

As a Phase II permittee, the city is not required to perform drainage basin planning. The current NPDES permit includes drainage basin planning requirement for Phase I permittees and requires Phase II permittees within a Phase I selected drainage basin to participate or conduct their drainage basin plans independently. The city is not within any of the drainage basins selected for Phase I planning.

However, in 2009 the city began studying the stormwater and surface water systems on a drainage basin level. This study was aimed at understanding the needs of the system in the seven drainage basins within the city boundaries. The basin plans included GIS mapping updates, condition assessment of pipes and catch basins, assessment of drainage and flooding issues, review of operations and maintenance records, and stream and water-quality assessment in each of the drainage basins. In 2016, the city completed the final basin plan and compiled all the data and assessments into a comprehensive plan, the Surface Water Master Plan. This

Table 1. Levels of Service and Level-of-Service Targets

Level of Service		Level-of-Service Target
1	Surface Water Impacts—Manage public health, safety, and environmental risks from impaired water quality, flooding, and failed infrastructure	No verifiable health and safety issues or environmental damage caused by the stormwater services outside of risk tolerance
2	Equitable Service—Provide consistent, equitable standards of service to the citizens of Shoreline at a reasonable cost, within rates and budget	Meet the levels of service as measured by customer satisfaction and rate and revenue projections
3	Communication and Outreach—Engage in transparent communication through public education and outreach	Maintain a communication plan to inform the community on utility goals and progress
4	Regulatory Impacts—Comply with regulatory requirements for the urban drainage system	Meet or exceed regulatory requirements for NPDES Phase II and federal, state, and local regulations affecting surface water management

The AM program helps the city maintain its mission of protecting public health and the environment by improving the knowledge and management of assets.

master plan includes the enterprise strategy and risk mitigation elements of the AM program.

Service Levels

Levels of service are key in assessing the utility's AM program. The LOS are the services provided by the utility to meet the residents' expectations and permit requirements. This requires a clear understanding of customers' needs, expectations, and preferences. The associated targets and performance measures will guide the city's activities, such as maintenance frequency, inspection techniques, and capital improvement sizing.

With the help of consultants (Brown and Caldwell and FCS Group), the city worked with residents through open houses and surveys to define the LOS and LOS targets shown in Table 1. Having defined LOS and LOS targets helped frame the identified activities and long-term management needs in the context of the residents' and the utility ratepayers' expectations and has been foundational in establishing the AM program.

A public survey was conducted to solicit feedback on the LOS and gain a better understanding of customer expectations for stormwater services. Key findings from the web-based survey include the following:

- Respondents ranked "Manage public health, safety, and environmental risks from impaired water quality, flooding, and failed infrastructure" as the highest priority.
- Respondents ranked "Engage in transparent communication through public education and outreach" as the lowest priority.
- General concerns about the stormwater services were relatively evenly distributed among flooding, water quality/pollution, and impacts to streams and wetlands (Figure 2).

Each of the defined service levels will have key performance indicators (KPIs) or metrics to determine if each service level is being met. These metrics will be the basis for revising priorities for funding among competing demands and will ultimately be used to demonstrate how resources will be dedicated to achieving specific results for the long-term management of the stormwater system.

Risk Mitigation

Risk mitigation in implementing the AM program involves developing options and actions to enhance opportunities to meet the LOS targets while reducing threats to asset performance. Evaluating risk will ensure that failure modes can be identified,

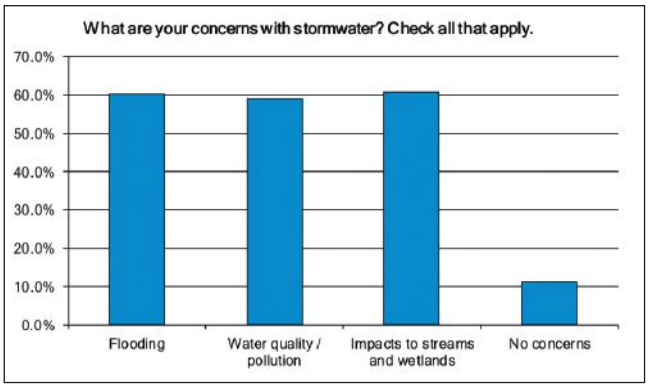

Figure 2. Survey responses about stormwater services in the City of Shoreline (2016)

acceptable levels of risk can be evaluated, critical assets and business processes are identified, consequences or failures are known, and risks are avoided or reduced. Outcomes for the risk mitigation will involve assets with low consequences of failure and no periodic maintenance requirements simply being used until broken, while assets with high consequences of failure will be prioritized for repair and replacement.

Enterprise Strategy

The enterprise strategy in the master plan identifies the goals of the utility and the approach for reaching these goals. This strategy includes prioritizing projects and program activities for the utility and establishing a management strategy for implementing these activities within a corresponding financial strategy.

Prioritization Process. A systematic process was developed for prioritizing the improvement projects and current and recommended programs, including a spreadsheet tool that applies a consistent set of criteria and a procedure for scoring. Key steps of the prioritization are described below and summarized in Figure 3:

- Refine LOS Targets. As discussed earlier, the LOS and LOS targets are the basis for articulating customer expectations for the services provided by the utility. LOS targets were refined to reflect key goals relating to flooding and erosion, water quality, aquatic habitat, responsible stewardship of assets, customer service and communications, and regulatory compliance. These targets were then carried forward to support project and program prioritization, as well as monitoring and tracking of operational activities.
- Develop Evaluation Criteria and Scoring. LOS targets were further refined into specific evaluation criteria. For example, the target for "flooding and erosion" was divided into three separate criteria relating to drainage capacity, hazard reduction, and erosion control. Scores of 0, 1, or 2 are assigned to each criterion based on guidance provided in the spreadsheet tool. These scores are then multiplied by

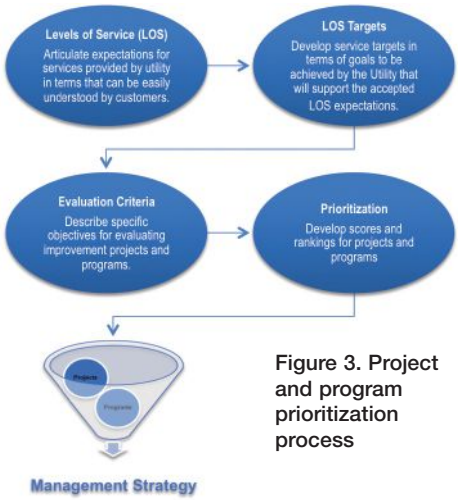

Figure 3. Project and program prioritization process

Level of Service (LOS)			Prioritization System						
LOS	Expectations	Targets	Evaluation Criteria	Scoring 0	Scoring 1	Scoring 2	Weighting Factor	Maximum Scores
A- Surface Water Impacts	*Manage public health, safety and environmental risks from impaired water quality, flooding, and failed infrastructure*	**A. Flooding and Erosion** No verifiable health and safety issues or environmental damage caused by flooding or erosion outside of an accepted risk tolerance	**A.1 System Capacity** Addresses capacity needs	No direct benefit	Provides moderate benefit	Provides substantial benefit	60	320
			A.2 Hazard Reduction Addresses an apparent (observed and recurring) public safety hazard.	No direct benefit	Provides moderate benefit	Provides substantial benefit	60	
			A.3 Erosion Control Addresses erosion problems related to public stormwater conveyance.	No direct benefit	Provides moderate benefit	Provides substantial benefit	40	
		B. Water Quality Improve the quality of stormwater discharged to impaired receiving waters to mitigate environmental damage	**B.1 Stormwater Treatment** Addresses stormwater treatment in accordance with applicable regulatory standards.	No direct benefit	Provides moderate benefit	Provides substantial benefit	40	160
			B.2 Low Impact Development (LID) Supports or encourages LID principles.	No direct benefit	Provides moderate benefit	Provides substantial benefit	5	
			B.3 Impaired Water Impacts Provides cost effective opportuntiy for stormwater treatment	No direct benefit	Provides moderate benefit	Provides substantial benefit	35	
		C. Habitat Protect aquatic habitat by reducing impacts to ecosystem health and biotic diversity in lakes, streams, and wetlands	**C.1 Habitat Protection** Protects aquatic habitat from degradation to minimize the loss of ecosystem function and diversity.	No direct benefit	Provides moderate benefit	Provides substantial benefit	25	100
			C.2 Habitat Restoration Restores ecosystem function and diversity, is cost-effective, and provides multiple benefits	No direct benefit	Provides moderate benefit	Provides substantial benefit	25	
B- Equitable Service	*Provide consistent, equitable standards of service to the citizens of Shoreline at a reasonable cost, within rates and budget*	**D. Responsible Stewardship** Provide equitable services through cost-effective planning and management of utility assets, sound fiscal planning, and efficient operations.	**D.1 System Preservation (Asset Management)** Supports reliable service by maximizing the useful life of assets and reducing life cycle costs.	No direct benefit	Provides moderate benefit	Provides substantial benefit	80	460
			D.2 Operations and Maintenance Reduces and/or avoids operations, maintenance and administrative costs	No direct benefit	Provides moderate benefit	Provides substantial benefit	20	
			D.3 Financial Planning Supports sound financial planning and/or helps the Utility qualify for alternative funding sources.	No direct benefit	Provides moderate benefit	Provides substantial benefit	20	
			D.4 Future growth Supports future population and/or economic growth.	No direct benefit	Provides moderate benefit	Provides substantial benefit	30	
			D.5 Customer service Improves customer service and addresses observed service issues	No direct benefit	Provides moderate benefit	Provides substantial benefit	20	
		E. Internal Resources Manage internal resources to provide adequate resources, training, and support; maintain workforce diversity; and retain institutional knowledge	**E.1 Workforce** Increases/retains the capabilities of City staff.	No direct benefit	Provides moderate benefit	Provides substantial benefit	60	
C- Communication and Outreach	*Engage in transparent communication through public education and outreach*	**F. Customer Service and Communications** Provide effective communication, public education, and outreach.	**F.1 Communication and Education** Provides opportunities to enhance public understanding of surface water issues and/or utility services.	No direct benefit	Provides moderate benefit	Provides substantial benefit	20	40
D- Regulatory Impacts	*Comply with regulatory requirements for the urban drainage system*	**G. Regulatory Compliance** Meet state and federal regulatory requirements for stormwater utilities.	**G.1. Regulatory** Addresses current and future regulatory requirements.	No direct benefit	Provides moderate benefit	Provides substantial benefit	200	400
							Maximum Score:	1480

