Taking Root UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER 2017–2019 TRIENNIAL REPORT

Stormwater Center

In this report

Effective stormwater management is taking root

We have good news for every community in the country: effective stormwater management is in your reach.

After 17 years of research and outreach focused on stormwater system design, installation, and maintenance, we know your community can improve its capacity to control runoff and protect water quality. You can reinvent your stormwater program without reinventing the wheel, with the resources you have on hand. In the process, you will meet regulatory standards, while saving money and time.

What's the catch? Getting there will require you to think differently about managing stormwater at the site and throughout the watershed. Since 2003, the University of New Hampshire (UNH) Stormwater Center has worked with hundreds of communities in every season and setting—from deserts to mountains and from coast to coast. In the process, we have transformed our research into flexible, no-regret solutions to the stormwater challenges faced by all cities and towns.

In places as diverse as Philadelphia, Pennsylvania, and Dover, New Hampshire, these solutions are taking root. Stormwater managers are meeting their goals by emphasizing filtration and infiltration; they are reaching across town borders to collaborate and save money; and they are finding that restoring pre-development hydrology offers benefits that reach beyond water quality into the heart of community resilience. In this report, we are excited to share some of these solutions, alongside new research and tools, with you.

UNH Stormwater Center by the numbers

1,000s of website hits each month

72 Communities and organizations served in 16 states and countries

48 Different structural and nonstructural stormwater control measures tested

22 Publications

2,914 Students educated

50 Bodies of water protected

4,430 Professionals trained

From left: Dr. Thomas P. Ballestero, P.E., Director and Principal Investigator; Dr. James Houle, Ph.D, CPSWQ, CPESC, Program Director; and Research Engineer Daniel Macadam, EIT.

Our mission

The University of New Hampshire Stormwater Center is a dynamic research, testing, and educational facility that serves as a technical resource for water managers, planners, and design engineers in New England and throughout the United States. We are dedicated to the protection of water resources by promoting more effective stormwater management.

Down to earth science

Do more with less. How often do you hear that? As urban populations grow denser and storms become more severe, stormwater managers have less space for system expansion, smaller budgets for expensive system designs, and fewer staff to run behind maintenance. Making the most of the space you have, optimizing the operations of existing systems, and understanding a system's true capacity to manage runoff is critical. In the last two years, we've combined knowledge accrued from more than a decade of system monitoring with a series of targeted studies to develop some tips and tools to help you achieve your stormwater goals, even when you're in a tight spot.

Not all filter media is created equal (but we have recipe tips)

"Green" sounds eco-friendly, but not if it's the color of surface waters in your town! Excess nutrients like nitrogen and phosphorus in runoff are a major source of nonpoint source pollution and the harmful algal blooms plaguing waterways around the country. UNH Stormwater Center research has found that the right filter media is key to meeting nutrient removal targets for the bioretention systems commonly found in urban and suburban settings.

Filter media is typically a mix of sand, loam, wood chips, and other amendments. Together, these ingredients help manage peak stormwater flows, nurture vegetative cover, and filter pollutants. Because filter media is the most hydraulically restrictive component of a bioretention system, it also dictates the filtration footprint and sizing. In a series of laboratory studies, we looked at the capacity of different filter media textures and amendments to remove phosphorus. We found when it comes to phosphorus management, not all filter media is created equal.

27 columns, four takeaways

UNHSC field work is supported by laboratory studies. We conducted 27 column studies that examined the performance of different soil textures, depths, and amendments when subjected to simulated urban stormwater runoff with typical phosphorus concentrations. The studies looked at the performance of the UNHSC filter media mix (sand, loam, and wood chips); other mixes containing different percentages of sand and loam; and five soil amendments: water treatment residuals (WTR), iron filings (Fe2), basic oxygen furnace slag (BOF), pulverized limestone (LS), and zerovalent iron (ZVI).

1. **Loamy versus sandy?** For phosphorus removal, finer textured, loamy soil mixes outperformed coarser sandy soils when no other amendments were added. However, the low permeability rate of finer soils does not allow for commonly specified drain times. Engineered media often needs bulking agents, such as sand or wood chips, to increase the permeability rate and reduce the required drainage to filter area ratios.

   Takeaway: Filter media soil characteristics are an important component of design—they must balance water quality treatment and hydraulic capacity objectives. Recommended mixes may be found at https://www.unh.edu/unhsc/specs-and-fact-sheets-0

Harmful algal blooms like this one are a pervasive water quality challenge nationwide.

We used controlled column studies to explore how different soil gradients, depths, and amendments perform with respect to phosphorus removal from typical urban stormwater runoff. Column studies are a quick, efficient way to test the performance of a wide range of filter media.

Sand, loam, wood chips, and compost are common components of filter media. Research has shown that compost can be a source of phosphorus and therefore is no longer recommended. Coconut coir fibers or peat moss are suitable substitutes.

2. **To compost or not to compost?** Adding compost to the mix can nurture vegetation and provide organic carbon that helps decompose nitrogen. Unfortunately, many types of compost also produce phosphorus that offsets the system's overall phosphorus removal capacity. In some cases, this results in the system becoming a source of phosphorus. Therefore, we do not recommend using compost for bioretention filter media unless the compost has been verified to have very little phosphorus.

   Takeaway: Skip compost or use a low phosphorus version. Or add shredded wood as a carbon source and apply compost only to the vegetation's root zone, i.e., the top six inches of the filter media.

3. **WTR or FE2?** Of all the amendments we tested, water treatment residuals (WTR) and iron filings (Fe2) were the top performers, exhibiting phosphorus removal efficiencies higher than 95%. As little as 0.5% Fe and 5% WTR by volume boost phosphorus removal efficiencies above 95%, even in amended soils with high phosphorus leaching compost. Conversely, slag and lime amendments resulted in removal efficiencies between 30 and 40%.

   While WTR might appear more cost effective than Fe2, the difference is almost negligible in the context of overall system costs. Fe2 allows for shallower filter media beds that are less expensive to install and may be more appropriate for the site, especially where elevations are at a premium.

