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Green Infrastructure Rising

Best practices in stormwater management

By Steve Wise

The future of stormwater has arrived, and that future is green. Green infrastructure, that is.

First, a definition. Green infrastructure is the interconnected network of open spaces and natural areas — greenways, wetlands, parks, forest preserves, and native plant vegetation — that naturally manages stormwater, reduces the risk of floods, captures pollution, and improves water quality.

In cities and other urbanized areas, that network can be extended by means of rain gardens, green roofs, tree planting, permeable pavement, and other landscape-based drainage features. They restore, protect, and mimic natural hydrologic functions within the built environment.

Growth in paved and other impermeable surfaces increases stormwater runoff pollution, even if that pollution is directed toward conventional stormwater infrastructure. But green infrastructure provides an antidote by intercepting rainfall before it reaches sewers. And green infrastructure usually costs less to install and maintain when compared to conventional "gray" forms of water infrastructure that rely on concrete gutters, sewers, and end-of-pipe treatment. This is important in a time of shrinking financial resources and increasing public and regulatory demand for clean water.

Green infrastructure projects also foster community cohesiveness by engaging residents in planning, planting, and maintaining highly visible stormwater infrastructure that beautifies and adds value to neighborhoods.

For planners, examples from Prince George's County, Seattle, Portland, Minneapolis-St. Paul, and Chicago show how green infrastructure features can help improve water quality and general quality of life. They also show how green infrastructure approaches can support broad planning goals pertinent to clean water, neighborhood development, and community livability.

Green common ground

Places employing green infrastructure have several things in common. They all recognize the multiple ecological, financial, and community objectives green infrastructure serves. And each is using pilot projects on individual sites to expand green best management practices to broader block and neighborhood scales within existing and planned urban landscapes.

Consistent evidence from pilot projects shows that green infrastructure can capture, retain, infiltrate, or evapotranspirate 90 percent or more of the rain from typical storms delivering an inch or less of precipitation. This is crucial because the majority of runoff pollutants are carried in the first half-inch to one-inch "first flush" of precipitation.

Monitoring studies show that green infrastructure practices retain or remove 30 to 90 percent of runoff pollution, depending on the pollutant and the particular practice. Tools such as the Chicago-based Center for Neighborhood Technology's Green Values Calculator can be used to evaluate site-level costs and impacts, comparing green and gray infrastructure costs and runoff impacts.

At this point, several cities have developed regulations encouraging or requiring green infrastructure or low-impact development in most projects. Seattle's city council is considering a requirement that green infrastructure technologies "must be incorporated throughout a project site wherever feasible."

The local regulations are accompanied by design specifications to ensure their hydrological effectiveness, and to give clarity to planners and builders on acceptable approaches. Key standards cover siting in relationship to buildings and other infrastructure, sizing to absorb target storm volumes and rates, soil conditions that may limit infiltration or present risk based on previous contamination, and limiting duration of ponded water to prevent mosquito infestation.

Perhaps most significantly, the leading green infrastructure cities are integrating these practices into a wide range of public and private spaces, at both new and developments and existing sites.

Taking it to the streets

Integration with transportation plans is a common element of many green infrastructure programs. By designing vegetated drainage and porous materials into streets, alleys, rights of way, and parking lots, cities can increase on-site neighborhood stormwater capacity. Green streets and green parking areas take advantage of the need for periodic resurfacing, adding stormwater management elements when paved areas are repaired or replaced.

Green infrastructure is also becoming a component of the movement toward complete streets, in which the landscape is used to integrate transit, pedestrian access and safety, and stormwater management. And green infrastructure is closely tied to smart growth practices like cluster development, reduced parking ratios, and the general reduction of impervious area.

The current wave of low-impact development can be traced to Prince George's County, Maryland. In 1992, Larry Coffman, then associate director of the Environmental Services Division, created a prototype rain garden in response to concerns about pollution reaching Chesapeake Bay. He inverted a parking lot island, creating a planted island that sat below the surface level of the parking lot. By cutting an opening in its curb, replacing soil with a more porous mixture, replanting with local forest species, and letting runoff drain through the below-grade soil and vegetation, Coffman showed that it was possible to keep runoff out of sewers and enhance natural filtration.