Figure 4. Project and program prioritization matrix

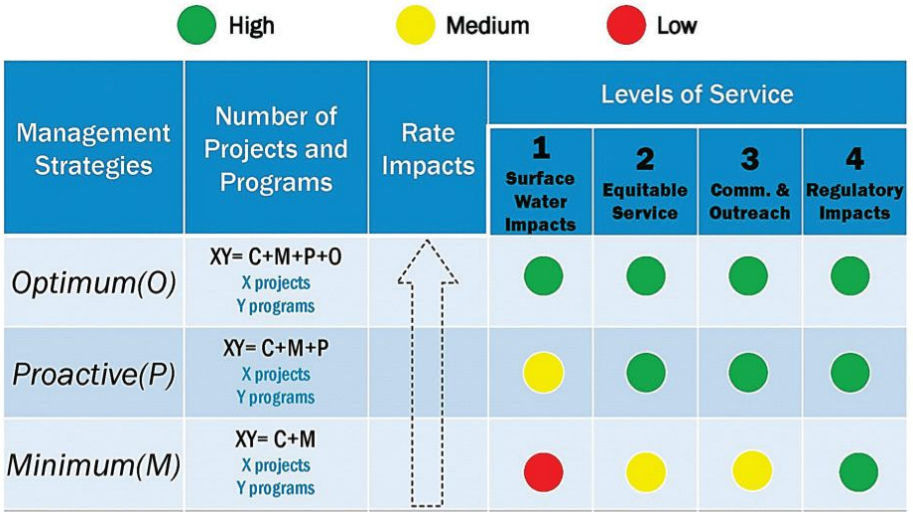

Figure 5. Management strategy and rate impacts matrix

a weighting factor and added to the scores from the other criteria for a total project score.

- Develop Rankings. After scoring was completed, the projects and programs were ranked highest to lowest by their total scores and tabulated with other key information such as estimated cost, type, location, and the primary issue addressed. For the projects, the rankings table and supporting information were used to identify projects for the six-year capital improvement program (CIP), with the remainder moving to the 20-year horizon. Projects selected for the six-year CIP were then examined in closer detail with respect to implementation. Several projects were divided into phases where pre-design/feasibility studies were needed or engineering and planning must be done well in advance of construction.

Figure 4 shows the prioritization process matrix and the steps in developing this process from the LOS to scoring.

Management Strategy. The prioritized projects and programs were then examined within the context of different management strategies to examine the long-term financial impacts. Projects (capital expenses) and programs (operational expenses) were packaged into three options reflecting the different management strategies as described below and shown in Figure 5. The management strategies range from Minimum to Optimum based on how they address regulatory requirements, system needs, and levels of service, as well as the long-term financial impacts. The management strategies are described as follows:

- Minimum: Projects and programs that meet the minimum in terms of existing system needs and anticipated new regulatory requirements
- Proactive: Minimum plus new high-priority projects and new/enhanced programs that address high-priority long-term needs, as well as anticipated new regulatory requirements
- Optimum: Proactive plus additional priority projects and programs that enhance water quality and aquatic habitat

Figure 5 shows how the three management strategies relate to the number of projects and programs and the LOS impacts. The "C" in Figure 5

The survey showed that 49% of the surveyed residents preferred the proactive management strategy.

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indicates current projects and programs. A key objective of the master plan and AM program is to identify improvements that will help the utility meet LOS that reflect the expectations of the residents and are appropriately in line with stormwater fees. In telling the story to the council and residents, Figure 5 was helpful in explaining the rate impacts for each of the management strategies.

A web survey was also conducted to solicit feedback from the residents on the management strategies. Key findings from the survey included 49% of the surveyed residents preferred the proactive management strategy (Figure 6).

After these detailed processes were used to inform the council on the financial implication and LOS impacts of each management strategy, the council provided direction for the utility to pursue the proactive management strategy and supported that direction by approving the six-year financial plan for the management strategy. The proactive management strategy, as indicated in Figure 7, includes construction of up to 26 projects and implementation of 24 programs that address high-priority long-term needs, as well as anticipated new regulatory requirements.

Performance Measures

The effectiveness of the AM program can be measured using KPIs that track the LOS targets. The LOS and KPIs are the primary measures of performance.

As the utility moves forward with implementing the programs included in the proactive management strategy, staff will collect data and monitor the performance of these programs over time. Brown and Caldwell and FCS Group worked with staff to assess each of the programs and describe the characteristics of a successful program. Staff then identified quantitative performance measures related to the successful implementation of each program. These performance measures were then narrowed down to one per program, and thresholds for success were set according to three possible ratings:

- Meets Expectations: Program meets expectations and is consistent with meeting LOS targets
- Needs Improvement: Program is active and is being implemented by staff, but still needs improvement to meet expectations and LOS targets
- Below Expectations: Program either does not exist, or falls short of meeting expectations and LOS targets

Table 2. Combined Assessment of Programs Supporting Level of Service #1

Relevant Program	2017 Program Status	Combined Status
Drainage Assessment*	Needs Improvement	Below Expectations
Water-Quality Monitoring*	Meets Expectations	
Street Sweeping	Meets Expectations	
System Maintenance	Needs Improvement	
Pipe Condition Assessment Program*	Below Expectations	
SW Pipe Replacement Program*	Below Expectations	
System Inspection*	Meets Expectations	
Catch Basin Repair and Replacement*	Below Expectations	
LID Maintenance*	Below Expectations	
Pump Station Maintenance*	Below Expectations	
Utility Crossing Removal*	Below Expectations	

*Programs that are new or enhanced for the proactive management strategy; these programs may have gaps or may not exist currently, which would lead to a "below expectations" rating in 2017.

Table 3. Levels of Service and Level-of-Service Targets for the City of Shoreline Surface Water Utility

	Level of Service	Level-of-Service Target	2017	2018	2023
1	Manage public health, safety and environmental risks from impaired water quality, flooding, and failed infrastructure	No verifiable health and safety issues or environmental damage caused by the stormwater services outside of risk tolerance	Red	Yellow	Green
2	Provide consistent, equitable standards of service to the citizens of Shoreline at a reasonable cost, within rates and budget	Meet the levels of service as measured by customer satisfaction and rate and revenue projections	Yellow	Green	Green
3	Engage in transparent communication through public education and outreach	Maintain a communication plan to inform the community on utility goals and progress	Green	Green	Green
4	Comply with regulatory requirements for the urban drainage system	Meet regulatory requirements for NPDES Phase II and federal, state, and local regulations affecting surface water management	Red	Green	Green

Green - Meets Expectations Yellow - Needs Improvement Red - Below Expectations

An overall assessment of LOS can be made by combining the ratings of all related programs for a particular LOS. For example, if there are 11 programs that support LOS 1 (surface water impacts), staff can assess the status of each program and then determine an average rating (Table 2). LOS 2, 3, and 4 have similar assessments.