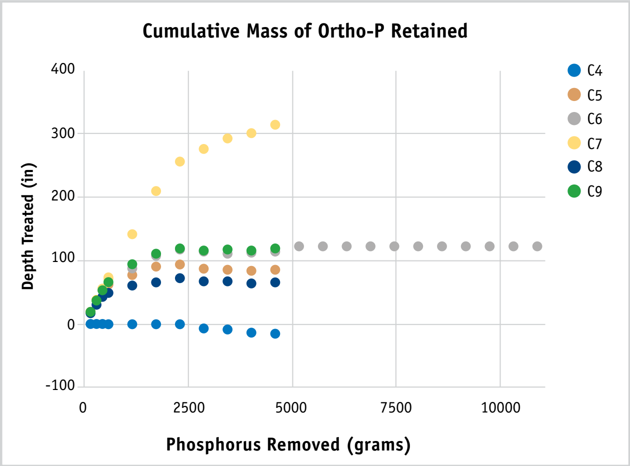
   For example, the removal rates of two feet of media amended with WTR yielded results similar to those of one foot of media amended with Fe2.

   Takeaway: You can engineer your soil media to achieve higher than 95% phosphorus removal, even in designs with small footprints and large drainage to filter area ratios. However, the filter media design should be further refined to consider other targeted pollutants for your site.

4. **Can ZVI Take on ortho-P?** Orthophosphate (ortho-P) is phosphorus in its most "bioavailable" form, meaning that it is extremely good at accelerating harmful algae growth and impairing water quality.

Column	Media depth (in & cm)	Sand %	Loam %	ZVI % (By volume)
1	12, 30.5	70%	30%	0%
2	6, 15.2	70%	30%	0%
3	6, 15.2	100%	0%	0%
4	12, 30.5	70%	29.5%	0.5%
5	12, 30.5	70%	29%	1%
6	12, 30.5	70%	27%	3%
7	6, 15.2	70%	29.5%	0.5%
8	6, 15.2	70%	29%	1%

Mixes with at least 3% ZVI, 27% loam and 70% sand had the highest performances, with deeper filter media layers out performing shallower ones.



Cumulative ortho-P retained per gram of ZVI used.

In studies at the UNH Stormwater Center and across the country, zerovalent iron (ZVI) is a soil amendment that has shown it may be up to the ortho-P challenge, especially in areas where ortho-P loading is higher, such as agricultural watersheds and heavily fertilized residential areas.

We tested the ability of different depths of ZVI-amended filter media to treat simulated agricultural runoff, i.e., runoff with high phosphorus loading. For all columns, removals were high during the first year, but steadily declined in the following years. For columns of the same media depth, those with higher percentages of ZVI performed better than those with lower percentages. Columns with bioretention filter media but no ZVI showed some removal capacity initially, but this was exhausted within the first two years. ZVI was necessary to continue any meaningful performance past this point.

Takeaway: Using ZVI as a bioretention media amendment is an effective way of treating ortho-P in runoff, even when influent concentrations are high. Farmers or stormwater managers who need to reach significant ortho-P reduction targets should strongly consider a ZVI-amended treatment system to bolster its long-term performance.

5. **ZVI Lifespan Prediction Tool:** Considering a system with ZVI amendments? We developed a lifespan prediction tool that can help with your design. You input media depth, ZVI percentage, hydraulic loading, and expected mean influent ortho-P concentration, and the tool will produce a percent removal prediction curve and expected lifespan based on acceptable percent removal threshold. Check it out at https://www.unh.edu/unhsc/sites/default/files/media/automated_isotherm_spreadsheet.xlsm

Outperforming expectations

Things rarely go according to plan, but how often do they go better than expected? Turns out that when it comes to green stormwater systems, you can expect them to perform above and beyond.

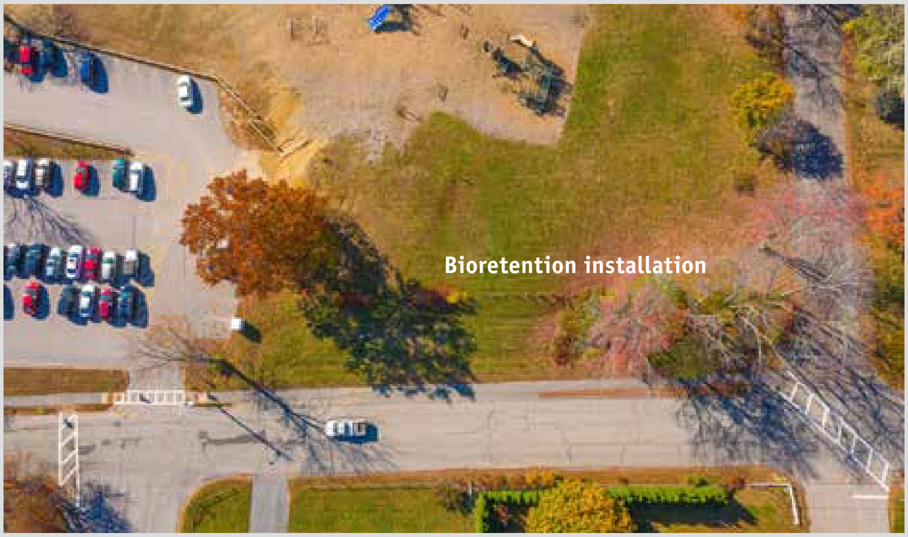
Since 2004, the UNH Stormwater Center has studied the field performance of green stormwater systems, including bioretention systems, gravel wetlands, and tree filters. In study after study, we've found these systems manage higher volumes of stormwater than predicted by models and designs.

Understanding the reason for these differences can help cities and towns work smarter, not harder, when choosing the best green system for their needs.

Green stormwater system dimensions are often based on static designs. To comply with regulations, a system must be capable of holding a certain volume of runoff or water quality volume, which is usually the runoff from one inch of rainfall over an associated drainage area. However, static design is based on the idea that total runoff volume enters the system instantaneously.

In reality, rain (and runoff) often enters a stormwater system over the course of several hours or days. In such cases, water is draining from the system as it enters. Runoff can also leave through outlets or subsurface pathways, a capacity that increases the volume of runoff the system can process.

A characteristic of the soils used in stormwater treatments also seems to help green systems outperform design expectations: infiltration rate, or the rate at which water permeates the soil. While runoff moves horizontally and vertically through these soils, static designs commonly only credit infiltration at the bottom of the system, where infiltration rates tend to be lower. Horizontal infiltration, which occurs at the sidewalls of systems, is often significant, but not accounted for in design or projected performance.



Tucked between the Horne Street School's playground and the road is a bioretention system that consistently outperforms expectations.

A little going a long way at Horne Street School

Everyone has an opportunity to learn at the Horne Street School, even stormwater scientists and managers. In 2008, the UNH Stormwater Center teamed up with the City of Dover to use Horne Street as a test site for better understanding the hydrology of green stormwater systems.

