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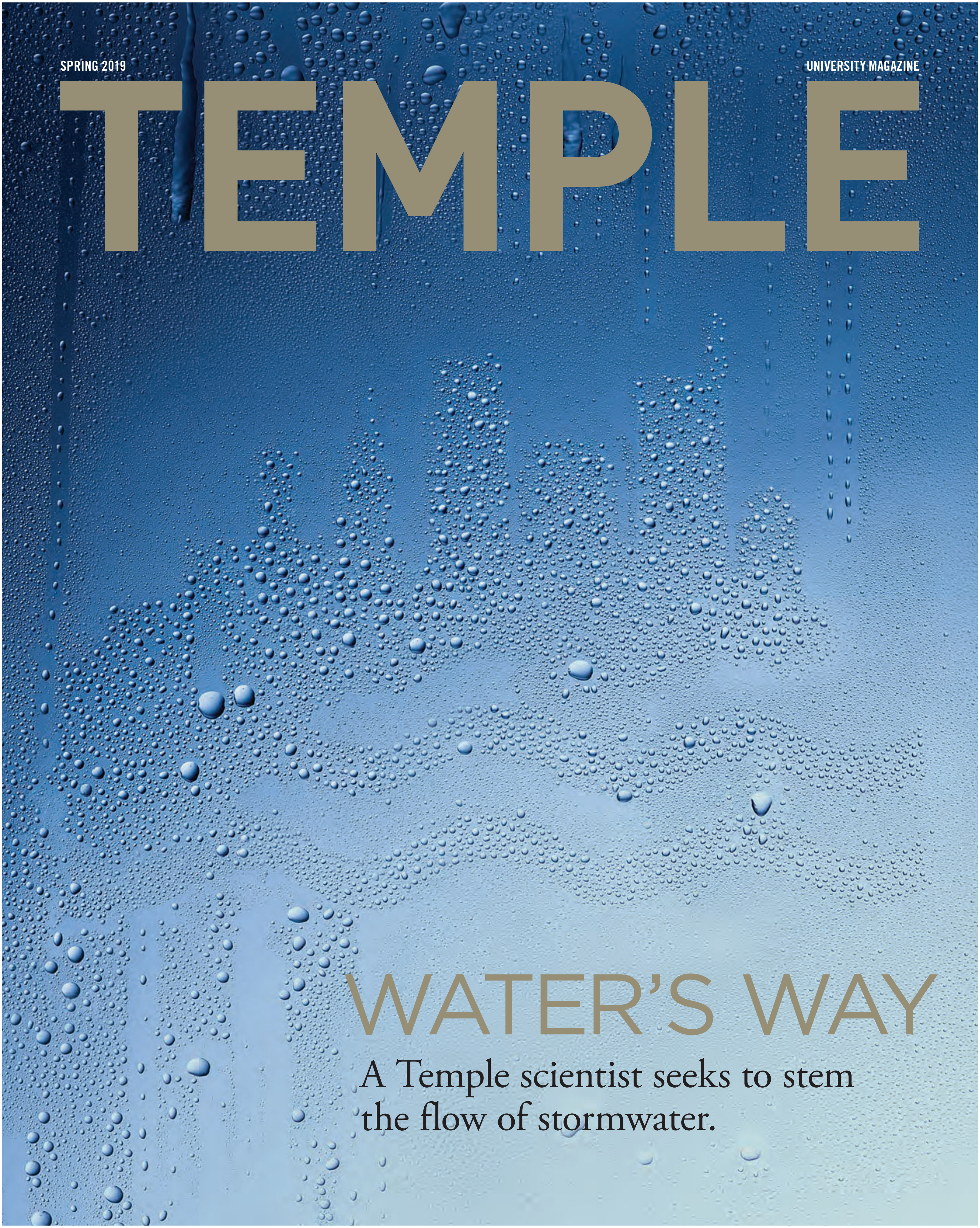


WATER'S WAY

A Temple scientist seeks to stem the flow of stormwater.