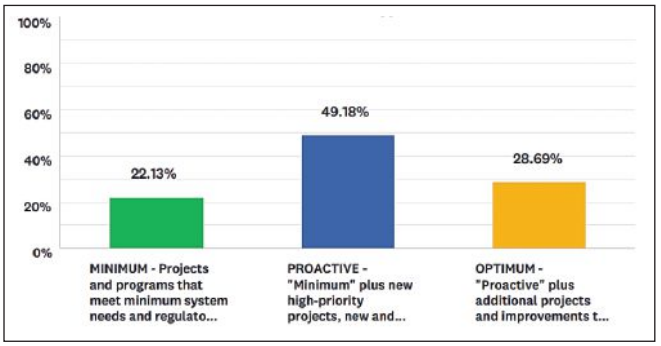

Figure 6. Survey responses about preferred management strategy for stormwater services in the City of Shoreline (2017)

In measuring at the program level, the utility can better identify program needs and adequately adjust program activities and funding to ensure success. This process will also allow for a transparent reporting process where staff, residents, and the city council can see trends and impacts of the program performance in providing the stormwater services. The goal, as indicated in Table 3, is that in implementing the AM program and monitoring the program success, the utility will be meeting all LOS within the six-year planning period of the 2018 master plan.

High Medium Low

Management Strategies	Number of Projects and Programs	Single Family Rate (monthly)	Levels of Service			
			1 Surface Water Impacts	2 Equitable Service	3 Comm. & Outreach	4 Regulatory Impacts
Optimum(O)	57 30 projects 27 programs	$20	●	●	●	●
Proactive(P)	50 26 projects 24 programs	$18	●	●	●	●
Minimum(M)	35 13 projects 22 programs	$17	●	●	●	●

Figure 7. Management strategy and rate impacts (2017)

Key Performance Indicators

As program performance data are collected and reviewed, utility staff will assess trends and evaluate which performance measures track closely with variations in LOS. These insights will be used to identify KPIs, which are those metrics that most strongly reflect the overall goals of the utility. KPIs will continue to be tracked over the long term even after programs have been fully implemented. KPIs may need to be added, eliminated, or adjusted over time as the utility anticipates or responds to changing external factors such as new regulations.

Conclusion

This AM approach and AM program provide a transparent way to inform difficult investment decisions for meeting permit requirements, educating residents and the city council about the system needs, and ensuring proper allocation and acquisition of funding for construction, operations, and long-term maintenance of the stormwater system. They also tell how and when ratepayers will choose to pay for higher or lower LOS for stormwater management.

Using asset management principles helps tell a comprehensive story for stormwater management, including reporting how well the utility is performing in meeting the LOS for the stormwater services.

***Uki Dele**, P.E., has served the City of Shoreline, WA, as surface water utility and environmental services manager since 2015.*

Filtration Systems

Options for keeping pollutants and debris from the storm system

BY CAROL BRZOZOWSKI

In recent years, the focus on stormwater mitigation in Surfside Beach, SC, has been on water quality, notes John Adair, public works director.

"The topography along the coast is very flat, so getting the water to go toward the ocean is always a challenge because you might only have very slight variations from block to block in elevation," he says. But a second challenge comes "under our NPDES permit in maintaining that water quality that we look for to discharge clean water into the ocean.

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We're always trying to find the best ways to handle that."

In the past, the mindset was to move stormwater out as fast as possible in concrete pipes or ditches—whatever means necessary—and get it into the nearest pond and out to the ocean without much thought for water quality, he says.

"In recent years, we've taken advantage of the good soils here by the beach. We have a lot of Class A and B soils, which infiltrate very well, so we've been using a lot of infiltration pipe and deep sump catch basins," he says.

Surfside Beach also uses the SNOUT from Best Management Products, a vented catch basin hood or trap that captures gross pollutants such as floatables and trash as well as free oils and sediment. The town also uses the Bio-Skirt, designed to capture and retain hydrocarbons. It is treated with an anti-microbial to inhibit bacteria growth on the boom and prolong its service life.

"We've implemented the use of the SNOUTs to keep sediments out of the pipe, but we've also gotten a little innovative in using them as weirs within the system to hold water back," says Adair. "You can put the SNOUT upside down at the tail end of a pipe—the effluent side—and a large catch basin, and it can hold back some water, so it has more of a chance to infiltrate before it goes down to the next segment of pipe."

The town's approach also uses deep sump catch basins and infiltration pipe. "That and a lot of other BMPs we're doing in town have really made a good impact on our water quality," says Adair. Testing has shown that water quality is the best it's been in 10 years.

Adair points out that although no single BMP is a "magic bullet," they are tools that, in combination, contribute to clean water, along with other approaches including public education, promoting the use of dog waste disposal bags, and street sweeping.

Surfside Beach belongs to a consortium of neighboring municipalities that use public service ads, billboards, and posters on solid waste trucks and street sweepers to promote the idea of "clean streets, clean beaches," notes Adair. "We're trying to make that connection in people's minds that everything goes to the ocean."

Saving the Trees

A new residential development in La Verne, CA, presented some spatial challenges for managing stormwater. Joy Hendricks, project engineer for C&V Consulting, explains that the site for the City Ventures La Verne Emerald project consisted of undeveloped, pervious land with several mature oak trees. Some of the trees would remain in place, and others were to be moved to other site locations, but all the trees had to be protected during construction.

That presented a challenge for

Photos: Oldcastle Precast

placement of proposed drainage facilities, including an underground 48-inch detention pipe, sump catch basins, an area drain system, and other utilities.

The developer chose to install Modular Wetlands biofiltration system (MWS Linear) units from Bio Clean Environmental. Designed to function like wetlands, MWS Linear uses horizontal flow to improve performance, reduce footprint, and minimize maintenance. It is designed with a greater filter surface area, a pretreatment chamber, and pre-filter cartridges to remove sediment and hydrocarbons from runoff before it enters the biofiltration chamber. The units are installed inline and are designed to support almost any plant life.

Instead of using multiple MWS Linear units at each sump area, Bio Clean Environmental's DVERT system was used, enabling the collection and conveyance of low flows to one primary unit. With DVERT low-flow diversion, the diversion trough can be installed in existing or new curb and grate inlets to send the first flush of runoff to the MWS Linear. It works similarly to a rain gutter and is installed just below the opening of the inlet, capturing the low flows and channeling them to a connecting pipe exiting out the wall of the inlet and leading to the MWS Linear. The DVERT can be used in retrofit and green street applications, allowing the MWS Linear to be installed anywhere space is available.

StormCapture system installation

C&V Consulting and Bio Clean Environmental collaborated to develop a Modular Wetlands System (MWS-L-8-16) vault to meet the required water-quality treatment flow rate for the whole site. The vault could accommodate the connection of three DVERT systems and the area drain system while meeting downstream storm drain depth restrictions.

"The Modular Wetlands Systems have the flexibility to be located anywhere onsite and can be easily incorporated into the landscape design," notes Hendricks. "Most importantly from an engineering perspective, the MWS provides the ability for area drain connections and diversion of low flows, ensuring the entire site meets the governing agency's water-quality regulations."

The MWS Linear has been approved in the Washington State Technology Assessment Protocol - Ecology (TAPE) program and by the Rhode Island Department of Environmental Management, the Virginia Department of Environmental Quality, and the University of Massachusetts at Amherst Water Resources Research Center.

Washington granted General Use Level Designation for basic (total suspended solids [TSS]), enhanced (heavy metals such as zinc and copper), and total phosphorus treatment regiments.

The Virginia DEQ assigned the MWS Linear the highest phosphorus removal rating for manufactured treatment devices to meet the new Virginia Stormwater Management Program Technical Criteria.

The MWS Linear's 4-foot standard planter width enables it to be used in parking lot islands and medians. In streets, its small footprint works around existing utilities on retrofit projects. It can be installed as a raised planter to treat runoff from rooftops or patios. It is sometimes used to help industrial sites meet EPA-mandated effluent limits for dissolved metals and other pollutants.

The MWS Linear can be used in decentralized LID designs and end-of-the-line configurations in low- to high-density residential developments. On commercial sites, the MWS Linear is used to meet treatment and volume control requirements in a smaller footprint. The system has available

"pipe-in" options on most models along with built-in curb or grated inlets to integrate into a storm drain design.

The curb type configuration accepts sheet flow through a curb opening in roadway and parking lot applications. The grate type has a grated or drop inlet above the system's pre-treatment chamber. It enables pedestrian access over the inlet. ADA-compliant grates are available. This configuration is also used in scenarios where runoff needs to be intercepted on both sides of landscape islands.