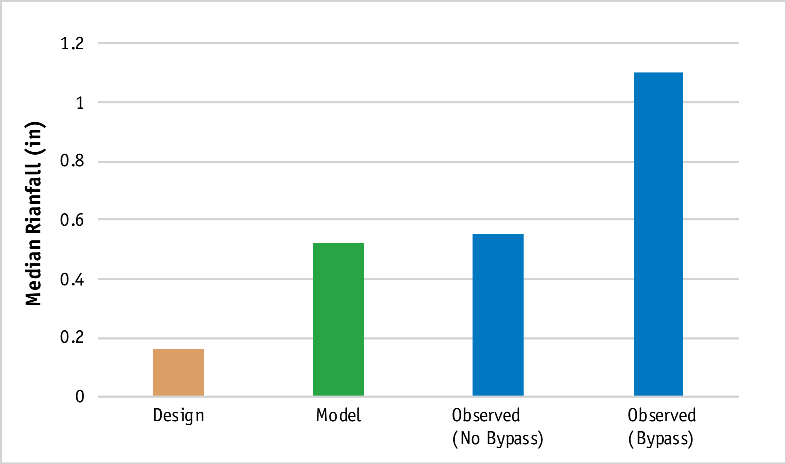
One of dozens of such installations in Dover's Berry Brook watershed, the bioretention system at Horne Street is sized to manage 0.16 inches of rainfall. As an urban retrofit with limited space, this was the largest system the site could accommodate. The static design predicted that runoff from larger storms would fill the system to above the rim of the secondary (overflow) spillway, allowing excess water to directly enter the storm sewer system without moving through the bioretention media.

Instead, after seven years of monitoring we found that the system managed 95% of all rainfall events without overtopping and bypassing the secondary spillway. The mean storm size managed by this system without overtopping was 0.59 inches. The largest event it managed without overtopping was a whopping 1.27 inches of rainfall— almost eight times more than anticipated by the design! As small as this system was, it achieved 62% peak flow reduction and a 35% volume reduction.

These results support the discrepancies observed during modeling. Using the Green and Ampt infiltration model, we found that calculating bottom infiltration rate under predicted infiltration and over predicted outflows to the storm sewer. Employing the model to calculate both bottom and sidewall infiltration rates and comparing them to all monitored rain events predicted overtopping for 0.52 inch rainfalls, versus the 0.16-inch rainfall static design.

The significance of these results are not lost on other New England communities interested in innovative stormwater management

"UNHSC partnered with us to provide a practical, easily scalable design of a simple infiltration trench," says Wayne A. Chouinard, an engineer with the Town of Arlington's Department of Public Works in Massachusetts. "We've already put this tool to use and found it easy to determine the most efficient size to maximize removal rate while minimizing material costs and stretching our



Event summary for Horne Street Bioretention System for events without high-flow bypass (n = 30) and events with bypass (n = 15).

How green is your artificial turf?

No fertilizers, no mowing—is it surprising that artificial turf is popular with communities and institutions looking for a four-season field surface? Yet many have concerns about what these fields may be leaching into local water systems. Since 2012, we have monitored artificial turf fields at the University of New Hampshire (UNH) in Durham to see if these concerns "hold water."

A typical artificial turf field includes a drainage system composed of crushed stone and drainage piping at its base, a finish gravel layer that provides structural support, and turf infilled with shredded tires or crumb rubber infill that is known to possess metals and semi-volatile organic carbon constituents (SVOCs).

Thus far, our monitoring data demonstrates that UNH's artificial turf fields are leaching low, but measurable amounts of metals and SVOCs. Runoff from these fields contains higher amounts of dissolved inorganic nitrogen than nearby impermeable asphalt parking lots, and it appears that the turf's crumb rubber infill is generating this nitrogen.

Armed with an improved understanding of the water quality impacts of artificial turf fields, we are developing best management practices to mitigate those impacts. Nearby Portsmouth, New Hampshire, is one community that has stepped up to trial these protocols.

Advancing the practice

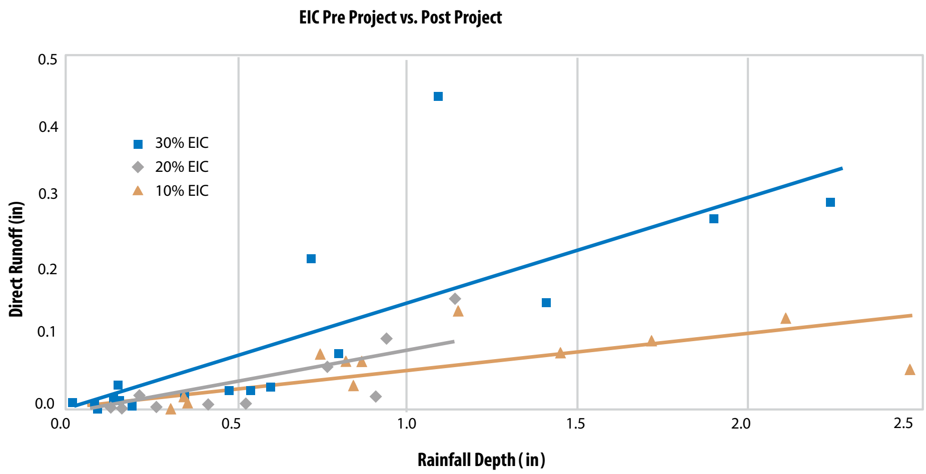
As a stormwater manager, the one thing you can count on is change. Shifting rain patterns, new regulations, emerging science—keeping up can be a challenge for seasoned veterans and new professionals alike. The UNH Stormwater Center has been working with communities around the country to design creative, no-regret solutions that are rooted in the latest science, able to pass muster with regulatory requirements, and make sense for the site at hand.

Berry Brook goes the distance

After only a decade on the list of federally impaired waterways, Dover's Berry Brook watershed has gone from zero to hero.

In partnership with UNH Stormwater Center and the New Hampshire Department of Environmental Services (NHDES) Watershed Assistance Program, the City of Dover transformed this watershed using a flexible approach to stormwater control that was in budget and within their capacity to maintain. They reduced the watershed's effective impervious cover from 30 to 10% through the installation of 26 green stormwater systems and other measures.

"Over the years of working on Berry Brook, we've learned a lot about retrofitting these systems for the urban landscape," says Tom Ballestero, UNH Stormwater Center director. "Perhaps even more importantly, together we have been able to demonstrate the positive impacts of using green stormwater infrastructure across the whole watershed."



