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Reducing Stormwater Runoff with Green Infrastructure

Madeline Fisher

In the late 1800s, the city of Omaha, NE did something that few other municipalities were even considering at the time. Inspired by the comprehensive plans of European cities, officials hired the renowned landscape architect, Horace Cleveland, to design a meandering network of tree-lined boulevards and leafy parks for Omaha's citizens to enjoy.

Much of the proposed parkland was too wet for roads and buildings anyway, composed as it was of riparian zones, floodplains, and streams feeding into the Missouri River on Omaha's eastern border. So during the following decades, city planners, architects, and engineers filled in the wet areas and planted gardens, grass, and ornamental trees on top. They also directed many of the streams into buried pipes—pipes that later became part of Omaha's combined sewer system.

This visionary system of green space remains a source of civic pride, and the city has now embarked on a major revitalization effort involving everything from preserving trees to updating street lighting. But aesthetics aren't all. As plans move forward, people are asking whether some of Omaha's historic parks can help address a modern concern: a torrent of excess stormwater that runs off the hard surfaces in Omaha's cityscape.

To reduce these runoff volumes, Omaha is now investing in "green infrastructure"—systems like bioswales and rain gardens (technically, "bioretention" gardens) that manage stormwater on site, rather than collecting it in pipes and sending it all downstream at once. To date, the city has installed green infrastructure next to municipal buildings and in parks. Permeable pavement has replaced some asphalt parking lots. One seldom-used street was even converted into a bioretention garden.

But because green infrastructure relies on the underlying soils to slow, filter, and move water, enlisting more of the city's parklands in stormwater control makes a lot of sense. For one, their soils are relatively undisturbed, explains Steve Dadio, a consulting soil scientist with Cedarville Engineering Group in Pennsylvania, never having been the sites of houses or streets. And as low spots in the landscape, Omaha's parks and boulevards are natural collection points for water in gardens, ponds, streams, and other features.

In other words, 125 years after city founders chose to dry out Omaha's parklands, people now hope to hold some water back on them again, with the goal of relieving pressure on the sewer system and other "gray" infrastructure.

Bioswales and bioretention gardens help manage stormwater on site, rather than collecting it in pipes and sending it all downstream at once. *Photo courtesy of Flickr/Aaron Volkening.*

Parking lot with concrete pavers allowing stormwater to infiltrate. Note the curb cut to the right of the tree, allowing excess stormwater to flow into a bioswale. *Photo courtesy of the University of Nevada Extension.*

The question is, "Can we use these soils as a sink for excess stormwater runoff and use parkland landscape features as a way to route stormwater to them?" asks Bill Shuster, a soil scientist and hydrologist with the Environmental Protection Agency (EPA).

To help answer this, he and Dadio recently classified, mapped, and measured the drainage capacities of soils in the city's parks and other green spaces for the first time. But the question resonates

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far beyond Omaha. Any community can benefit from including soils on its list of stormwater management options, Shuster says.

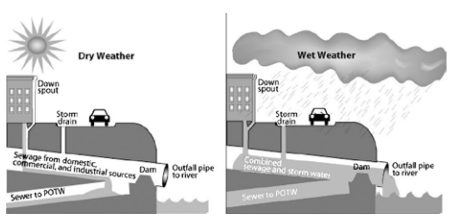
Bill Shuster (**left**) and Steve Dadio recently classified, mapped, and measured the drainage capacities of soils in Omaha's parks and other green spaces for the first time.

Putting 'Unused' Soil to Work in Cities

Shuster knows this better than nearly anyone. A scientist with the EPA's Office of Research and Development, he does field studies on water movement in urban soils, in support of municipalities that want to test green infrastructure as a new place for handling runoff in the city environment. The idea is to retain some rainfall where it lands, giving it time to percolate into the soil and be taken up by plants. Any remaining stormwater can then be discharged more gradually downstream, making it less likely to flood streets, erode stream banks, or trigger what are called combined sewer overflows, or CSOs.

Green infrastructure can help retain some rainfall where it lands, making it less likely that streets will flood (**top,** courtesy of Wikipedia) or stream banks will erode (**bottom,** courtesy of the U.S. Fish and Wildlife Service).

Combined sewer overflows are the biggest concern. It was popular at the turn of the 20th century for cities to construct "combined" sewer systems that transport sewage and stormwater in the same pipes. And much of the time, this works fine: Sewage travels as it should to the wastewater treatment plant. But even the smallest rainfall events can overwhelm the capacity of these systems, causing them to release a mixture of stormwater and septic waste directly into streams, rivers, and lakes.