Pre-treatment starts with separation of trash, sediment, and debris before entry into the pre-filter cartridges. The pre-filter cartridges have more than 25 square feet of surface area. They utilize BioMediaGREEN filter material and remove more than 80% of TSS and 90% of hydrocarbons. The filter material prevents pollutants that cause clogging from migrating to the biofiltration chamber. The horizontal flow is designed for less clogging than downward flow biofilters.

The MWS Linear system has two orientations: side-by-side and end-to-end. The side-by-side orientation places the pretreatment and discharge chambers adjacent to one another with the biofiltration chamber running parallel on either side to minimize the system length and provide a compact footprint. This application is used in situations such as streets with directly adjacent sidewalks, as half of the system can be placed under the sidewalk. This orientation also offers internal bypass options.

The end-to-end orientation places the pre-treatment and discharge chambers on opposite ends of the biofiltration chamber to minimize the width of the system to 5 feet and is typically used in linear projects and street retrofits where existing utilities and sidewalks limit the amount of space available for installation. The bypass must be external with this orientation.

A wide range of plants are suitable for use in the MWS Linear with selections based on location and climate. The plants add aesthetic value as well

> "The topography along the coast is very flat, so getting the water to go toward the ocean is always a challenge."

as pollutant removal.

The system maintenance requirements are limited to the pre-treatment chamber, which can be cleaned by hand or with a standard vacuum truck. The system also requires periodic replacement of the media in the pre-filter cartridges for long-term operation.

Flooding in Philadelphia

Aging infrastructure in Philadelphia's Grays Ferry area was unequipped to handle excessive amounts of stormwater during heavy rain events, causing the drainage system to become overloaded and flooding neighborhood streets.

The historic neighborhood is close to an important river crossing. In the 18th century, Grays Ferry was the southernmost of three ferries crossing the Schuylkill River to Philadelphia. Today, the Grays Ferry Bridge and several other rail lines span the Schuylkill River.

The neighborhood was once the site of the Schuylkill Arsenal, constructed in 1800 to provide the US military with critical supplies. The arsenal—the third federal facility in the nation—was the site of clothing and flag manufacturing for the military. Its most famous task was outfitting the expedition of Lewis and Clark.

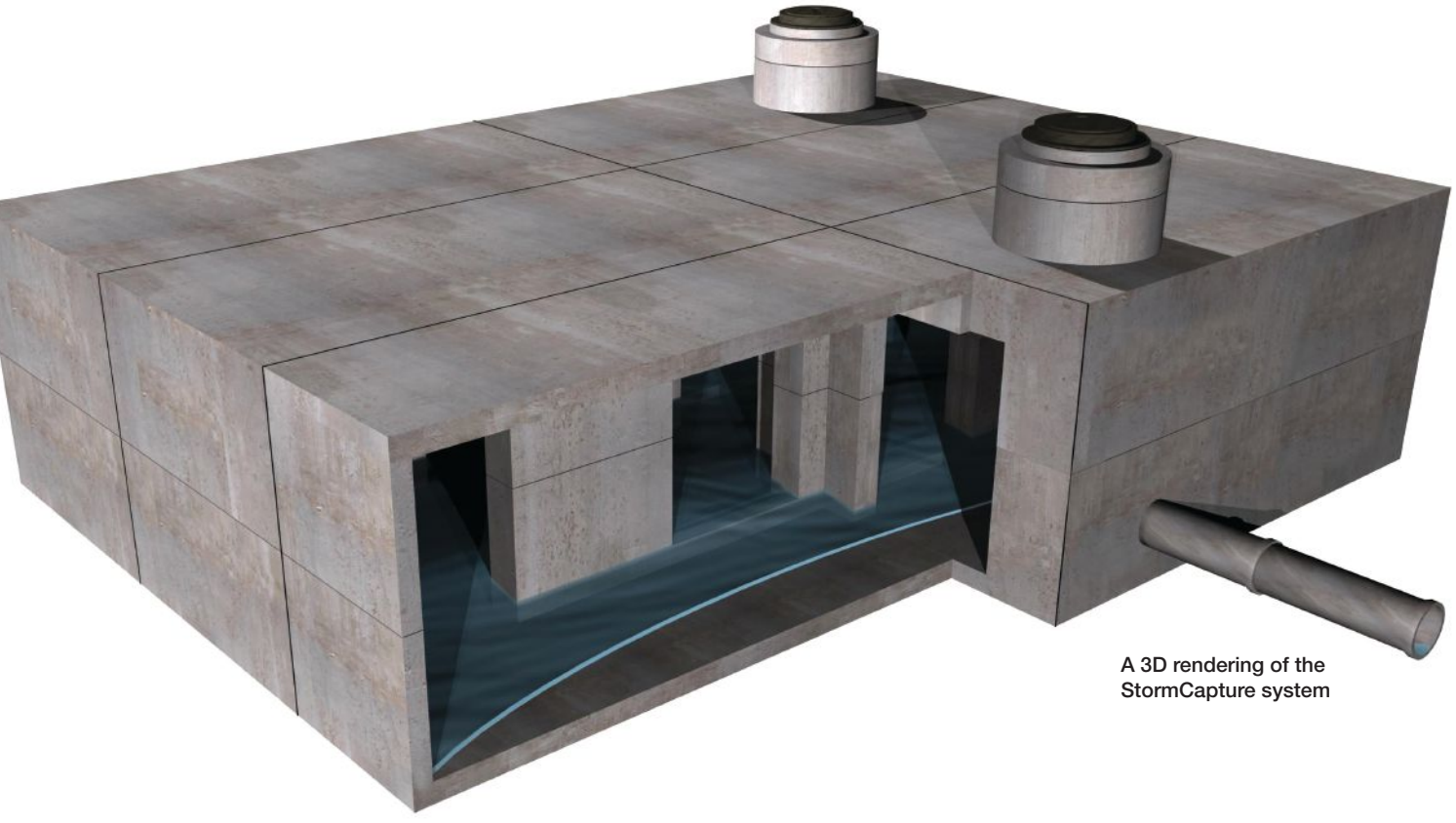
> "No one would ever know that we can store over a million gallons of water just inside of the park, right below the baseball field."

The Philadelphia Water Department (PWD) hired the consulting engineering firm of Hatch Mott MacDonald to find a solution to the flooding. The firm recommended building a detention system to collect stormwater runoff from the streets and then allow for a controlled release to the surrounding storm drainage system. The detention system, which had to meet the treatable flow rates as well as local regulatory requirements, was placed inside a city park beneath a baseball field.

The system uses the StormCapture system from Oldcastle Precast. StormCapture's modular system is designed to meet stormwater management needs including detention, retention, infiltration, treatment, and harvesting. Modules measure 8 feet wide by 16 feet long and can also be constructed in customized heights. The system beneath the park consists of 141 StormCapture modules and 81 LinkSlabs, which reduced the number of modules needed as well as the overall project cost. The system is able to detain 217,978 cubic feet, or 1,630,589 gallons, of stormwater runoff.

Two additional modules on the project allowed the placement of access manholes outside of the baseball playing field. The modules were offloaded from the trucks and installed by crane.

Michael Creeden, territory manager for Oldcastle's Mid-Atlantic and Northeast regions, notes the project exemplifies the direction of stormwater management in urban areas. "The



A 3D rendering of the StormCapture system

Photos: Oldcastle Precast

Completed StormCapture installation

city of Philadelphia saw an opportunity to eliminate a flooding problem while maintaining the city's green space," he points out. "In the end, no one would ever know that we can store over a million gallons of water just inside of the park, right below the baseball field."

A School for Stormwater

At a high school in Quakertown, PA, stormwater treatment was needed that would meet water-quality regulations and be able to function in limited space.

"They needed to use some type of treatment device in order to provide the necessary removal rates and flow rates as governed by Pennsylvania's Department of Environmental Protection design manual and different regulatory items," says Justin Nace, stormwater product specialist with Stormwater Solution Source (S3), a Suntree Technologies representative in the Northeast area.

The solution came from Suntree Technologies' Nutrient Removing Filtration System (NRFS) in conjunction with Bold & Gold, a biosorption activated media for nutrient removal. NRFS is a denitrifying treatment vault designed to remove solids and dissolved contaminants. It accommodates high flow rates without clogging. It provides post-detention removal of phosphorus and nitrogen.

Bold & Gold was developed by the University of Central Florida to remove TSS, phosphorous, and nitrogen. It is designed to resist clogging and has no organics to degrade.

Nace worked with design engineers to get the products specified and oversee construction by Skepton Construction in July 2017. "It's as simple as setting up the base, dropping it down in the hole, dropping the structure in, and tying in new or existing conveyance lines," he says.

Nace says the only challenge with the project was adjusting the installation date against a weather event. "The whole site got rained out the day before delivery," he says. "They weren't able to dig a hole—there was so much water on site. It delayed the delivery of the vault by a day and a half for them to get it installed on a day when it was drier."