The changing relationship between runoff volume (Y) and rainfall depth (X) reduction as the percentages of green stormwater systems increase and effective impervious cover (EIC) decreases. In 2008, the Berry Brook watershed had no green stormwater infrastructure and 30% EIC. Today, with 26 green systems in the watershed, Berry Brook is down to 10% EIC with greatly reduced runoff.

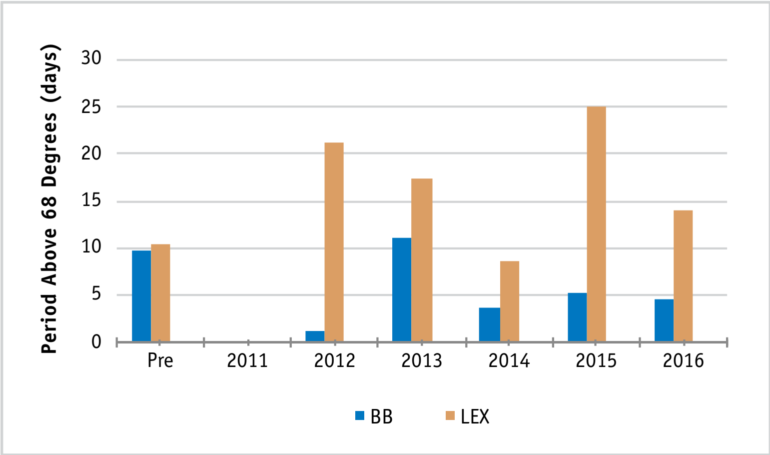
Dover's Berry Brook watershed has become a model for using "in reach" solutions to improve water quality.

From runoff to resource

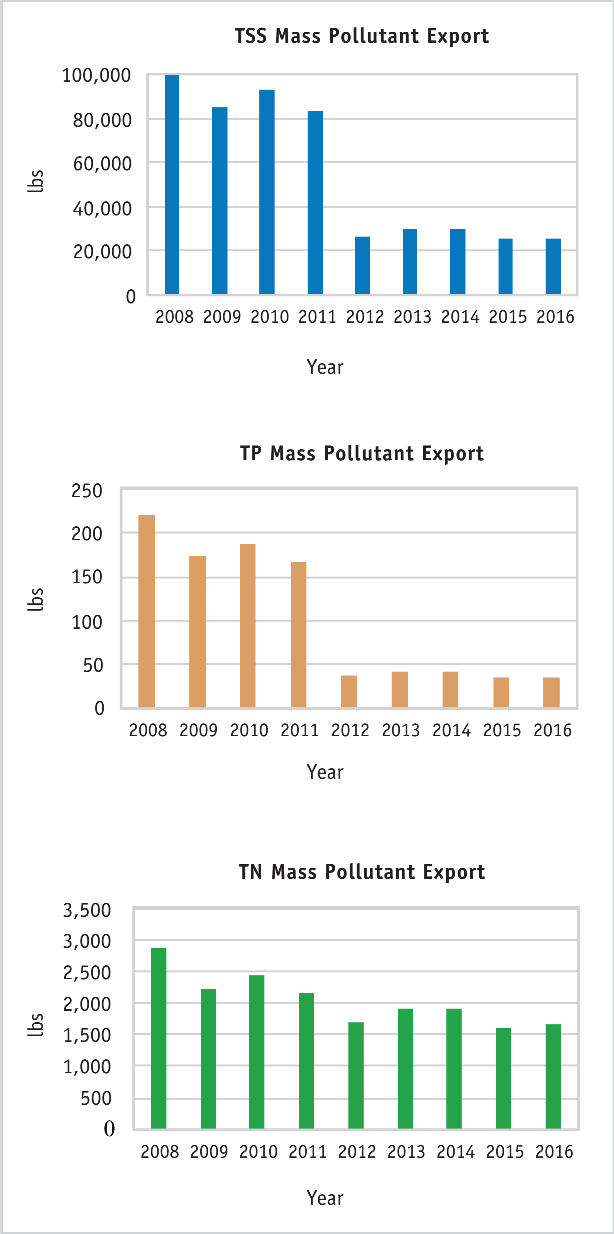
The most common storms drop a half inch or less of rain. The runoff these events generate predominantly comes from impervious surfaces, such as roads, parking lots, rooftops, sidewalks, patios, and driveways. Before Dover installed its green stormwater systems, that runoff—and the pollutants it carried—flowed directly into Berry Brook. Now it flows into permeable soils, where it can slowly infiltrate the groundwater and recharge the brook. On average, this green infrastructure has reduced the volume of runoff in the watershed by two thirds and almost eliminated runoff from the most common storms.

As a result, the watershed's streams are flowing higher and much cooler in the summer. Prior to 2011, Berry Brook had summer flows that were warmer than a similarly-sized reference stream in Lexington, Massachusetts, in a watershed with 24% effective impervious cover. Now Berry Brook is cold enough to stock trout!

Less runoff also means a reduced pollutant load to the brook and ultimately to the Great Bay. According to UNH Stormwater Center estimates, these green stormwater systems have resulted in the annual removal of 65,000 pounds of sediment, 150 pounds of phosphorus, and 650 pounds of nitrogen. They trap sediment so it can be periodically removed by Dover's Department of Public Works, allow time for petroleum hydrocarbons to biodegrade, and take up nitrogen and phosphorus to nurture vegetative growth.



Comparison of warm water (degree days) between Berry Brook (BB) and a reference stream in Lexington, Massachusetts (LEX). These were compared against Saddleback Mountain, a true cold water stream. Given that its summer temperatures stay below 68 degrees all year, Saddleback does not appear on this chart.



Pounds of total suspended solids (TSS), total phosphorus (TP) and total nitrogen (TN) removed from Berry Brook each year.

Filtration systems like this subsurface gravel wetland fit seamlessly into the landscape and improve water quality.

Daylighting streams, like the one flowing under this tree line, is an effective approach to improving water quality.

Philadelphia school gets green star

Chester Arthur Elementary School in Philadelphia became a green all-star in 2017, when they transformed their all-asphalt playground into a dynamic green space that is not only more inviting, it also can handle runoff from the school and surrounding streets.

As a collaboration of the UNH Stormwater Center, the Philadelphia Water District, SALT Design Studio, and the Friends of Chester Arthur, the playground's green stormwater systems are part of the UNHSC Science to Achieve Results (STAR) grant from the U.S. Environmental Protection Agency. The new systems include a bioretention garden, porous asphalt, a subsurface gravel filter, and green stormwater curb inlets—and the opportunity for big city kids to get a little more green in their lives.