With a combined sewer system, during dry weather (and small storms), all flows are handled by the publicly owned treatment works. During large storms, the relief structure allows some of the combined stormwater and sewage to be discharged untreated to an adjacent water body. *Illustration courtesy of the EPA.*

In Omaha's case, the combined sewer on the city's east side overflows dozens of times each year, discharging an estimated 8.1 billion gallons of combined stormwater and sewage annually into the Missouri River and its tributary, Papillion Creek. "So that's a big driver of a lot of things here," says Andy Szatko, an environmental quality control technician with the Omaha Stormwater Program. But Omaha is hardly alone. More than 700 U.S. communities operate combined sewer systems.

Shuster and his team have worked in many of those communities, yet it was an experience in Cleveland in 2009 that Shuster particularly remembers. Looking around at Cleveland's thousands of vacant lots, he saw an wealth of unused soil—soil that he knew had at least some potential to soak up, store, and move water. "So that's when certain wild ideas starting coming together," he says. "Maybe we could utilize these soils as a basis for green infrastructure to absorb or contain some of the water volume that would otherwise go into the combined sewer."

The hitch was—and continues to be—that people have generally paid urban soils little attention beyond wanting to know, "Is the soil good to build a building or road, or is the soil a gray or brown clay?" Shuster adds. "We want to go deeper with our knowledge: How well is it drained? And what are the prospects for these soils to sustain green infrastructure?"

Those still aren't common questions, though. When constructing a new green infrastructure installation, such as a bioretention garden, engineers will often excavate the native soil, replacing it with what's called an "engineered" soil mix. Composed of a high percentage of porous sand, these mixes are favored because they let stormwater soak, or infiltrate, very quickly into the ground.

Omaha, in fact, made use of engineered soil in its first bioretention gardens. But when Szatko studied their performance

New Bioretention Design for Better Stormwater Control

When Ted Hartsig started talking green infrastructure with the city of Omaha around 2007, the consulting soil scientist was still relatively new to such projects himself. But Hartsig, who works for Olsson Associates in Kansas City, KS, has never been shy about just trying something, evaluating it, and then improving on it the next time.

"So, in a meeting one day, we figured, 'We keep talking about this. Why don't we just do some projects?'" Hartsig recalls. From there, he, the City of Omaha's Andy Szatko, and Steve Rodie, a professor of landscape architecture at the University of Nebraska–Omaha, designed some bioretention gardens based on previous work. However, they gave the gardens their own twist: limiting the use of an "engineered" soil mix composed of sand, clay, and compost.

Managers typically spread engineered soil throughout an entire bioretention area, Hartsig explains, so as to let stormwater seep quickly into the ground. But this creates a lot of expense, especially when gardens or other infiltration zones can reach several hundred square feet in size. Plus, these soils drain extremely fast—too fast, in fact, for a bioretention system to function properly.

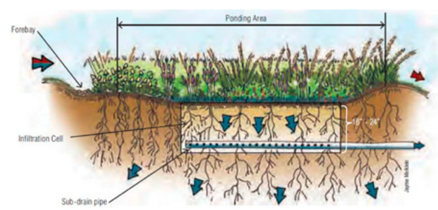
"So we looked at it pretty critically and then we thought, 'Why do we need to have engineered soil throughout?'" Hartsig says. What they decided to do instead was dig a 5-ft-wide, 20-ft-long, and 2-ft-deep trench; lay a perforated, PVC pipe at the bottom (for letting collected stormwater escape downstream); and fill the trench with engineered soil.

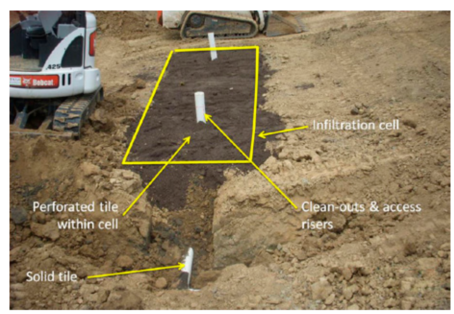
Native soil was then left in place in the rest of the garden, topped by native plants. And the plants are critical. When Szatko and Hartsig studied their new design, they found that stormwater entered the soil at rates of 3 to 3.5 inches per hour in vegetated areas. But just several inches away from the plants, infiltration was dramatically slower.

In the meantime, stormwater still drained too rapidly from the area above the trench—or what the group calls the "infiltration cell"—drying out the soil and stressing the vegetation. So in their next iteration, the team added a control valve to the pipe at the trench bottom. Now, the system no longer relies solely on the soil to regulate water flow. "I'm using a valve that I can manipulate to adapt to different conditions," Szatko says. For example, water can be held in the bioretention garden for longer during dry periods. Or the system can be emptied completely when repairs are needed.