During construction, a bypass pipe was used and then removed after construction when the unit was installed and functioning.

"They didn't want sediments from the site during construction going to the structure," notes Nace.

Pest Control

Mosquitos are becoming a significant problem throughout the US, especially in warmer areas and places with

standing water, notes Terry Flury, stormwater sales manager for United Storm Water. Mosquito abatement is at the center of many stormwater mitigation projects, which include United Storm Water's connector pipe screen (CPS).

The CPS—a stainless steel device with 5-millimeter-diameter holes and an overflow system inside—is constructed to fit down into a storm drain catch basin over the outlet pipe.

"When stormwater runoff comes down the curb, it ends up in the catch basin. The connector pipe screen prevents the trash from getting into the outlet pipe or the storm drain lateral," says Flury.

"The only way that water is going to be able to get into that lateral is during a large storm, and there is an overflow area. The connector pipe screen has a removable front screen so that it's easy for maintenance people in the case of an emergency to pull that front cover out from the street and let everything in the pipe so there is no street flooding."

The top deflector that fits over the top of the connector pipe screen has a hinged lid so when a mosquito vector crew conducts testing, they can reach down with a tool, lift up the top cover, and insert their test kit inside the pipe area, says Flury.

According to California state regulations, catch basins must be covered with 100% full-capture devices such as the CPS, he says. "However, there are a lot of counties that are now requiring mosquito abatement systems, whether they be CPS or other devices—something that makes it easy to be able to go in and test."

Alameda County's mosquito vector team wanted the device so workers don't have to remove heavy grates to get their test kits down into the catch basin, Flury says.

Joseph Huston, field operations supervisor for Alameda County Mosquito Abatement District, points out that the idea of stormwater trash capture devices "was built around capturing trash, and nothing was taken into consideration for mosquito abatement practices. Pretty much every district throughout the state has catch basins that hold water and breed mosquitos significantly."

For related articles:
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The Alameda County Mosquito Abatement District has vetted a number of devices to identify those that are effective for trash capture as well as allowing testing to take place. United Storm Water's CPS is among them.

Flury says that in situations where a CPS is used at a curb inlet basin, "we recommend that an automatic retractable screen [ARS] go in front of the curb-opening device. Whenever you put a CPS down in the catch basin, you're catching a lot more trash because it's not going into the outlet pipes, so with the ARS device in front of the curb opening, it keeps all of the big trash and debris from going in and eliminates a lot of maintenance for the cities."

Testing in Hawaii, Development in California

In mid-December, Denis Friezner, director of engineering and founder of Hydra TMDL, installed the Hydra Automatic Retractable Screen (ARS) into four catch basins in Honolulu, HI. The installation was part of testing and certification for the City and County of Honolulu so that the device can be used in the Waikiki area.

"We also will install them in four more locations for AECON for evaluation. AECON provides engineering services for the state of Hawaii," he notes.

Friezner designed the Surf Gate ARS for American Stormwater for Phase 1 of the Trash TMDL compliance the City of Los Angeles had to implement in 2004 and 2005. That ARS system had a mechanism to open or unlock when the water level reached 50% of the curb height.

The city of Santa Barbara, CA, used a Surf Gate without a locking system in a project resulting from the city's Creeks Division receiving a $1.6 million Clean Water State Revolving Fund Grant through the American Recovery and Reinvestment Act of 2009. The underlying goals were to improve water quality and increase community awareness about water pollution by addressing pollutants of concern, removing trash and debris that could be transferred from the streets' storm drain catch basin inlets to the storm drains and creeks.

The catch basin inlet screen design—which requires minimal maintenance—was developed over several years through a series of pilot studies with input from engineers and stormwater staff as well as the city's Creeks Advisory Committee, elected officials, and other community members.

The project consisted of installing stainless steel retractable screens at each catch basin opening on the curb face between the street gutters and sidewalks to prevent trash from entering the storm drains, creeks, estuaries, and ocean.

Two different forms of data were collected before and after project construction to evaluate the effectiveness of the project in reducing trash, including creek trash surveys and catch basin box trash surveys.

Monitoring has revealed a reduction in trash in the catch basins and in the creeks since the screens' installation. The city continues to maintain the storm drain screens.

"It was just a free-hanging 10-gauge (0.135-inch) perforated stainless steel panel," notes Friezner. "This ARS just hung there by its dead weight."

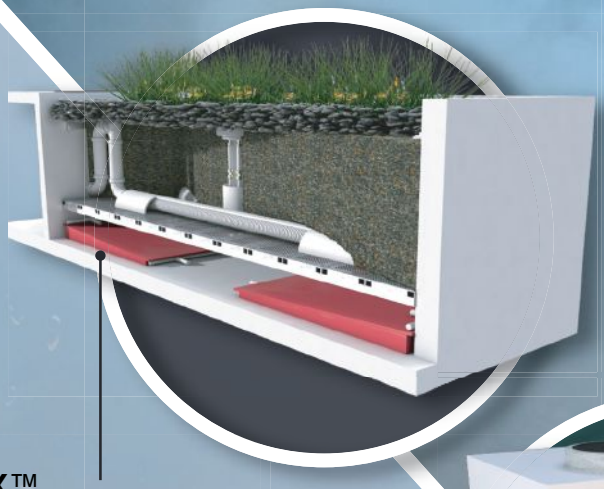
In a subsequent design of the Hydra ARS, Friezner utilizes multiple panels, or blades, with a stainless steel cable that is spring-loaded to return the blade to its home position.

"If a branch or twig gets stuck in the Hydra ARS, it only affects one or two of the Hydra blades, where the rest of the ARS still is preventing the trash from entering the storm drain," he says. "All other stainless steel ARS systems, including the original Surf Gate, will have that one panel stay open when a branch is stuck in there; now trash can enter the storm drain until street maintenance cleans it out."

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

TRIPLE THREAT

Stormwater contaminants don't stand a chance



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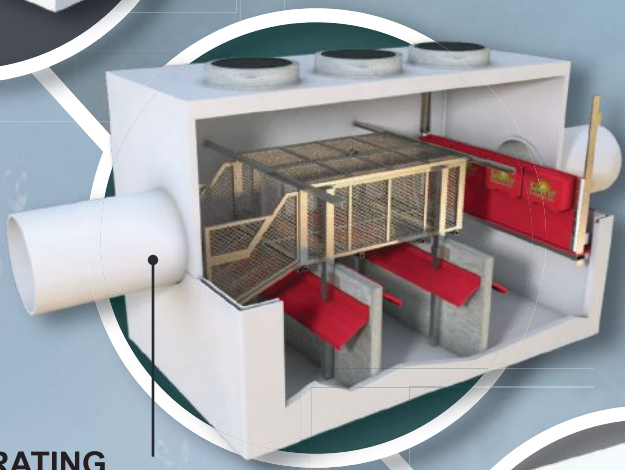

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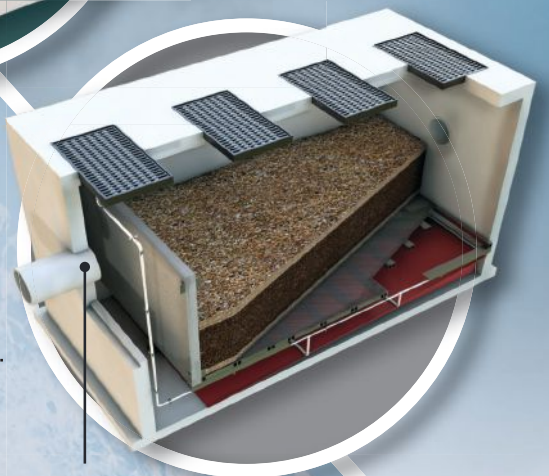

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Built to Perform Storm after Storm

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Controlling Flooding in the Desert

Las Vegas's complex stormwater management system

BY MARGARET BURANEN

The most common image of Las Vegas is probably that of its Strip of hotels and casinos. They are the reason the city is known as "The Entertainment Capital of the World."

But there is another part of Las Vegas, as significant to the city and its economy as the Strip, that most tourists don't see. It has its own title: "Oasis in the Desert."

The proper name for this essential part of the city and surrounding communities is the Las Vegas Wash. This 12-mile channel is the primary conduit for water to and from Lake Mead. The wash accounts for about 2% of the water volume of Lake Mead, which is the source of drinking water for Las Vegas.

The excess water that the Las Vegas Wash returns to the lake comes from four sources: urban runoff, shallow groundwater, stormwater, and releases from four water reclamation facilities located in the Las Vegas Valley. Average excess water flow is more than 150 million gallons per day.

The Clark County Wetlands Park is the final drainage point. It receives primarily wastewater effluent, about 90%. Stormwater accounts for about 4% of the water that goes through the wetlands park.

