

A photograph of a modern urban courtyard. In the background, there is a multi-story building with a glass facade and a brick section. The courtyard features a central water feature, lush green plants, and a concrete ledge where several people are sitting. The scene is bright and sunny.

Harvesting the Value of Water

STORMWATER, GREEN INFRASTRUCTURE, AND REAL ESTATE



Urban Land Institute Center for Sustainability and Economic Performance

On the cover: The Avenue, located in Washington, D.C., includes an inviting courtyard water feature that uses 100 percent reclaimed water. (© 2012 Craig Kuhner)

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Harvesting the Value of Water

STORMWATER, GREEN INFRASTRUCTURE, AND REAL ESTATE

About the Urban Land Institute

The Urban Land Institute is a global, member-driven organization comprising more than 40,000 real estate and urban development professionals dedicated to advancing the Institute's mission of providing leadership in the responsible use of land and creating and sustaining thriving communities worldwide.

ULI's interdisciplinary membership represents all aspects of the industry, including developers, property owners, investors, architects, urban planners, public officials, real estate brokers, appraisers, attorneys, engineers, financiers, and academics. Established in 1936, the Institute has a presence in the Americas, Europe, and Asia Pacific regions, with members in 76 countries.

The extraordinary impact that ULI makes on land use decision making is based on its members sharing expertise on a variety of factors affecting the built environment, including urbanization, demographic and population changes, new economic drivers, technology advancements, and environmental concerns.

Peer-to-peer learning is achieved through the knowledge shared by members at thousands of convenings each year that reinforce ULI's position as a global authority on land use and real estate. In 2016 alone, more than 3,200 events were held in 340 cities around the world.

Drawing on the work of its members, the Institute recognizes and shares best practices in urban design and development for the benefit of communities around the globe.

More information is available at uli.org. Follow ULI on Twitter, Facebook, LinkedIn, and Instagram.

About the Center for Sustainability and Economic Performance

The ULI Center for Sustainability and Economic Performance is dedicated to driving more sustainable, environmentally responsible, and profitable outcomes in real estate development and investment, and to helping ULI members create healthy, resilient, and resource-efficient communities around the world. The Center advances knowledge and catalyzes adoption of transformative market practices and policies that lead to improved sustainability, health, resource efficiency, and resilience. ULI's stance on sustainability is grounded in the belief that, properly designed and implemented, these practices ultimately deliver stronger investment returns and improved fiscal performance.

Within the Center for Sustainability and Economic Performance, ULI's Urban Resilience Program aims to help ULI members and the public make their communities more resilient in the face of climate change. Through research, conferences and events, technical assistance projects, and its work with ULI's District Council network, the Urban Resilience Program focuses on opportunities relevant to the built environment, real estate markets, and the land use policy sector. Many of the Urban Resilience Program's projects have focused on the management of water in urban settings during peak and routine events, including methods for capturing water through green infrastructure.

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ABOUT THIS REPORT

This report was made possible by the generous support of the Kresge Foundation. Numerous ULI members and staff contributed to the report and research process, including the Sustainable Development Council and the Responsible Property Investment Council.

ULI's Urban Resilience Program undertook this research project in response to both policy trends and increased interest in water management among ULI member networks and communities. The research also builds from the program's recent work, including Advisory Services panels focused on resilient approaches to water management, *Returns on Resilience* case studies highlighting projects with innovative approaches to water management, and the 2015 Shaw Forum in Philadelphia, which brought together leaders in green infrastructure to explore best practices in stormwater management and low-impact development policies.

This report seeks to address a gap in today's research on stormwater management approaches. Although much has been written on the topic of green infrastructure and water management, most recent reports focus on stormwater policies or opportunities for capturing stormwater in the public realm. Fewer have focused on implications for private sector real estate developers.