Digging in at Chester Arthur

Surprises are not usually welcome on a construction site, but at Chester Arthur Elementary School, an unexpected discovery led to more effective stormwater treatment.

Preconstruction bore holes showed that the soils beneath the proposed stormwater systems—which would make up its receiving layer—had low infiltration rates. Water would only be able to creep through the soil at 0.2 inches per hour. As a result, the stormwater systems had to be fully-sized to hold runoff from 1.5 inches of rain and include an underdrain to manage the design storm over the course of 24 hours.

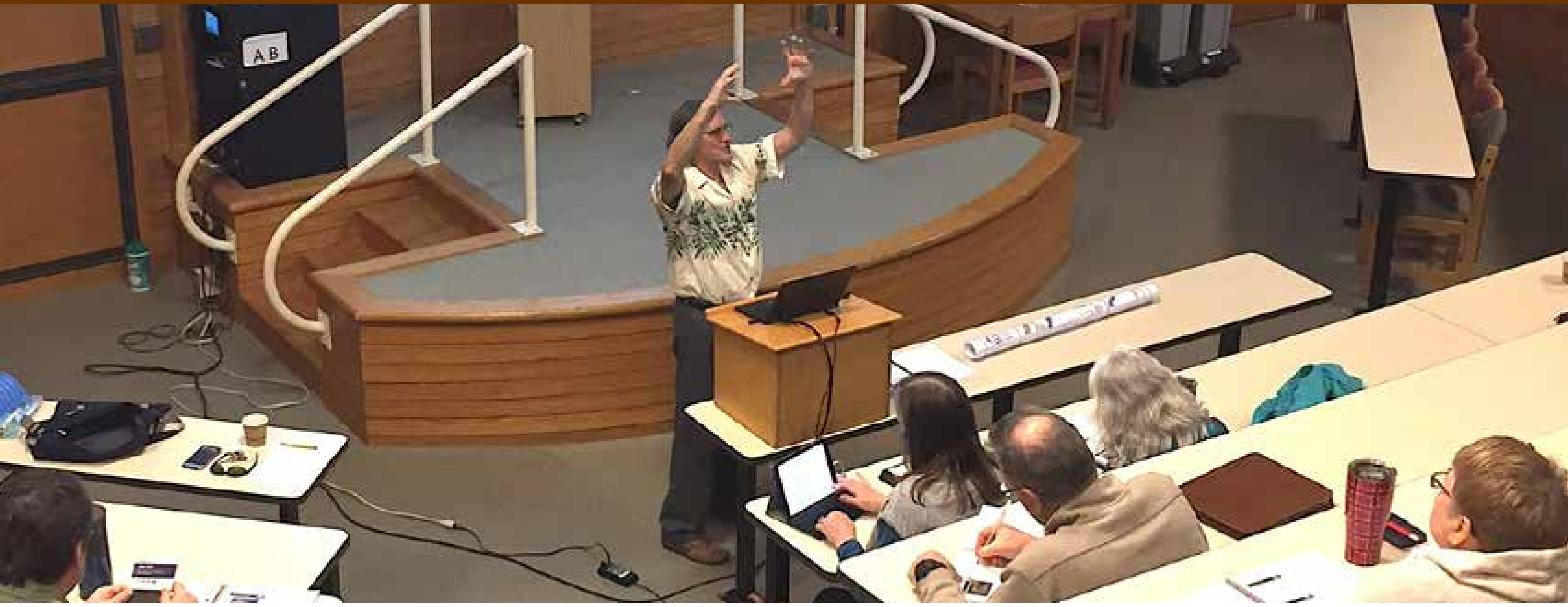
However, once excavation began, the crew found the majority of the site was over demolished brick row homes. These foundations created a strata of highly permeable material above the soils of the receiving layers. The crew capped the perforated pipe underdrain that connected to the combined sewer so that runoff water could only leave the system through lateral infiltration or overflowing into the combined sewer.

To date, the system has not yet filled or overflowed, and the school children at Chester Arthur now enjoy a dynamic green space that also serves a community environmental need. In 2019, the project was recognized with an Excellence in GSI Award by the Sustainable Business Network of Greater Philadelphia.

Chester Arthur Elementary School's playground before the project began.

Design materials are where you find them: demolished bricks formed a permeable layer that improved the playground's stormwater performance.

Children can now enjoy the new, green, playground at Chester Arthur. Photo courtesy of SALT Design Studio and photographer Sahar Coston-Hardy.



Training puts stormwater professionals ahead of the curve

Stormwater management is a fast-growing, constantly evolving field. Balancing the latest science with tried and true best practices can be a challenge for regulators and stormwater designers alike.

"We've reviewed hundreds of site designs over the years, and many people struggle with the same issues," says James Houle, program director at the UNH Stormwater Center. "Some are related to keeping up with the research, but it's clear people also need refreshers on the fundamental concepts of hydrology and design."

To address this need, the Stormwater Center partnered with UNH Cooperative Extension to offer a certificate program for stormwater professionals. "We wanted to apply research to real situations that people recognized and create opportunities for dialogue with state regulators on how to move forward with what we know," says Houle.

The course is designed for stormwater professionals who want to expand their skill sets and regulators who need to keep pace with the latest technologies and approaches that are appearing in permits. It consists of five workshops that explore hydrology, design, sediment control, operations, maintenance, and visits to demonstration sites.

Participants receive a certificate that can be applied to professional accreditation. In its first year, the workshop series drew 80 participants from across New England.

"When New Hampshire rules changed in 2008, there were precious few resources to design for stormwater quality beyond the new Stormwater Manual which was heavily influenced by the UNH Stormwater Center," says Kenneth Berry, principal and vice president of technical operations at Berry Surveying and Engineering.

"I saw they had a certificate program, and I knew it was important. The resources and expertise it provided led to the design of the state's first known hybrid rain garden [Enhanced Rain Garden with Internal Storage Reservoir] by our firm's engineers, including Kevin Poulin, a UNH graduate."

The course has furthered discussion on regulatory challenges in the stormwater field from both sides of the table. It exposed differences between what the research points to and what is written in the state's design guidance, which can be challenging to change.

"For me and my colleagues, the UNH Stormwater Management Certificate program provided a valuable review of design principles," says Ridgely Mauck, administrator of the Alteration of Terrain Bureau at the New Hampshire Department of Environmental Services. "We found the program to be an excellent vehicle for stormwater professionals to stay current with best management practices and enhance their ability to develop effective, compliant designs."