Extended experiments through the early 1990s, many led by the Maryland-based Low Impact Development Center and the Center for Watershed Protection, helped the division formulate early guidelines for the practice of bioretention, ultimately including a technical design manual in 1999, and an updated version in 2002. The results were impressive. Extensive installation of rain gardens and swales at a subdivision in Somerset, Maryland, netted a 20 percent reduction in runoff compared to a conventional subdivision, and implementing the low-impact development practices cost a mere 25 percent of their gray counterparts.

Those early efforts have grown into a statewide standard. The 2007 Maryland Stormwater Management Act mandated environmental site design to the maximum extent possible. The Maryland draft standard includes objectives to capture stormwater on site, maintain 100 percent predevelopment groundwater recharge, and prevent pollution.

The standard also requires early design steps to protect functional local hydrology and recommends a variety of "micro scale" practices to drain areas of less than one acre, describing many practices like green roofs, permeable pavement, rain gardens, swales, downspout disconnection, and rainwater harvesting in barrels or cisterns to treat runoff at its source.

Best practices go west

Green infrastructure practices appeared in the Pacific Northwest in the 1990s, partly in response to the requirements of the federal Clean Water Act and Endangered Species Act, both of them pertinent to the endangered salmon.

Seattle's urban forestry effort became an offshoot of its infrastructure system in 1994, when it committed capital from its Cumulative Reserve Fund for parkland forest restoration. By 2005, a mayoral executive order was issued requiring that two trees be planted for each one removed.

Seattle's 2007 Urban Forestry Management Plan set broad goals to increase canopy cover from 18 to 30 percent, requiring about 650,000 trees in 30 years. Among the key benefits from the strategy is the trees' stormwater retention, valued at an estimated $10 million per year out of $14 million in total benefits. Those also include improved air quality, carbon sequestration, energy savings, and aesthetics.

Seattle's best-known green infrastructure demonstration project is called Street Edge Alternatives, the prototype of its current SEA Streets program. In that first project, completed in 2001, the city narrowed a street to create a meandering, river-like road that reduced impermeable coverage by 11 percent. The street was 14 feet wide, with 18-foot intersection flares and a sidewalk on only one side.

This project, also known as SEA Street #1, involved replacing a gravel shoulder and surface drainage with colorfully planted drainage swales along a block in the salmon-bearing watershed of Piper's Creek, including 100 new evergreens and 1,100 shrubs. The results were convincing, both financially and hydrologically: Runoff volume was reduced by 98 percent, at a cost 25 percent below that of conventional street designs.

In another experiment, the city built its prototype Cascade design on a sloped street, linking several stepped bioretention features into a feature that resembles local waterfalls and captures at least half the runoff and up to 92 percent of pollutants through infiltration and plant uptake.

The ecological, economic, and community success of SEA Streets has led to neighborhood-scale green infrastructure approaches. Seattle Public Utilities is now working with green grids rather than individual blocks. The 15-block Broadview green grid manages stormwater from the adjacent 10-acre neighborhood but also 22 acres nearby, combining the SEA Streets and Cascade designs.

The Cascade design cost $285,000 per block, and the Broadview green grid $280,000 per block, compared with $520,000 for a comparable street with conventional drainage.

A third project is a combined effort of Seattle Public Utilities and the Seattle Housing Authority. The 129-acre mixed income housing redevelopment called High Point covers eight percent of the Longfellow Creek sub-watershed. High Point spreads 1,600 housing units and mixed use areas over 34 blocks of new streets.

There, curb cuts drain into swales along the street edges, most downspouts are disconnected from storm drains and flow into grassy areas or rain gardens, some streets and sidewalks are made of porous pavement, and a conveyance system and detention pond absorb the impacts of larger storms.

According to the Seattle Public Utilities website, "Longfellow Creek will receive no more flow from High Point during and after a two-year, 24-hour storm than it would if the 129-acre site were still a grassy pasture."

Seattle now has a proposed drainage code that will require green infrastructure in new and redeveloped areas and will give residents credits against utility fees for installing recognized features. The city has also instituted a "Green Factor" program that requires property owners to install minimum landscaping, potentially including green roofs, street trees, and permeable paving and other natural drainage system practices on commercial properties.

Portland's response to growth

In Portland, Oregon, sustainable stormwater initiatives grew out of goals similar to Seattle's: the need to meet federal requirements for water quality and helping endangered wild salmon. Although Portland is building a conventional sewage deep tunnel to divert combined sewer overflows from the Willamette River to its treatment plant, it is counting on green infrastructure to limit the overall runoff volume over the long term — an important strategy in a city facing rapid growth.