The Pennsylvania Department of Transportation has enlisted the help of Toran and her colleagues to analyze infiltration basins along I-95 in Philadelphia, built to help manage excess stormwater by collecting runoff and allowing it to soak into the soil.

RAIN, RAIN, GO AWAY

Hydrologist Laura Toran is pioneering green methods for stormwater management.

STORY BY **BRUCE E. BEANS**
PHOTOGRAPHY BY **JOSEPH V. LABOLITO**

Early one morning last spring, heavy rain falling on her Fort Washington, Pennsylvania, home woke Laura Toran before 5 a.m.

When your life's work focuses on urban stormwater—where it's been, where it's going, what it's carrying and how best to control it—your antennas are on high alert 24/7.

An urban hydrologist, Toran jumped from bed, fearing that the nearby Wissahickon Creek could soon top its banks.

A quick check online of the U.S. Geological Survey gauge in the creek confirmed that the water was rising—fast.

Hastily dressing, Toran drove to the creek and discovered that the stream was indeed close to destroying two expensive battery-operated devices, called loggers, that she had placed there to measure the stream's fluctuating depth and chemical concentrations. She rescued and disconnected their batteries as the creek peaked at 2,500 cubic feet per second, 7 feet above normal.

Just another day at the office for Toran, the Weeks Chair in Environmental Geology in the College of Science and Technology, whose research boasts a current funding total of $5 million. Since her arrival at

Toran and postdoctoral fellow Sarah Beganskas assess the shallow groundwater near the Wissahickon Creek in the Philadelphia suburbs to test the effectiveness of suburban stormwater control efforts.

Temple University 21 years ago, she has pioneered studies of the region's watersheds, conducting her research on controlling stormwater runoff both in the city and in the surrounding suburbs.

Stormwater runoff is rainfall that flows over paved surfaces—such as roads, driveways, parking lots and rooftops—and into nearby waterways. These surfaces, rife with pollutants, do not allow for stormwater to soak into the ground. Runoff thus picks up a slew of metals, chemicals, excess nutrients and sediment, causing erosion in streams and rivers and compromising water quality.

In natural environments, explains Toran, 10 percent of rainfall runs into streams, while 50 percent gradually infiltrates the soil; the rest evaporates back into the atmosphere. But in urban environments, just 15 percent of rainfall infiltrates, with a staggering 55 percent entering our waterways.

And an increase in local rainfall only threatens the health of our streams and rivers further. Last year, precipitation in Philadelphia reached record levels, 20 inches above the normal 41.44-inch average. As a result, the Schuylkill River set a new annual record for average streamflow, while the Delaware River registered its second-highest streamflow level ever. These alarming trends show no sign of slowing in 2019.

Each year, billions of gallons of raw, untreated sewage foul the Delaware and Schuylkill rivers.

"When we create cities, we enhance stormwater runoff, and climate change has amplified those effects," says Toran. "Stormwater runoff is one of the key impacts that humans are having on this planet."

On a recent mid-October day, Toran was checking both the surface and shallow groundwater underneath the headwaters of Sandy Run, a Wissahickon Creek tributary, thanks to a recent $1.1 million grant from the William Penn Foundation (WPF) to Toran's lab. It's all part of the foundation's $40 million initiative to protect and restore clean water in the Delaware River Watershed—a basin that spans four states and provides drinking water for 15 million people.

Toran's task at the site is to monitor the effectiveness of stormwater control efforts. Among her findings: Though a lot of vegetation types stabilize soil, knotweed—an invasive plant from Asia that grows along local streambanks—actually contributes to erosion, which is a major cause of stream-choking sediment.

Philadelphia and its suburbs differ in their approaches to stormwater management. Suburban communities want to send most of the runoff into their sewers, so the creeks stay healthy for aquatic life.

By contrast, the city tries to keep water out of its storm sewers, where it can overwhelm the old, dual storm and sanitary systems.

Introduced in 1855, combined sewer systems were designed to collect rainwater and household waste in the same pipe, before discharging both directly into nearby streams and rivers. By the mid 20th century, treatment plants were built to clean the water before it hit the waterways.

But, during periods of heavy rainfall, the volume of water could exceed the sewer's capacity. For this reason, the systems were designed to overflow.

