Researchers emphasize the importance of stormwater research

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Credit: Duke University

A cormorant splashes around in the Duke Stormwater Reclamation Pond while Megan Fork, sitting in the shade under the shelter at the end of the pier with colleague Chelsea Clifford, takes a break from writing her Ph.D. thesis, "Stormwater and Organic Matter in the Urban Stream Continuum." Fork tells stories of stormwater investigation, which can at times go somewhat rogue.

"A lot of my work involves chasing the storms when they come," says Fork, whose thesis requires undertakings like figuring out what comes out of people's gutters right after it rains. "Looking for that first flush, as we call it"—the runoff from the first minutes of a rainstorm, water that's laden with whatever's been steeping in dampness since the last rain. Which means she has a network of people prepared, if she lets them know it's raining, to leap from their couches and scurry off to grab receptacles she's placed in the yards of willing homeowners around Durham to catch that first flush so she can sample them. Lost in the sudden scramble, occasionally, is clarity of things as basic as destination. Assistants have on occasion found themselves in the wrong yards, looking for buckets that are not there. Unknown persons bumping around the yards of the un-notified at night, wearing headlamps in rainstorms, can cause alarm. The police have even been called.

It's not exactly Tony Stark's laboratory from Iron Man, but science goes where it needs to, and if you're chasing the emerging science of stormwater, that's a bucket in someone's backyard in a midnight rainstorm. Stormwater, of course, includes everything from the gentlest fall mist to the many inches a hurricane can drop in a day. The gentle mist isn't usually a problem, but think of Hurricane Matthew, which dropped more than four inches of rain on Durham County's approximately 300 square miles. That gave Durham enough rainwater to keep Niagara Falls going for almost eight hours. The erosive power of that water alone in Durham's gullies makes it worth thinking about. But then consider what it brings with it: motor oil and brake dust and settled emission particles from cars; fertilizer and pesticides from lawns; plus pet waste, trash, and everything else. All making its way through our streets, ravines, and pipes into our rivers in anything from the trickle of that misty morning to the torrent from the hurricane. And until recent years, most engineers treated it as a problem to get rid of, and most scientists didn't think of it at all.

That's changing. Fork's research investigating organic matter in the urban stream continuum, for example, means finding out what's happening to, say, the leaves that end up in your gutter. They sit there, "steeping like tea," as Fork says, with microorganisms chewing on them and turning the water brown with dissolved organic matter, primarily carbon but also nutrients like nitrogen and phosphorus, pollutants to all kinds of urban streams. "All kinds of biological processes can happen with bacteria in these places," she says. "Each of those places is potentially removing something or adding something, so you get the combined signal when you get to the stream," where scientists have traditionally begun their measurements. "A lot of my work takes built infrastructure and says, 'What can we learn if we apply ecological methods and conceptual models?' It's looking at it and saying, 'What happens at this place?' "

Fork is taking measurements in people's gutters, standing waist-deep in catch basins on suburban streets. The buildup of damp leaves in catch basins makes for low-oxygen conditions, "so I think we could be getting a lot of really cool biogeochemistry going on down there." She goes where the stormwater first goes, not just where it ends up, teasing out what happens where.

Assistant professor of ecosystem ecology and ecohydrology Jim Heffernan, Fork's thesis adviser, approves. "That's an example of, essentially, [how] we're at the point where we need to do basic ecology in the cities," he says. His lab, one of four that constitute the Duke River Center, investigates all kinds of issues affecting rivers, including "processes that generate stormwater in the urban landscape and influence its chemical composition, and we also study the consequences of that downstream."

Though scientists have traditionally discounted the ecology of places like front lawns and gutters, they have in recent years woken up to the built environment as a subject of study—and not just to see how it harms the environment. "We're not just trying to understand how do we design cities to cause less pollution," he says, "but what is the ecology of cities? Just last year the Ecological Society of America had its centennial meeting, and urban ecology was all over the place." His recent publication contributions include work on urban lawn care (work toward sustainability will need to take different tacks as everybody has different ideas about fertilizing and irrigating) and on the values urban residents perceive that they get from the ecosystems surrounding them. (People in the South value their lawns' cooling effects and aesthetics more than those in the North, where people favor lawns that don't need much work.)

Blurring the distinction between lawns and fields, between gutters and rivers only makes sense, he says. "There really isn't that much landscape anymore that we do not exhibit some control over." That Anthropocene we've all been hearing about, the era in which human activity has been the dominating influence on climate and the environment? It's everywhere, and when the rain falls, raindrops land on an environment affected by people. Rain is the source of life: It charges aquifers and fills rivers and lakes, though it also carries along with it everything it finds along the way. Stormwater is what we drink, eventually, and we need to understand it. And Heffernan and his grad students aren't the only people at Duke on the case.