Portland's Bureau of Environmental Services began testing experimental vegetated swale designs in 1998. Those tests showed native plants were superior in performance to turf grass swales. The initial monitored results led to further pilot efforts, particularly in ecoroofs, swales built into curb extensions, and streetside planters.

Another strategy, launched in 1996, has had a positive effect throughout the city. Home owners have two options for disconnecting from the city's combined sewer system so that stormwater can flow over appropriate vegetated sites. The city will pay home owners who disconnect their own downspouts, or city crews will disconnect them for free.

Downspout disconnection is one of several actions eligible for residential utility fee discounts under Portland's Clean River Rewards Incentive system. By disconnecting nearly 60,000 downspouts, the city diverted 1.5 billion gallons annually from combined sewers.

Another Portland project — native gardens built along the sides of Siskiyou Street — have become nationwide models of affordable green infrastructure projects that work. The 2003 Northeast Siskiyou Green Street Project converted 590 square feet of street pavement into landscape in curb extension bump-outs, also called "pocket swales." The areas were excavated to 14 inches below grade and refilled with an amended soil mix and a selection of drought- tolerant plants. Both sides of the residential block are involved, and 9,300 square feet of adjacent pavement are drained by means of four planted compartments that capture the street's runoff through native vegetation.

Simulated flow tests showed the street swales to be effective enough at reducing peak flow to prevent basements from flooding. They also controlled 85 percent of runoff volume for a simulated 25-year storm (1.89 inches in six hours, with a peak intensity of 3.32 inches per hour). The project was designed as a simple retrofit for existing streets and costs $20,000 to build.

Numerous additional pilot projects involving green roofs, swales, rain gardens, and streetside planters in a variety of locations led to Portland's adoption in 2007 of a Green Streets policy. It recognizes that green streets manage stormwater on-site, improve water quality and groundwater recharge, and lead to "attractive streetscapes that enhance neighborhood livability by enhancing the pedestrian environment and introducing park-like elements into neighborhoods."

Under the new policy, green street facilities will be incorporated into all city-funded development, redevelopment, or enhancement projects, according to Portland's stormwater management manual. The policy seeks to foster cross-departmental communication and encourage programs among bureaus in the interest of water quality and watershed health. It also explicitly seeks to use green streets to connect neighborhoods and save on infrastructure costs.

Under the Green Streets policy, designers and planners can find precise minimum design specifications (including section drawings) for the types of green infrastructure elements that are allowed, their location, materials, and varying conditions — for example, designs to use when an installation is adjacent to parking spaces. Those design standards can be adapted to fit right-of-way patterns in the city's transportation system plan.

Like Seattle, Portland helps engage the public in sustainable stormwater initiatives. It provides plant selection lists, design ideas, and extensive neighborhood outreach to stimulate the involvement of private land owners. The city also gives grants for certain private projects, and offers workshops for residential and commercial developers on green infrastructure techniques, costs, and benefits.

Greening Middle America

Green infrastructure is being adopted in the Midwest as well. In Minnesota's Twin Cities region, the seven-county Metropolitan Council issued technical guidance encouraging use of green practices in 2002. "A lot of those planning elements that make communities more livable also make them better for water resource management," says senior planner Karen Jensen.

Revisions to be made this year to the Metro Council comprehensive plan will include a surface water management requirement for on-site infiltration of the first half inch of stormwater. Some Twin Cities watershed districts have already increased that requirement to on-site capture of the first inch of rainfall.

Those requirements, combined with cost-share grant funding, have helped spread green infrastructure throughout the region. Ramsey-Washington Metro Watershed district provides a 50 percent best management practice cost share, up to $2,000 for residential or $30,000 for commercial or governmental projects. "It's amazing in the Twin Cities how there has been this tremendous momentum in the last couple of years," says Virginia Gaynor, open space naturalist for the city of Maplewood.

Her community and nearby Burnsville undertook early neighborhood-scale rain gardens. Maplewood built 350 rain gardens in a series of six street redevelopment projects between in 1996 and 2004. By 2008, the city had 400 home gardens and 25 on city property. Those projects led Maplewood to incorporate rain gardens in all future street redevelopment projects.

For home owners willing to host a stormwater garden in the right-of-way in front of their house, the city provides excavation, amended soil, plants, and technical assistance. Home owners can also pick one of 10 standard rain garden designs, developed for climatic resilience, aesthetics, and easy maintenance.