It also has provided critical feedback to help the UNH Stormwater Center focus its future work on the most pressing professional needs.

"One of the most frequent questions we received was around system modeling," says Houle. "We know that real-world systems perform differently than models predict, but this training helped us understand how big that gap really is."

As a result, the Stormwater Center is developing new modeling strategies with the potential to have a significant impact on retrofit designs and in sites that have design limitations. These will be available in April of 2020.

Counting what matters, together

Nonpoint source pollution carried by stormwater runoff is the number one threat to water quality nationwide. It's also a big challenge for Municipal Separate Storm Sewer System (MS4) communities that must maintain stormwater programs that protect water quality and track their effectiveness as part of their MS4 stormwater permits. Working with partners throughout New England, we are helping communities receive credit for green approaches to stormwater management and save costs by collaborating to track the effectiveness of their work.

Pollution tracking and accounting

In southern New Hampshire (and everywhere else), nonpoint source pollution carried by stormwater runoff does not respect town boundaries. It originates from sources across the watershed to contribute to poor water quality conditions in Great Bay and its tributaries. Local cities and towns have developed their own approaches to managing stormwater, but when it comes to measuring the success of their efforts, communities are starting to move like runoff—crossing boundaries and joining forces.

The Great Bay Pollution Tracking and Accounting Project (PTAP) is a forum for the region's communities to build a consistent system to track and measure their efforts to control stormwater runoff, as required by Municipal Separate Storm Sewer System (MS4) permits and other plans to control pollutants. Facilitated by the UNH Stormwater Center and supported by the New Hampshire Department of Environmental Services (NHDES), PTAP has become a framework for towns and cities to wrestle with the challenging and expensive problem of tracking and accounting for pollutants with limited financial resources.

"PTAP is a cutting edge, adaptive approach to stormwater management that is relevant not just in Great Bay, but anywhere," says James Houle, program director at the UNH Stormwater Center. "At its core, it provides flexible strategies for pollution reduction, trusted science, and cooperative solutions, and it strengthens community investment in contemporary environmental challenges."

In its pilot phase, PTAP brought eight Great Bay communities together to take up the challenge. They collaborated on a nutrient control implementation framework that all of the region's cities and towns can use to track pollutants and comply with their permits. The process also led to a database to track activities that affect pollutant loads, provide an accounting system for associated credits, and estimate long-term pollutant load reductions and watershed management trends.

"We continue to meet with cities and towns to make improvements so that ultimately the tool can be self-sustaining and work for everyone," says Houle.

A fully-realized PTAP database has the capacity to have significant economic impacts on community stormwater budgets, as it would allow them to share the cost burden for tracking and accounting. It will also create a streamlined approach for communities to comply with stormwater permit requirements, promote collaboration and resource-sharing, and—the ultimate goal—measure water quality improvement over time and across the watershed.

"The City of Dover runs a robust stormwater operation and maintenance program because we recognize the importance of stormwater in the quality of our rivers, streams, drinking water sources, and the Great Bay," says Gretchen Young, assistant city engineer for the City. "We see PTAP as an essential next step in really understanding where the greatest benefits are so we can continue to focus our program to strategically improve our operations."

Most of the communities testing the PTAP framework and database are those with MS4 permits or other regulatory pressures. As the need for greater pollution control grows in the region, PTAP's facilitators hope that all of the New Hampshire towns in the Great Bay watershed will get involved.

Stormwater runoff from across the region flows into Great Bay, making the protection of water quality a shared responsibility for the Bay's 42 New Hampshire communities.

Stormwater champion: **Sally Soule**

A love for water runs in the family for Sally Soule of New Hampshire's Department of Environmental Services (NHDES). Soule grew up spending summers on a lake front property that's been in her family for seven generations and she wants future generations to have the same access to beautiful, clean water that she did.

So it's no surprise that she has spent 23 years working with water resources, currently as the manager for watershed restoration grants for NHDES. This work helped her identify a need for a unified pollution tracking and accounting system for Great Bay's watershed, and she knew there was only one partner who could make that vision a reality.

"The UNH Stormwater Center is seen in the region as the leader on stormwater," says Soule. "NHDES can bring financial and coordination resources, but the center has the technical expertise and the respect of the municipalities. They were key to bringing towns on board."

Soule also knew that Stormwater Center specialists saw the same thing she did: towns were trying to track pollutants independently and there was a better way. "We could see a unified system could save time and money for all partners and make it easier for municipalities to meet regulatory requirements and increase their capacity to improve water quality."

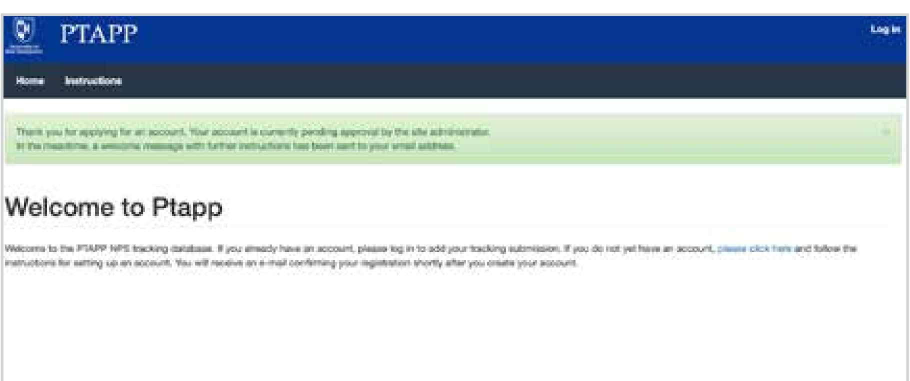
For such a system to work, it would have to originate from the communities themselves. "DES has certain regulatory requirements," she says, "but we wanted to build something towns would actually use instead of telling them how it would be."

The first stage was to convene a series of meetings with communities to collect their input on how towns preferred to do their tracking. The second involved building a database to record and manage tracking and accountability data.

"The database was key, because it was where municipalities would actually enter their data," says Soule. "We relied on UNH's technical expertise to build it; they handled the programming. From there, we rolled it out to municipalities to test it."

This ambitious project—a pollution tracking and accounting system that could work for all 42 towns with different needs, capacities, challenges, and stormwater rules—was born out of collaboration and, according to Soule, can only be sustained by that collaboration.

"Collaboration is critical to the success and future of PTAP," says Soule. "We need the help of towns to ensure that PTAP is functional, useful, and fulfills municipal needs for pollutant tracking."