"It's not really stormwater," says professor of resource ecology Curt Richardson, founder and director of the Duke University Wetland Center in the Nicholas School of the Environment. "It's rainwater. The reason we call it stormwater is because engineers got hold of it and put it in pipes." Stormwater makes it sound like wastewater, which comes out of the drains in your house and needs a treatment plant before it can safely enter the environment. Storm...err, rainwater comes from the sky and is in the environment by the time we catch up with it. "You don't have to treat stormwater like you treat wastewater," Richardson says.

But you do need to think about it. In the first place, stormwater brings to rivers all that stuff it finds along the way: chemical pollutants like the fertilizers and weed killers and antifungals people put on those lawns, for example. And lots more: brake dust and pet waste and air pollutants that have settled onto the ground, nanoparticles entering the environment from vehicle exhaust, and discarded candy wrappers and Bud Light cans that end up washed along by the rains. All those garbage patches in the oceans? Most of those plastics weren't dumped by evildoers from ships and oil platforms; they just washed into the oceans from our yards and streets.

So when Richardson says you don't have to treat stormwater (we'll keep calling it stormwater because just about everyone but Richardson does), he's right, but he knows better than anybody else that you really sort of have to, as he has. He created the SWAMP—the Stream & Wetland Assessment Management Park, a fourteen-acre restoration of the Sandy Creek watershed that drains Duke's West Campus and 1,200 surrounding acres. The five-phase SWAMP project started in 2004 and was completed in 2012 and followed Richardson's work in wetlands in China and the Florida Everglades.

The SWAMP now functions as a kind of outdoor laboratory, hosting dozens of research projects every year. Each issue of the "Wetland Wire," a newsletter put out a couple times a year by the Wetlands Center, includes a listing of papers published by center researchers and affiliates, many of which focus on SWAMP-based research. In 2015, for example, Richardson and associates published a piece on how the habitat differences between restored and unrestored streams affected turtle populations (the turtles seem to like the restored ones) and the source of mercury pollution in the SWAMP (probably leachate from antifungals once sprayed on upstream athletic fields).

Richardson estimates between 500 and 800 Duke students, undergraduate and graduate, do some sort of work in the SWAMP every year, and they're not just from science labs; English and art classes use the SWAMP as well as ecology and biology classes. Busloads of Durham schoolkids visit the SWAMP every year, too.

What's more, it works. According to research Richardson has published, the SWAMP reduces nitrogen loads in Sandy Creek by 64 percent and total phosphorus by 28 percent. Instead of fast-moving water carving deeper and deeper trenches for the creek and carrying silt into troubled Jordan Lake, the SWAMP supports just the opposite: It allows 488 tons of sediment every year to settle, rather than flow into Jordan Lake. Some 113 species, tripled from before, now frequent the SWAMP, including the American Bittern, which Richardson isn't sure ever frequented the creek before it got cleaned up. Macroinvertebrates—fly larvae, dragonflies, and the like—have tripled, too, and you can find ten species of fish in the Sandy now, double what the creek supported in 2004.

Credit: Duke University

"Water quality, biodiversity, education, research," he says. "We're getting a lot of use out of it."

As Megan Fork discusses her work as a stormwater chaser, she sits on a pier over the Duke Reclamation Pond, a five-acre stormwater pond on a 12.5-acre site that, like the SWAMP, has ended up benefiting students, researchers, the creek, and the community. The pond operates much like the SWAMP does: It slows down water to allow time for settling and natural processes.

But the pond has its beginnings as nothing more than an expensive problem. In 2007-08, an extreme drought lowered reservoirs and put Duke in the situation where it had to look down the road at the possibility of limiting its capacity to cool its buildings. Duke cools its buildings with chiller plants, which are much like enormous air conditioners that cool water and run it through pipes to buildings all over campus. Using a shrinking store of potable water for air-conditioning wasn't going to work in the long term, says James Caldwell, assistant director for water resources and infrastructure at the John R. McAdams Company, the engineering firm that does large stormwater studies for the university. "It was initially conceived to provide harvested stormwater as a straightup capacity issue," Caldwell says. That is, damming the creek tributary that drained 22 percent of West Campus would create a pond that could supply Duke's chiller plant number 2, which, using 200 million gallons of water per year, is the biggest user of water in Durham. It only made sense.