Collaboration with home owners helps keep city costs in control, as home owners take responsibility for maintaining rain gardens on their property. Gaynor says failures in early efforts showed the importance of helping developers avoid problems such as soil compaction during garden construction.

In Burnsville, the rain garden project began in 2002 and became operational in 2004 in an effort to protect nearby Crystal Lake. Seventeen rain gardens were installed in a 25-lot, five-acre neighborhood that was built in the 1980s with existing traditional curb and gutter infrastructure. The Burnsville rain gardens were designed to hold runoff from a 0.9-inch storm, with their results measured against an untreated similar neighborhood as a "paired watershed" experiment. They turned out to be more effective, retaining 90 percent of runoff even when storms were larger than the target size.

The Burnsville retrofit project cost $7.50 per square foot of rain garden, but can cost half as much for new developments, according to Burnsville water resource specialist Daryl Jacobson. He says the city has adopted a "first inch infiltration" standard to bring green infrastructure into new developments. Now Burnsville wants to replicate its pilot program in other neighborhoods, aiming to retrofit one neighborhood per year as part of its street maintenance cycle, Jacobson says.

"If you get (green infrastructure) in at the front end and make it part of your stormwater management, it will get you the level of water quality treatment you need and is cost-effective," Jacobson says.

The Burnsville project also is addressing the question of cold climate performance. Results there are similar to those in New Hampshire and other cold regions where native plant roots and porous soil help to keep rain gardens infiltrating runoff even during winter.

Minnesota green stormwater projects are addressing the need to spread beyond individual sites. St. Paul Riverfront Corporation — a nonprofit advocacy and design organization — published a Water Quality Manual in 2007 that describes various green practices in terms of their application at site, block, neighborhood, and city scales. Within each of those categories, the manual describes various techniques as well as sequential green infrastructure features — "treatment trains" — that can be connected to progressively purify runoff.

The Heritage Park redevelopment created a treatment train designed to handle 1.25-inch storms on a 130-acre area and to manage drainage on 300 off-site acres in what was historically part of the Bassett Creek drainage area. Stormwater treatment is done using medians and developed blocks, in which runoff filters through a sediment forebay into a filtration basin and pond before reaching a storm drain at the end of the train.

The system is designed to remove 70 to 80 percent of the runoff's total phosphorus and 85 percent of its sediment (exceeding the local requirement for 70 percent suspended solid removal) while creating water amenities for the new neighborhood.

Back alley story

Chicago's green infrastructure efforts underscore the city's declared quest to be "the greenest city" in the nation. Chicago now has about two million square feet of vegetated roof, with another two million planned or under construction. The city's stormwater ordinance, which took effect this year, requires that the first half inch of runoff be captured, or that there be a 15 percent reduction in impermeable surface, on most development and redevelopment projects. But Chicago has taken a creative path to innovative green practices.

The Chicago Department of Transportation began experimenting with permeable alley designs in 2006, seeking to take advantage of the city's 1,900 miles of alleys — which include 3,500 acres of impermeable surfaces. Green alley experiments on the first 40 alleys required the development of porous concrete and asphalt mixes using local and recycled materials. The city learned that alley designs using a partial porous surface, such as a center trench or porous edges, worked well and cost less than full porous surfaces. Another 48 green alleys are scheduled for completion this year.

The pilots led to an award-winning Green Alley handbook and led the city to work toward a sustainable streets approach. While the city will continue to repave its alleys to improve drainage, green infrastructure along rights of way now integrates design for stormwater drainage with transit, pedestrian access, energy, and air quality.

The latest project, a retrofit along part of Cermak Boulevard on the city's south side that is planned for construction this year, integrates drainage swales, permeable pavement, energy-efficient lighting, and bike lanes. Chicago is even testing a photocatalytic pavement coating originally developed to keep the Vatican from graying in Rome's polluted air. As a street surface, the coating is intended to filter street-level air pollutants.

"Good sustainable design is integrated design, that sweet spot that occurs when all disciplines work together to achieve quality, beauty, and efficiency," says Janet Attarian, project director of Chicago's Sustainable Streetscape and Design Program. "When designing the public right-of-way, old fashioned principles of walkability, access, and great public space have to be combined with new technologies and best management practices to maximize the use of these spaces and create beautiful places for people to live, work, and play."