What's more, the city has added real-time control to two of its green infrastructure installations, allowing personnel to open and close the valves via the internet. At one location, a porous concrete parking lot, the valve is even programmed to operate in sync with National Weather Service data—opening to drain water stored in the system prior to a big storm and then closing right before the downpour hits to capture the resulting stormwater.

"I'd rather spend money on things like this than a huge amount on amended soils," Szatko concludes. But only if the technology nets results, he adds. "If it doesn't, then we'll evaluate that." And the evolution will continue.





Bioretention garden design (top) and actual infiltration cell (bottom). *Images courtesy of Andy Szatko.*

with Ted Hartsig, a consulting soil scientist with Olsson Associates in Kansas City, KS, they found that engineered soil actually drained much too fast, making it tough for garden plants to survive. Placing a sandy soil mix atop a very different type of native soil can also cause failures. And, besides, engineered soil is expensive.

"When you consider the extent of the issues in places like Omaha, it's just not cost effective to be importing sand as an infiltrating medium," Dadio says.

This is why the city is now trying to leverage its own soils as much possible in its new green infrastructure projects. Water movement is aided by a few clever, design tweaks (see sidebar), and the soil is conditioned with compost to better support growth of native plants. But otherwise, it's pretty much left alone, says Hartsig, "to function as it once did when it was a prairie."

Working with the Unique Characteristics of Prairie Soils

The soils in the region are indeed prairie soils—known scientifically as Mollisols—which formed as vast deposits of wind-blown silt and clay materials and were then blanketed in grasses and prairie flowers. [During the city of Omaha's development, the soil surface in some areas was cut away, forming another soil type known as "Alfisols."] Their relatively high clay content means they can be slow to infiltrate water, but this is counteracted to some extent by big blue stem, Indian grass, and other prairie plants, whose deep, penetrating roots loosen the soil, improve its structure, and create channels for water to flow through.

The relatively high clay content of prairie soils (known scientifically as Mollisols) means they can be slow to infiltrate water. *Left photo courtesy Flickr/Soil Science. Right photo courtesy of Flickr/JeromeG111.*

That's one of the great joys of working with a living, evolving system like a rain garden, Szatko says. "The worst day is the first day that [the systems] go in. They only get better with time."

Still, if you had to choose an ideal soil for draining a landscape of runoff, the clayey, fine-textured soils of Omaha would not be it. Their history as prairie soils means they're also chock-full of organic matter in some locations—another property which causes them to hold onto water, rather than move it, Dadio explains. He's quick to add, though, that this doesn't imply green infrastructure can't work for Omaha. It just requires a different mindset.

"In cities, because the magnitude of the [runoff] problem is so great in terms of volume, your first tendency is to think about infiltration: Where can I find sand or coarse material that will readily drain?" he says. But what Omaha has is a "wonderful resource" of soils that can store water and then release it slowly. "So you have an opportunity to deal with stormwater in a different way."

This may mean more bioretention than rapid infiltration, for example; now that Dadio and Shuster have completed their analysis of the soils in Omaha's park and boulevard system, the city is reviewing its options for new green infrastructure installations with state and federal cooperators. Then once those new systems are constructed, city and state agencies will monitor their performance with assistance from the EPA and the U.S. Geological Survey.

As soil scientists and engineers continue to dig into the subtleties of these systems and how they function, however, Szatko hopes they keep something else in mind: people. He notes that while Omaha's combined sewer program focuses on big green infrastructure installations that can potentially curb CSOs, his department builds small, demonstration rain gardens and other projects expressly for educating the public. And they get a lot of response.

Rain garden at Benson High School in Omaha, NE. *Photo courtesy of the Omaha Stormwater Program.*

"It never ceases to amaze me, the benefits on a social level—that people really embrace [green infrastructure] as their own and enjoy it," he says.

That's not trivial, he adds, because even in a city that cherishes its gardens, parks, and boulevards as much as Omaha does, green space can still be perceived as "frilly" when stacked up against other needs. "But in this case, [the green space] serves a functional purpose," Szatko says—giving people reason to value and support it on a whole new level.

For his part, Shuster hopes the appreciation runs even deeper one day—down into the soil, no matter where it's found. Detroit, Cleveland, and New Orleans have an abundance of vacant lots, for instance, while places like Phoenix, Tacoma, and Omaha have a profusion of parks. Each community, in other words, has its own unique portfolio of soil resources that can be leveraged, Shuster says. "So our research is trying to connect the dots that lead to a more sustainable urban water cycle."