Native Americans lived adjacent to the wash, valuing it for its more than 2,000 acres of wetlands. The Las Vegas Wash was truly an oasis in the desert for pioneers traveling westward. Its presence led to the founding of Las Vegas and surrounding communities.

However, as the city of Las Vegas and other nearby communities were developed, the wetlands were gradually reduced. Now they total a little more than 200 acres of the 2,900-acre park.

"The wash is pretty shallow, about seven to 10 feet deep. It's a perennial stream, about 40 to 50 feet wide," says John Tennert, environmental mitigation manager for the Clark County Regional Flood Control District (CCRFCD).

In 1998, the Southern Nevada Water Authority joined with more than two dozen local, state, and federal agencies, the University of Nevada at Las Vegas, and other groups to form the Las Vegas Wash Coordination Committee. Its purpose is to protect and enhance the wash and its surrounding wetlands.

Tennert says that as flow from storms increases, it causes heavy erosion in the channels leading to the wash. Hundreds of millions of dollars have been spent to stop the erosion.

Erin Neff, CCRFCD's public information manager, notes that flow rates in the wash vary. "We measure cubic feet per second passing the last gauge before the lake. Rough flow rate on a normal day is 250 cubic feet per second at that point, and it's estimated to be 16,000 cubic feet per second for big storms."

The Southern Nevada Water Authority has installed a series off 22 erosion control weirs, ranging from 10 to 15 feet deep and measuring up to 100 feet in width. Other long-term protection strategies include continued streambank stabilization, managing invasive plant species, and revegetating the land with native plants.

A History of Flooding

Because of the scarcity of rain combined with the intensity of the storms that the Las Vegas Valley receives, stormwater management is intertwined with flood control in the region. The valley has a history of flooding; the US Soil Conservation Service documented 184 flooding events there from 1905 to 1975.

Since 1960, eight floods have occurred that caused $1 million or more in damages. Twenty-five people died during those floods. In July 1999 torrential rains caused widespread street flooding in local communities. Two people died and property damages totaled more than $20 million.

"Our biggest challenge is the highly intensive and sporadic nature of storms. We get roughly 4.2 inches of annual rainfall, in six to 11 storm events a year," explains Tennert.

The limited amount of rain and infrequency of storms —especially when considered together—suggest that stormwater and flooding don't cause many problems. Members of the public tend to forget about rain, and most visitors to Las Vegas never see it.

"It's hard to justify implementing stormwater measures when it's a long time between storms," he says. "We've gone over two months now without rain." But when the Las Vegas Valley gets a storm, it's usually fast and hard. The monsoon season is in July and August, sometimes lasting into September.

Culvert installation under the Centennial Bowl

Clark Country Regional Flood Control District

Topography plays a big role in how storms affect Las Vegas and surrounding communities. "We live in a big bowl. The whole Las Vegas Valley drains into the Las Vegas Wash that goes to Lake Mead," says Tennert. CCRFCD's goal is "keeping that water from going downstream. We have lots of flood control detention basins and flood control channels."

Staff members at CCRFCD focus on regional management of stormwater and flood abatement. Of course, individual communities have their own specific projects to manage stormwater within their jurisdictions.

Although Las Vegas does not have a stormwater utility, "We have a stable source of revenue—one-quarter of each cent of sales tax [paid] in Clark County—and we also bond major projects," says Neff.

One significant project that CCRFCD undertook involved the site of a golf club now called The Club at Sunrise. Formerly known as Desert Rose Golf Course, the site was overhauled to improve flood control in the surrounding area. "This area flooded terribly. The project was a big win for residents," says Tennert.

"Just by widening the Upper Las Vegas Wash, we took 2,300 houses out of the flood zone," says Neff. "Thousands of people no longer are required to buy flood insurance."

Besides peace of mind from worrying about potential flooding, these residents now have more money to invest in their properties for remodeling or maintenance. Those collective expenditures help stabilize the neighborhood.

"Before we did this project FEMA estimated that the area could hold 10,000 cubic feet of water. Now the capacity is 15,500," says Neff.

"In the past year we've been going in and under streets in older developed areas to provide more flood control. We have worked with the DOT on this," she adds.

One such massive traffic project was a flyover ramp where Interstate 215 connects to I-95. Known as the 215 Centennial Bowl, the project involved placing a massive reinforced concrete box culvert (32 feet by 10 feet) under the highway for one mile.

Neff says that CCRFCD's stormwater and flood control projects are "generally a mixture of small drainage projects, some in rural areas and some in urban areas." Traditional green infrastructure doesn't play a major role in stormwater management, as rainfall is too scarce.

"We don't have a lot of green infrastructure," says

The limited amount of rain and infrequency of storms—especially when considered together—suggest that stormwater and flooding don't cause many problems.

Tennert. "Large parking lots are required to treat a certain amount of runoff." Not surprisingly, "green roofs are not popular here. There's not enough rainfall. Solar panels are very popular though."

He notes, "There is a shallow aquifer in the valley created by over-irrigation. It releases selenium into the Las Vegas Wash, so we discourage infiltration [of stormwater runoff] because we don't want to exacerbate the problem with selenium."

Clark Country Regional Flood Control District

Culvert installation under the Centennial Bowl

"Our NPDES [National Pollutant Discharge Elimination System] program is a little bit different," he says. "As the regional flood control district, we serve as the regional coordinating agency for the five permitees on the permit: Henderson, Las Vegas, North Las Vegas, Clark County, and the Regional Flood Control District.

"In 1990 we bonded together and, as the coordinating agency for the group, we stepped forward with money to support projects to address water quality associated with stormwater. Our biggest challenge is that many traditional BMPs don't work here," he says.

"A lot of our efforts, such as our detention basins, are pretty important to maintain water quality for sediment. These basins collect sediment and keep it from entering the Las Vegas Wash and Lake Mead." Ninety-one of these detention basins are in place throughout Clark County. They average 8 to 9 feet deep. "The largest basins are in the foothills of the mountains," Tennert says.

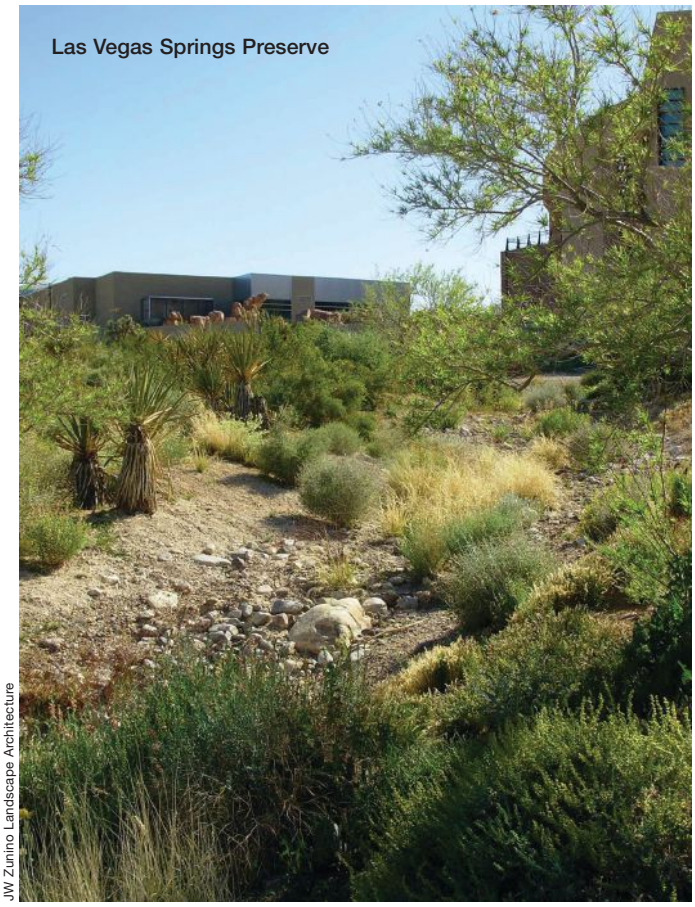
The Kyle Canyon Detention Basin is a mile long, 50 feet deep, and 300 feet across. Even with its massive capacity, this detention basin overflowed during flash flooding in 2013. A wildfire had burned 28,000 acres in the Spring Mountains. When major storms hit, water, sediment, and debris flowed down into the surrounding northwest Las Vegas neighborhood. In 2015, the Kyle Canyon Detention

Basin was upgraded. Its $17 million retrofit connected the basin to underground channels that would handle a greater volume of water.

"One thing our permit requires is that we construct water-quality features in some of these detention basins. We're required to treat up to a two-year storm, so we installed weirs within the detention basins to capture sediment and pollution. We regularly clean the detention basins of sediment," explains Tennert.