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1,000 Points of Infiltration (or Thinking Big)

Communities around the U.S. are expanding their green infrastructure practices to embrace entire neighborhoods and cities. Here are a few examples.

• **Milwaukee Metropolitan Sewerage District Greenseams**
As part of a comprehensive green infrastructure program, the Milwaukee Metropolitan Sewerage District, in collaboration with the Conservation Fund, has invested nearly $12 million to acquire 1,700 acres of undeveloped riparian and forested areas. The district estimates that the increase in natural storage in four otherwise fast-developing watersheds would equal a $300 million investment in structural storage.

• **Philadelphia: Clean Waters, Green City**
Philadelphia's Watersheds Office is developing a "60 percent solution" to manage runoff from three-fifths of the city's impervious area. The city will reduce sewage overflows from stormwater runoff by enforcing an ordinance requiring first-inch on-site capture at regulated developments, setting stormwater rates according to impervious area, providing tax credit and permit incentives for green infrastructure, and building projects on public streets, schools, parks, buildings, and roofs. One goal is to uncover every buried stream in the city's watersheds.

• **Washington's 20-20-20 Vision**
What would happen if green roofs replaced 20 percent of the surface area of conventional roofs measuring more than 10,000 square feet? In studying Washington, D.C., the Casey Trees Foundation and LimnoTech, an Ann Arbor-based consultant, have estimated that 20 million square feet of green roofs would be built there in 20 years. According to the study, such a program would produce the equivalent of 430 million gallons of annual runoff storage, reduce sewer overflows by 15 percent, and remove nearly 17 metric tons of air pollutants.

• **Kansas City's 10,000 Rain Gardens**
About 400 new rain gardens have been installed so far in Kansas City, Missouri, through a collaboration between the city, the private sector, and the Mid-America Regional Council. Now the city is considering using green infrastructure as a feature of its official sewer overflow control program, currently under negotiation with U.S. EPA. Fort Wayne, Indiana, is aiming for 1,000 rain gardens under its EPA stormwater consent decree.

• **Portland's Grey to Green Initiative**
Portland Mayor Sam Adams has proposed a five-year, $50 million Grey to Green infrastructure initiative, including 43 acres of green roofs, 920 green streets, 88,000 street and yard tree plantings, 419 acres of land acquisition, and 350 acres of natural area plantings. The anticipated results include better stormwater flow, habitats, livability, air quality, energy efficiency, carbon sequestration, and cost-effectiveness.

• **Chicago's Growing Water Projects**
Chicago's UrbanLab design studio won a national design competition for its "Growing Water" strategy, which would create eco-boulevards running east along the city's major thoroughfares. In this 100-year vision, natural treatment of stormwater and wastewater would lead to big changes: re-reversing the Chicago River (turned toward the Mississippi River in 1900 to send the city's waste away from Lake Michigan) and converting the city's deep tunnel sewage collector into a subway line. UrbanLab and the Illinois Institute of Technology are developing pilot projects.

Resources

Images: Top — Seattle installed its first Street Edge Alternatives project in 2001 — a 14-foot-wide, meandering road that uses plantings to filter pollutants from stormwater. Photo courtesy City of Seattle. Middle — In Portland, Oregon, the Northeast Siskiyou Green Street Project uses landscape curb extensions to capture street runoff from 9,300 square feet of paved surfaces. Photo Portland Department of Environmental services. Bottom — Burnsville, Minnesota — a Twin Cities suburb — has built 17 rain gardens in a five-acre neighborhood. The aim is protect nearby Crystal Lake. Photo courtesy Dakota County Soil & Water Conservation District.

Readings: *Better Site Design: A Handbook for Changing Development Rules in Your Community,*

Center for Watershed Protection, 1998.

Green Streets: Innovative Solutions for Stormwater and Stream Crossings, Metropolitan Council, 2003.

On the web: For more on Seattle's natural drainage system: **www.seattle.gov/dpd/Permits/Greenfactor**

Learn about Portland's water gardens at **www.portlandonline.com**

Twin Cities Metropolitan Council surface water management: **www.metrocouncil.org/environment/Water/BMP/manual.htm**

The Center for Neighborhood Technology Green Values Took Kit: **www.greenvalues.cnt.org**

See the American Planning Association's Policy Guide on Water Resources Management: **www.planning.org/policyguides/waterresources.htm**