The PTAP database is a unique, effective approach to tracking and accounting for efforts to reduce pollutant loading at the watershed scale. It is online at https://www.unh.edu/unhsc/ptapp

Credit for going green

Almost everyone agrees, buffers make just about everything better. These natural lands around wetlands and water bodies keep water clean, provide habitat for wildlife, control erosion, reduce flooding, and much more. However, until now there has not been a way for New Hampshire communities to meet water quality regulations by restoring or maintaining buffers

To address this gap, the UNH Stormwater Center teamed up with the Great Bay National Estuarine Research Reserve. The outcome? New Hampshire communities are getting regulatory credit for "going green" by using constructed buffers as a water quality best management practice (BMP) in development and redevelopment projects.

"We knew our communities valued buffers for different reasons, but they were not able to quantify those benefits in ways that would meet state regulatory requirements, which are focused on water quality, " says Cory Riley, manager of the Great Bay Reserve. "They couldn't consider buffers in the same way as 'grey' infrastructure BMPs. They needed incentives and a credible method to do so."

The challenge was existing local science and data, which could not conclusively support recommendations for how to quantify a buffer's ability to reduce pollution. Fortunately, the team had a mentor and a solid case study to show how this gap could be overcome.

"The Chesapeake Stormwater Network and their partners had faced a similar problem on their bay," says James Houle, program director of the UNH Stormwater Center. "They developed a weight of evidence approach to working with an expert panel to review existing literature and make science-based recommendations to credit green infrastructure and other pollution reducing solutions."

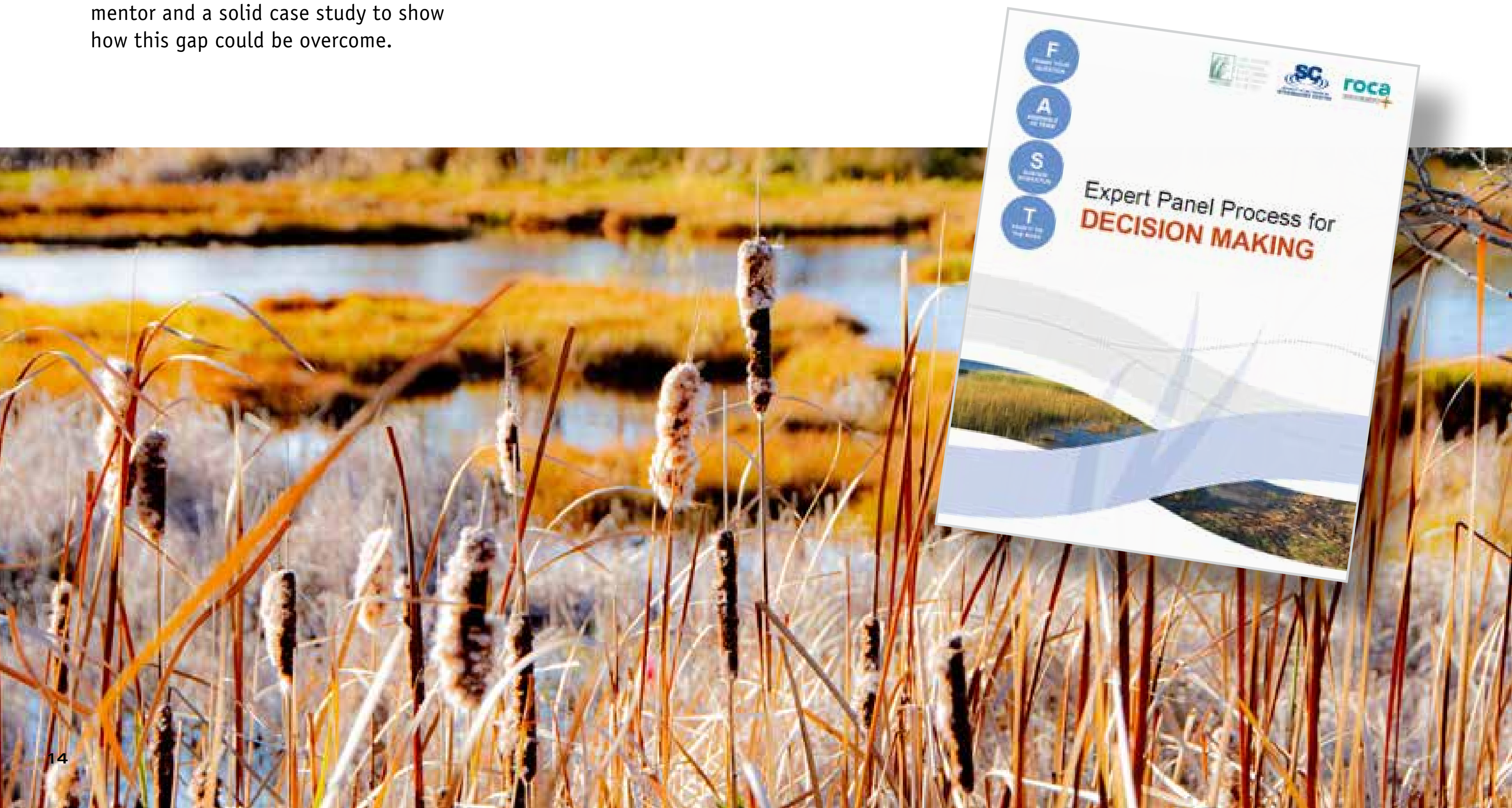
With a transfer grant from the National Estuarine Research Reserve (NERR) System Science Collaborative, the New Hampshire team borrowed a page from the Chesapeake team's book. They convened a panel of experts who were able to generate science-based recommendations for calculating the pollutant removal rate of restored or constructed buffers in development, redevelopment, restoration, and other projects involving land use change.

"The notion of keeping track of the 'credits and debits' of nutrient pollution has never been more critical as state and local communities look to improve water quality," says Ted Diers, director of the Watershed Management Bureau at the New Hampshire Department of Environmental Services. "These curves are a step forward and fill a gap in our knowledge. I also think that this effort will help to articulate the importance of natural and restored buffers."

With the input of an advisory committee that engaged municipal staff, civil engineers, regulatory officials, technical assistance providers, and coastal training coordinators from the Rhode Island, Massachusetts, and Maine NERR sites, the Going Green team is sharing these results throughout the region.

"These pollutant reduction curves should expand and enhance recognition of the essential functions buffers provide for watershed health and good water quality in New England," says Mark Voorhees, coordinator for the USEPA Region 1 Total Maximum Daily Load (TMDL) Program. "They provide water resource managers with a starting point for including credible estimates of pollutant removals for buffers as part of the full suite of management practices needed to achieve watershed pollutant reduction goals."