"Then we realized we could use it for peak flow retention and nutrient removal." That is, Duke has obligations to manage its stormwater for every new project it creates. In the case of the pond, slowing the flow and allowing for nutrient removal allows Duke to "bank" nutrient removal for other projects, saving the costs of developing stormwater management facilities for future development as well as providing a source of free water. Add in the pond as a new opportunity for research and recreation, with a trail around it and places to sit like the pier, and you start to see stormwater as opportunity, not problem.

Again, that's not the tradition regarding stormwater, as shown by some older elements of Duke's campus. Edens Quad, a group of West Campus dorms built in a flood plain in 1966, accommodated the tiny tributary atop which they are built by simply lining the creek's course with Duke stone. Stormwater, full of pollutants, would race through the channel on its way to Jordan Lake, but at least it was gone. Sometimes called Duke's version of the L.A. River, the hardened creek cannot do what the creek does as it passes through the SWAMP—swell with rainwater, spreading water to settle along its floodplain, slowing it down, encouraging absorption.

Take a look at the hardened creek now and you see that nature has been pushing back; bald cypress trees have set roots next to the creek, cypress knees pushing up through stone and earth into the channel. The knees snag passing leaves, pine needles, and trash, sometimes even branches; that creates little dams and ultimately pools. Small fish dart in the water near where the channel passes directly under the buildings. The stone bottom will not allow water to percolate into the earth, and the next big rain will wash all the pollutants downstream: no nutrient uptake by plants, no silt retention, no charging the groundwater. But it's instructive to see how hard nature works to make this hardened channel something useful, something that it recognizes as a stream.

Exploring places where nature is trying to do useful work on its own is the purview of Chelsea Clifford, another of Jim Heffernan's graduate students. If Fork's interest in gutters seemed to stretch the boundaries of science, what to make of Clifford's focus on the quotidian roadside ditch? "I'm trying to figure out under what conditions ditches can function like natural ecosystems, like wetlands or streams," she says.

She's sampling what she finds in roadside ditches in highway, agricultural, and forested areas. "They're not as good as natural wetlands," she says, "but they are a real ecosystem."

Walk along a rural road and you commonly see, where water settles near the pipes that run beneath driveways, sunny little swampy ecosystems growing up around stormwater. Because roadside ditches are mowed, Clifford says, they are "kept in this early successional, treeless phase." She sees grasses like broom sedge and needlerush, which are early ditch gentrifiers. Once the grasses are there, ditches support frogs, macroinvertebrates, and even reptiles. And given the species' complex interplay, they're doing ecosystem work, too.

Coming out of gutters, Fork says, stormwater has concentrations of dissolved organic matter she describes using the scientific term "crazy bananas"—five or six times the levels found in Florida blackwater rivers, which are like the gold standard of high levels of dissolved organic matter. A colleague of Clifford's studying denitrification in ditches found that ditches were removing substantial amounts of nitrogen and phosphorus. "So in ditches and other places where there is an organic substrate," Clifford says, "there's actual pollutant reduction."

Nature takes our built environment and manipulates it for its own ends. Will Wilson, associate professor of biology, whose original research focused on mathematical evolutionary ecology, has in recent years turned his attention to stormwater and the built environment, developing a course around his Constructed Climates: A Primer on Urban Environments and just this year publishing Stormwater: A Resource for Scientists, Engineers, and Policy Makers. Like Richardson, he decries the perspective of stormwater as something you have to put in pipes or ponds. He prefers to address stormwater at its many sources, before it becomes streams with volume large enough to require pipes. Green-building techniques—green roofs, rain barrels, cisterns—will help.

"Every acre of land needs to say, 'I'm not going to export any extra rainwater.' But cities are just the opposite of that."

He notes that even the best-constructed wetland will be overwhelmed by more than an inch or so of rain. Hurricane Matthew had just passed through, dropping more than four inches of rain on Durham. Wilson shrugged. "It's precipitation. You have to do it at the source. Because as soon as you collect water, you have a problem."

Wilson sees stormwater as an all-of-the-above situation. Green roofs to catch it, rain barrels to store it, wetlands to slow it down, but stormwater pipes and cisterns and retention ponds for when there's just too much of it. And then, behind that, comes an army of grad students and scientists ready to analyze it. Sometimes working with nature, with undertakings like the SWAMP or the new pond. Sometimes almost working against nature, in places like gutters and roadside ditches and even the hardened, stone-sided channel of the creek beneath Edens Quad.

"We think because we built them that they're just there for utilitarian purposes," Fork says, speaking not just of her gutters and Clifford's ditches but of the SWAMP and the pond and all kinds of built environments.

"But there is a lot of stuff going on."

Provided by Duke University

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