"We implement standard BMPs on construction sites. That's done on the ground by the different municipalities. We have a constant inspection program. The focus is really education and compliance. Of course we do issue fines when we have to. As stormwater becomes a bigger issue from the regulatory standpoint, our requirements increase. Our permits never go backward. The requirements only get stronger."

He adds, "We have a good working relationship with the regulatory community. Periodically, once or twice a year, we have outreach training for contractors. We talk to them about NPDES, what the purpose is, what specific requirements on their part are. We talk to cement truck companies, roofers, any company involved in construction. You name it, we've done some kind of stormwater outreach with them."



Las Vegas Springs Preserve

JW Zunino Landscape Architecture

Tennert says that the Nevada Division of Environmental Protection is "a partner, rather than just a regulator. Our work with the state is really a collaborative effort."

Neff says that in the next year or so, CCRFCD's stormwater and flood control projects will be "mostly related to transportation, such as the US 95 interchange in the northwest portion of Las Vegas." Stabilization efforts on the Las Vegas Wash will continue. Duck Creek, which drains into the wash, is also a planned project site.

Tennert notes, "Given the flows during storms, we really have to use hard armor for stream and channel stabilization." He says soil in the Las Vegas Valley is "largely alluvial, with some sandy loam. There is very little absorption. Rainfall mostly runs off."

Protecting the Strip, Tourists, and Locals

Neff says Las Vegas gets about 30 million visitors a year. "Most of them have no idea of flooding here."

Describing a flood control project above the Las Vegas Strip, Neff says, "The Army Corps of Engineers spent $400 million on flood control. All of the basins and channels [installed] over a nine-year period have reduced flooding on the Strip."

She notes that with natural washes existing in what is now an urban area, part of one hotel still sometimes turns into "a flood zone during a major storm, so the property closes down that area [completely]."

Some natural scenic areas around Las Vegas, such as Red Rock, are subject to flash flooding every summer. Signs are posted to warn hikers.

"We do have extensive public outreach," says Neff. "We go into schools and talk to second and third

Bridge at Centennial Hills Park

JW Zunino Landscape Architecture

graders, giving them age-appropriate information on how to stay safe during storms."

CCRFCD has some partnerships with the county school district that involve older students, too. The agency has partnered with the University of Nevada Las Vegas for two studies on flood control.

The Las Vegas Wash starts in the northwest part of the valley and drains to the southeast. The Lower Las Vegas Wash is the part that flows into the wetlands park. Bird species recorded in the park number 310, including

> "We go into schools and talk to second and third graders, giving them age-appropriate information on how to stay safe during storms."

many species of herons. Neff adds that more than 70 species of other animals live there too, including beavers. More than 200 species of upland, riparian, and wetland plants grow there; wetland plants flourish in the ponds created behind the weirs.

Tennant says the park is a great asset to the Las Vegas Valley. "The wetlands are all connected. There are hiking trails, paved bike trails, and bridges over the wash."

Golf courses' demands for water in locations where it is not abundant have drawn criticism on many fronts. "We've done a lot in the last 15 years in the region for conserving water use on golf courses," says Tennert.

Notable Projects

Las Vegas Springs Preserve was created to preserve the history of the birthplace of the city. Since its opening in June 2007, more than two million visitors have toured this interesting and attractive site, which is owned by the Las Vegas Valley Water District.

"It's about five miles from downtown Las Vegas," says Jack Zunino, FASLA, PLA, president of JW Zunino Landscape Architecture. His firm created the final concept plan and construction drawings for various sections of the preserve.

Zunino calls the 320-acre site "a gem in the desert. When I have visitors to Las Vegas, that's the first place I take them."

The preserve has a 30 million-gallon reservoir and a working water well field. The wells pump to three different hydraulic zones. "They draw water from the aquifer in the sum-

mer and replenish the aquifer in the winter," says Zunino.

He persuaded the Las Vegas Valley Water District to put a parking lot atop the reservoir area. Trees in pots are located on the roof, and photovoltaic cells shade the cars.

"They also collect onsite water," he notes. "There is a dry riverbed that runs almost the length of the project. All site water goes into a contrived wetland that looks natural. It is a natural filtration system."

He adds, "You can see where the water enters. The forbs and reeds are taller at the beginning of the system because they get more nutrients—or pollution—there."

Clark Country Regional Flood Control District

Clark County Wetlands Park

The water flows into tanks and is recirculated to irrigate the landscaping.

The name "Las Vegas" means "the meadows," and Zunino notes that the Springs Preserve site was once called The Meadows. There was standing water there, so when the railroads ran steam engines the site was a stop for adding water before traveling on to either Los Angeles or Salt Lake City.

In earlier times, the Paiutes and other Native Americans lived there. Evidence shows that both the Mormon Trail and the Spanish Trail crossed through the location. The site's first building has been made into a history museum for visitors.

Thirteen groupings of indigenous plantings are arranged according to where the plants grow by elevation. Zunino explains that quail bush, Joshua trees or yucca, and creosote are among the plants that grow at lower altitudes. Pine trees grow at the higher points in the mountains.

"The site also has a detention basin. Flooding comes down an adjacent street, Alta. We put in an open trapezoidal channel under Alta so water flows down into the basin. We created a wetlands there also," he explains.

The natural rock channel and the basin cover 10 acres. The basin is deep enough to contain islands. Groupings of native trees—honey mesquite, cottonwood, native ash, and a native (though not true) willow that grows near the wash—line the entry to the basin.

"The trees have grown up now. They shade the site and block traffic noise. You wouldn't believe that you're in an urban area," he says.

Zunino says that his firm's work on the Centennial Hills Park "required some special care for drainage. Las Vegas is still not used to design and development up in the foothills." Instead of installing one big flat parking lot that would have allowed flooding from a major storm's runoff, "we made several parking lots that follow the slopes—upper, middle, and lower parking lots," he explains.

He is especially proud of the park's play lot, which is the first one in the Las Vegas Valley with universal access. "Every slide, every swing, every section is rated ADA-accessible for kids."

Another Zunino project is the World Market Center in downtown Las Vegas. The 57-acre site includes several large buildings in a highly urban setting. Although fire trucks have to have access to such a site, "instead of a typical asphalt, 20-foot-wide fire lane, we were able to make it look like a pedestrian corridor, not an industrial site. It has a large palo verde tree in front."

The firm created landscaping around the various buildings. Some water is collected from the large central plaza area and saved for irrigation.

Zunino says that practicing landscape architecture in the Las Vegas Valley "is very challenging—how we do soil amendments, shading of sun in the summer, and so on. We live in a desert."

He adds, "Our soils are almost impervious, so even a half inch of rain is a pretty big storm. We've been cognizant of that, so we try to do rain harvesting on any project we do."

One way of including rainwater harvesting on projects is to add or to use existing dry river beds to funnel stormwater into a collecting basin at the lowest point on the property. Then the runoff can't cause flooding and is available for irrigating plants.

"Instead of [installing] pipes to carry the water to the storm sewer system, we think it's more important to use the water onsite," Zunino says.

The Zunino firm's office building, converted from a former residence, has a water harvesting river bed. The trees and other vegetation—including native mesquite, Chilean mesquite, chokecherry, bear grass, lantana, and yucca—are irrigated by the rain collected. It's convenient to show clients, along with demonstration gardens on the property.

Zunino says that using only native plants "limits our palette," so he likes to include some nonnatives that have become adapted to the desert. For grass or turf he prefers a hybrid Bermuda that "repairs itself quickly" rather than regular Bermuda. He advocates having turf in areas where people play, but "not turf just to have turf. That's the right thing to do."

Scarce rain that falls in intense storms, soil that won't infiltrate water, a hot desert climate, a location in a valley below foothills and mountains—all of these factors make stormwater management and flood control interconnected for Las Vegas and surrounding communities.