The New Hampshire team also synthesized their process for other groups working at the interface of science and management who want to collaborate with experts to develop timely, science-based solutions to coastal environmental problems. For more information, visit www.unh.edu/unhsc/news/credit-going-green



Stormwater champion:
Mark Voorhees

Mark Voorhees is not a fan of getting dressed up. Nor does he much like sitting behind a desk. What he does love, however, is being outside near a healthy stream or lake. After joining the U.S. Environmental Protection Agency in 1993, he found his niche in stormwater permitting—work that takes him outside and on the road to develop stormwater management solutions for impaired waters.

"I work with stormwater practitioners at all scales to find commonsense, research-based approaches to improve water resource health and attain state water quality standards," says Voorhees. "My goal is to bring people together for constructive conversations that enable the collective 'us' to make progress. It's just the right balance of theoretical and real life for me."

Voorhees is particularly interested in "pushing the boundaries about what we can do with stormwater to improve the quality of life in developed watersheds." He sees the UNH Stormwater Center as a critical partner in this effort for the New England region.

"No one does more to advance this conversation," he says. "They bring unbiased expertise and extensive experience in working through real issues faced by communities, consultants, states, and EPA. And like us, they are interested in a collective problem solving approach that directs limited resources to solve real problems in the most effective way."

Over the last decade, Voorhees and Stormwater Center specialists have collaborated to explore the true capacity of "undersized" stormwater systems to manage runoff and reduce pollutant loads. This work has led to performance curves and regulatory credits that accurately reflect the performance of these systems—welcome news for urban redevelopment projects with limited space for stormwater treatment.

"We demonstrated that these smaller, cost-effective systems are actually very efficient," says Voorhees. "That has been a game changer—so much so that the performance curves are part of stormwater permitting process for addressing TMDL requirements in Massachusetts, New Hampshire, Rhode Island, and Vermont."

Having flexibility to integrate more cost effective approaches where they make sense adds up, particularly for larger areas, like the Charles River Watershed in eastern Massachusetts. There, the cost of meeting the TMDL could easily approach $1 billion if conventional practices are used. More flexible, cost-effective strategies are likely to lower these costs by hundreds of millions of dollars.

"It's critical we approach this in a strategic way," says Voorhees. "Together with UNH, we are making progress toward our goals by looking for opportunities to make small, affordable changes with big impact. For example, what if 10 percent of the impervious cover in a watershed could in some degree be disconnected through simple diversion designs? We have regulatory credits for such actions, but this is generally unknown by many involved in the field."

Voorhees served as a panelist on a recent Stormwater Center-led effort to generate regulatory credits for the use of constructed or restored buffers in development and redevelopment projects. USEPA Region 1 now considers these credits suitable for use in stormwater permits in Massachusetts and New Hampshire and plans to formally adopt them in the next update of EPA's stormwater permits.

"The expert panel process was a sensible way of going forward when new or refined credits are needed," observes Voorhees. "This type of process can lighten the load for states and EPA and support wise management decisions."

All of this work is part of ongoing efforts to develop flexible, practical, and affordable approaches to improving water quality in New England. Yet according to Voorhees, this approach is still not yet mainstream in New England, and mostly unknown in the rest of the country. However, he suspects it will be welcome.

"When people get to be creative in solving problems, they just feel good," he observes. "And they feel better about a process that leads to more effective actions in reaching water quality goals. That's what a flexible approach can do. It's almost like art—it provides fulfillment for practitioners while also promoting wellbeing among watershed residents."

Looking ahead

"When we try to pick out anything by itself, we find it hitched to everything else in the Universe."

John Muir may have been inspired by the High Sierra, but he could have easily been talking about the art and science of stormwater management. For every problem we address, new questions and needs emerge. As we look to the next few years, we will continue to work with the greater stormwater management community to build on the knowledge we have gained together. Below are some of the research and testing opportunities we are exploring in 2020.

- **Rain is rain, wherever it falls, making the UNH Stormwater Center's field site an indispensable resource for stormwater managers and regulators nationwide.** The State of Washington Department of Ecology location recently selected our site to test the performance of manufactured stormwater treatment systems. To date, we have used this site to develop pollutant removal metrics for more than two dozen manufactured stormwater treatment systems. Performance data for any manufactured system tested our field site now will be accepted by Washington.

- Green stormwater systems have been in practice for more than 20 years, but there are few studies exploring their long-term performance. Bioretention systems, gravel wetlands, tree filters—systems like these have been in place at the UNH Stormwater Center field site for up to 15 years. **As in the standard of practice, they have not been maintained and, as a result, are ripe for studies to inform best practices for operations and maintenance.**

  Similarly, as part of its EPA STAR award, the UNH Stormwater Center is studying the long-term infiltration characteristics of permeable pavements. Not surprisingly, when these pavements are not routinely maintained (vacuumed), they are nearly impermeable within a few short years. However, aggressive pressure washing and vacuuming can restore infiltration rates, while removing a significant amount of the annual pollutant load.

- **Real-time ultraviolet optical sensors are a leap forward for stormwater monitoring.** Light absorbance can be measured almost instantaneously in the field or in the lab. As a result, these sensors have the ability to measure water quality at a high frequency. The recent development of field-rugged, ultraviolet-visual (UV-Vis) spectrometers have extended our ability to make long-term continuous measurements of multiple water quality parameters in many environments. After deploying these sensors over the past three years, we have developed calibration curves for common stormwater pollutants and are gaining a better understanding of the first flush of pollutants.

The University of New Hampshire Stormwater Center Field Site, adjacent the university's West Edge Parking Lot. The site is designed to provide an apples to apples comparison of how stormwater treatment systems reduce pollution and manage the volume of runoff.

Three new manufactured systems were installed at the UNH Stormwater Center's field site in fall of 2019.

Un-maintained gravel wetland at the field site reflects the standard of practice and is an excellent opportunity for research to support operations and maintenance for this system.

In 2019, USEPA honored James Houle, program manager of the UNH Stormwater Center (second from left), with an individual Environmental Merit Award for innovative work that "has led to green infrastructure technologies and policies to reduce stormwater pollution at local, state and national levels." According to EPA New England, Houle's work and accomplishments "help provide clean and safe water to the region and nation."

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The UNH Stormwater Center has provided training and education for thousands of undergraduate and graduate students since it was founded in 2003. Many of our graduate students go on to work in the fields of stormwater engineering, regulation and policy, and water resource management.

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