In Philadelphia, as in other older cities, these designs have not been significantly updated since the 1950s. The result: each year, billions of gallons of raw, untreated sewage containing disease-carrying, oxygen-depleting bacteria such as E. coli, not to mention pollutants and sediment, foul the Delaware and Schuylkill rivers.

The cost to replumb the 1,850 miles of the city's combined sewer lines would be exorbitant. As an alternative, the Philadelphia Water Department adopted its 25-year Green City, Clean Waters plan seven years ago. The plan calls for several billions of dollars worth of both public and private green stormwater infrastructure improvements to reduce combined sewer overflows.

"It's made Philadelphia a world leader in terms of encouraging green stormwater infrastructure like infiltration and retention basins," says Robert J. Ryan, a civil and environmental engineering associate professor of instruction and a member of Toran's research team.

When the construction of I-95 through Philadelphia first began in 1959, the prevailing strategy for handling stormwater was to divert it into the nearest sewer and stream as quickly as possible.

But that philosophy, explains Erica McKenzie, an assistant professor of civil and environmental engineering and one of Toran's Temple collaborators, has led to flash flooding, erosion and—in Philadelphia—combined sewer overflow.

Two years ago, PennDOT began partnering with Toran and other colleagues from Temple and Villanova University to analyze the effectiveness of infiltration basins built along newly reconstructed portions of the interstate in Philadelphia. The basins help manage excess stormwater by collecting runoff and allowing it to soak into the soil.

For the project, McKenzie regularly tests the water that flows into the narrow, two-block-long basin, which is sandwiched between the elevated interstate and brick row homes in Philadelphia's Fishtown neighborhood. She has detected a variety of metals like copper, iron and arsenic, derived from roadway sources such as tires and brake pads, and sodium and chloride from the rock salts and brine applied during the winter. The same metals and chemicals have been found in the basin's soil.

"So far, we haven't detected concerning concentrations in the soil, but we're doing ongoing monitoring and some computer modeling to try to understand how these contaminants could potentially build up or move

STORMWATER DISPERSAL

in NATURAL environments

- 10% flows into streams
- 50% gradually infiltrates soil
- 40% evaporates back into atmosphere

in URBAN environments

- 55% flows into streams
- 15% gradually infiltrates soil
- 30% evaporates back into atmosphere

To measure the fluctuating depth and chemical concentrations of the groundwater near the interstate, Toran uses a battery-operated device called a logger.

through the basin to determine if there could be future problems," McKenzie says.

Two Temple horticulture researchers identified a more immediate challenge: The vegetation PennDot planted in the basin, including 60 different species of grasses, flowering perennials, shrubs and trees, was struggling to survive.

The plants play an important role in the basins, explains Toran. "Most important is that their roots enhance infiltration by providing pathways that allow water to permeate," she says. "Compacted soil doesn't infiltrate well and basins without plants tend to get compacted."

Initially, Sasha Eisenman, associate professor and chair of the Department of Landscape Architecture and Horticulture, and Josh Caplan, a horticulture research associate, wondered if the plants were suffering from too much water. But this past fall, their analysis indicated the roots were accumulating excess sodium.

"Our monthly soil monitoring showed, understandably, huge pulses of sodium during the winter when salt washed off the roadway," Caplan says, "but even throughout the summer it persisted above ideal levels for plants that aren't salt-tolerant."

Replacing such plants with more salt-tolerant species is the kind of lesson learned that will affect how future basins are designed and planted. The monitoring of another I-95 basin has also triggered plans to replace some of the soil, which Toran's team determined is too compacted.

In 2018, Toran was the lead author of a report to PennDOT about these initial research findings. It won an award from the American Association of Highway and Transportation Officials for "high value research"—one of just four projects in the northeastern U.S. to be so honored.

"I-95 is likely to be a long-term project that involves lots of miles and dollars, and we're essentially creating a living urban laboratory," Toran says. "We're using what we learn to help improve PennDOT's future designs."