Margaret Buranen *writes on the environment and business for several national publications.*

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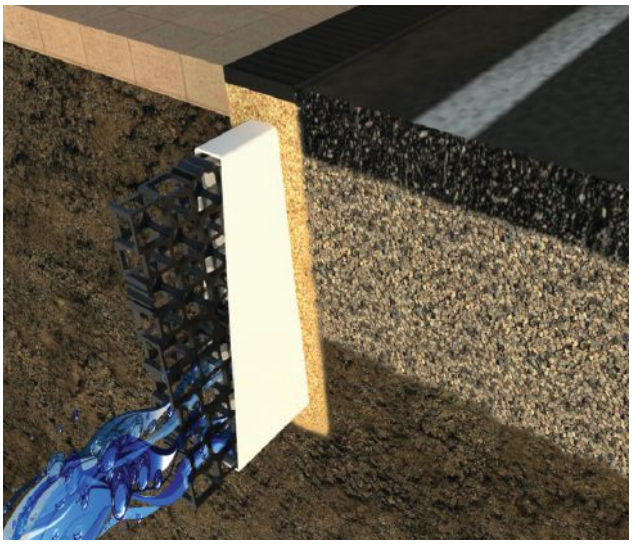

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www.hammerheadtrenchless.com

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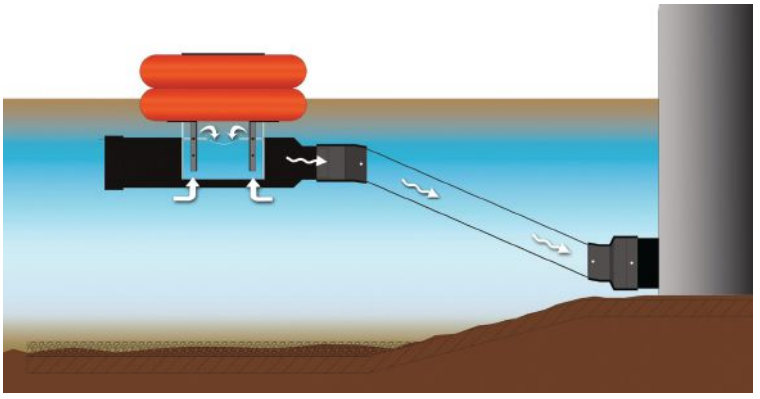

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READER PROFILE

Nick Trujillo

BY CAROL BRZOZOWSKI

As with anywhere else in the US, water is a precious source of life, recreation, and commerce in Denver, CO. Still, there are people who either purposely or accidentally engage in actions that compromise its quality. That's where Nick Trujillo, stormwater quality investigator, comes in.

After complaints of illicit discharges come through on the city's 311 line, dispatch sends them through the system to Trujillo, whose job it is to help protect the 155 square miles of the entire city of Denver as well as Denver International Airport property. Trujillo questions the person filing the complaint about the nature of the discharge, its possible source, and its duration. He then uses a GIS map of Denver, checking into aerial photos in the stormwater layer, which features every storm line and inlet. He finds the site, identifies its owner, and prints out a map. If it's an emergency, he responds immediately; otherwise, he's onsite within 48 hours.

Trujillo writes up a report on his findings and logs it in case the state or EPA wants to conduct an audit. It's also part of a record that goes into an annual report submitted to the state of Colorado. Illicit discharges into the city's storm sewer system can originate from a residence or business, resulting in anything from a verbal or written warning to a citation and order into court. The responsible party may have to do cleanup or remediation and bears the cost. An exception is when the city cleans up the area and then bills the offending party for cleanup costs. Trujillo uses all of the tools at hand and enlists the help of different city departments. "We've had cases where it's been monitored for several months trying to figure out where it's coming from. We get calls that it's starting again, and I'm pulling manholes. It really gets to be somewhat of an environmental CSI sort of deal," he says. "It takes time, but generally we find the responsible party. There are occasions where we don't, and that's the frustrating part." Trujillo also does post-construction investigations on sites over an acre that require a stormwater quality feature to filter stormwater coming off the site to ensure it is in place and operating as intended.

What He Does Day to Day

As a water-quality investigator for Denver Public Works, Trujillo handles between 70 and 100 reports of illicit discharges into the City and County of Denver's storm sewer system each year. Additionally, he's inspecting public and private post-construction water-quality systems "to ensure environmental standards in Denver are met to help secure the city's water resources for the long term," he notes.

What Led Him Into This Line of Work

Trujillo didn't initially set out to become a stormwater quality investigator. He had studied finance at the Metropolitan State University of Denver but became a stormwater quality investigator as a result of a promotion. "In the beginning of my career, I connected with great mentors who were experts in the field and taught me everything I know today," says Trujillo of his on-the-job training.

What He Likes Best About His Work

"Every day is different, bringing with it new challenges that test my knowledge to educate the public about environmental laws—even in some cases when I must enforce the rules, regulations, and penalties involved with those laws," says Trujillo. "A big part of my job that I'm passionate about is when I'm able to help resolve a resident's environmental concern. It's that interaction with the community, as well as environmental experts and other professionals, that I value the most about my work."

His Greatest Challenge

Trujillo notes that at times, it is challenging to help people understand the complexities of environmental laws and why they are in place. "However, with each case that comes to my desk, I approach it as another opportunity to help educate someone about why it's important to protect Denver's environment," he says. "This way, in the future, that person will hopefully gain more appreciation for the environment and make positive choices."

Carol Brzozowski specializes in topics related to stormwater and technology.

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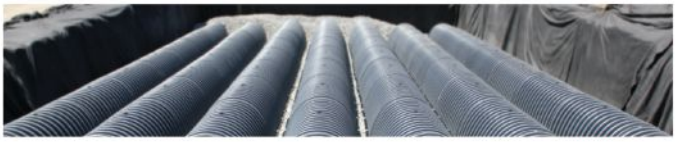

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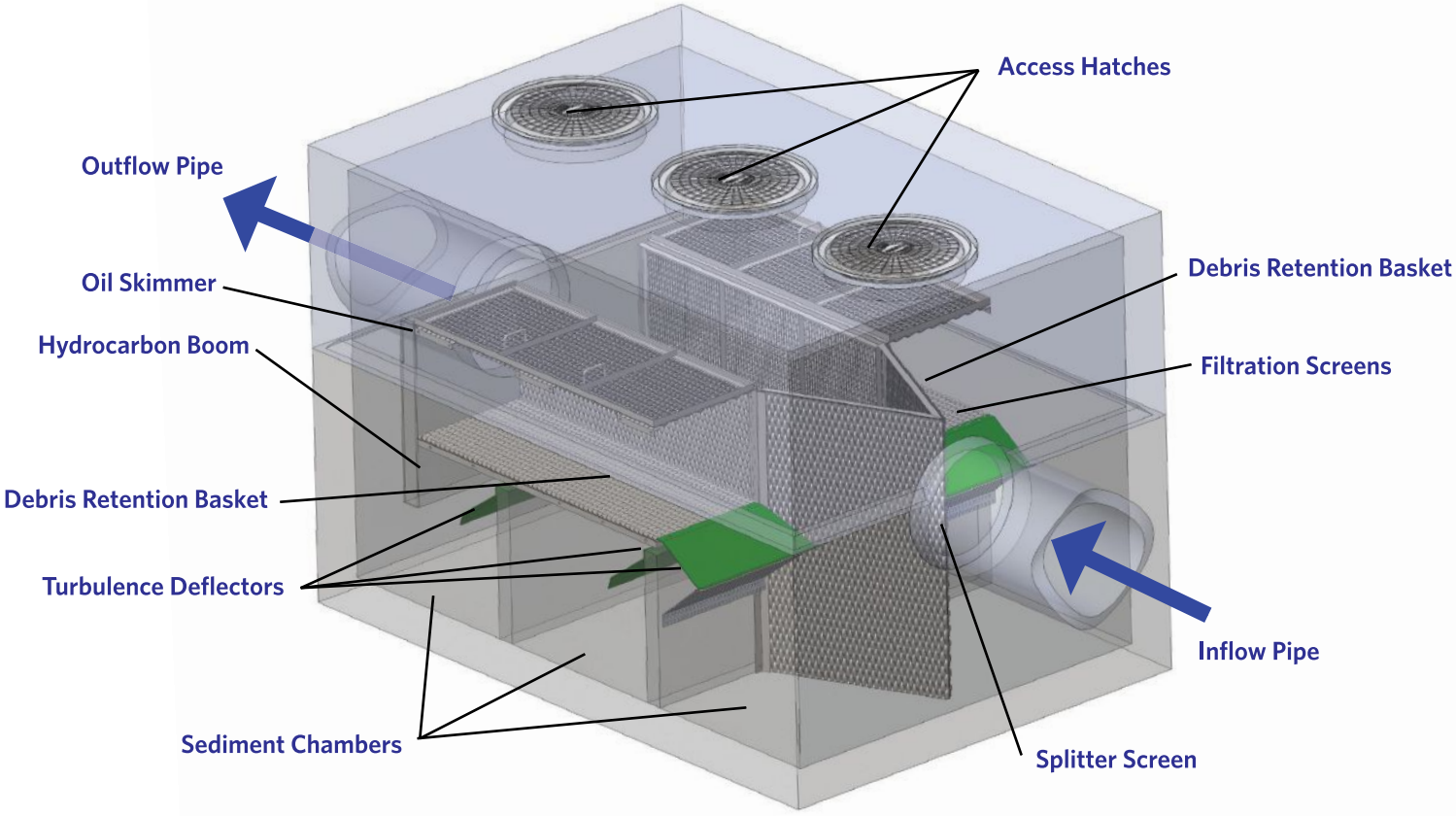

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