To explain her work on Main Campus, Toran walks out the back door of the Science, Education and Research Center (SERC) and steps out onto an attractive but seemingly unremarkable strip of grass bordered with landscape plants.

In fact, she is actually standing atop a 5-foot-deep, gravel-filled basin. Whenever it rains, a cistern that receives all of the SERC roof's rainwater overflows into the underground basin, from which the water gradually infiltrates the soil. The cistern's water also flushes the toilets on SERC's first two floors.

Toran has monitored six of the more than a dozen on-campus stormwater control measures, including the SERC infiltration basin, a huge storage chamber underneath the practice football field, a trench below a parking lot's grass dividing strip and Liacouras Walk's porous pavement. None of the sites has ever overflowed.

"Temple has overdesigned its stormwater infiltration basins so, if need be, they can handle more water from the surrounding neighborhoods," she says.

Engineering students often tackle on-campus stormwater control issues in their senior design projects. Other examples of the university's commitment to minimizing stormwater: a green roof atop the massive new library under construction and future plans to turn the current Beury Hall site into one of the city's largest infiltration basins.

"Stormwater is one of the key impacts that humans are having on this planet."

—***Laura Toran***
Weeks Chair in Environmental Geology

While urban hydrology depends on cutting-edge technologies, Toran's toolkit isn't all high tech. Social science is a big part of it.

"Urban hydrology is tricky; there's this whole social aspect to it because you are always working where people are living," Toran notes.

That's why the WPF grant also supports public outreach, including contributing to Earthfest, which each year hosts more than 6,500 students, teachers and visitors for an environmental educational day at Temple's Ambler Campus. Similarly, the grant supports the work of environmental consultant Susan Harris, who connects with community leadership and private landowners.

Residents' No. 1 concern? Mosquitos—which, surprisingly, tend not to be a problem. The basins' flowing waters don't serve as a breeding ground for the bugs, and the native plants of the basin attract insect-eating birds, frogs and dragonflies.

"Once they get beyond that, people get engaged in these projects," says Harris. "But it requires a mindset sea change to convince folks that turfgrass and old basketball courts should be converted to wildflower meadows, which can infiltrate 30 percent more water than a grass lawn."

Likewise, in Philadelphia, many people are concerned that infiltration basins will raise the water table and cause their basements to flood. "But so far we have seen no evidence of that," Toran says.

Her biggest ongoing challenge, though, is identifying what makes a healthy urban watershed.

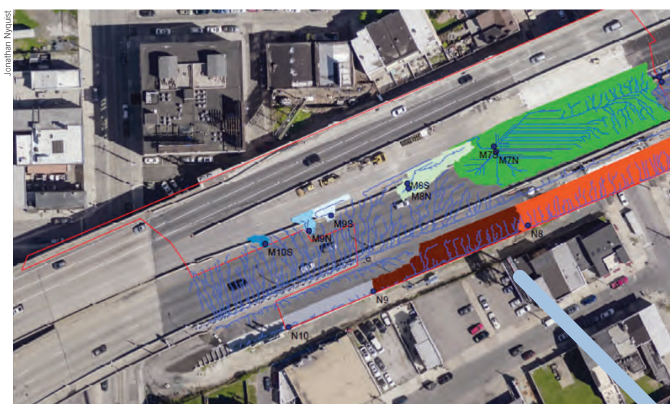
"Currently there are numerous regulations in place but not enough understanding of what is truly effective," she says. "Where should we put stormwater basins, and how many should we put in so they work better? Or, on a personal level, should individuals be installing rain barrels at their homes?"

Toran's ultimate goal is to answer these questions, so people can make better choices. "It's like when you say to yourself, 'Should I use paper or plastic bags?'" she explains. "If somebody could answer that question, people would just do it, right? Problem solved.

"I want to provide Philadelphians with equivalent answers for stormwater." ■

Bruce E. Beans, a freelance writer and editor from Bucks County, Pennsylvania, has written for Temple University since 2005.

Jonathan Nyquist



LIDAR (light detection and ranging) technology produces 3D landscape models, which are many times more precise than aerial photography, that are used to calculate where water is flowing down to the centimeter.