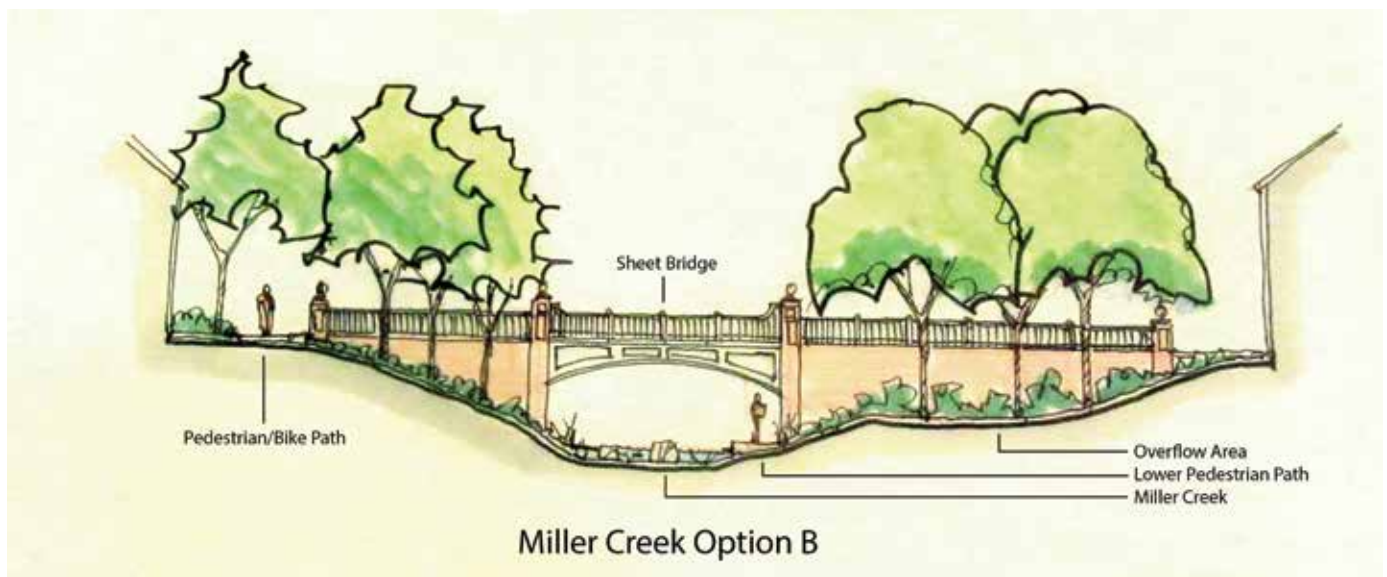
This report brings together an analysis of the stormwater policy landscape and an introduction to a variety of real estate development projects that have responded to them. After outlining the reasons that stormwater management is important to cities, this report introduces a series of real estate case studies



The 2015 Shaw Forum convened leaders in green infrastructure to discuss low-impact-development strategies and learn from the policies in place in Philadelphia. *(Jess Zimbabwe/Rose Center for Public Leadership)*

and a range of types of stormwater policies. The case studies come from locations across the United States and present both innovations in stormwater management and positive financial, operational, or design outcomes.

Discussions with real estate developers, policy makers, property managers, and designers greatly contributed to the development of this report. Numerous ULI members participated as interviewees and reviewers providing feedback on this paper and the overall project.



The Duluth, Minnesota, Resilience Advisory Services panel developed a series of options for the city to address recent flooding problems, such as the flash flooding in 2012, using green infrastructure and creek restoration projects. *(ULI)*

Introduction

Water abundance and scarcity are topics of increasing importance in cities across America. With growing concern about flooding, weather-induced overflows from sewer systems, and extreme storms, communities are seeking strategies to better manage stormwater runoff, improve local water quality, and decrease pressure on overloaded sewer systems. At the same time, water is increasingly recognized as a community resource, one that can be harnessed to make cities more sustainable and livable.

Managing Water: The Real Estate Sector's Role

Private sector developers and designers are playing a growing role in meeting cities' water goals. Local regulations are seeking increased participation from the private sector, requiring or incentivizing the real estate community to incorporate enhanced water management mechanisms into new development projects. These water management mechanisms have the potential to create value for real estate projects by enhancing aesthetics, operational efficiency, and building user experience.



The courtyard of ECO Modern Flats in Fayetteville, Arkansas, prominently features green infrastructure, including a bioswale that filters runoff from parking areas. *(Timothy Hursley)*



Vegetation adds texture and aesthetic appeal to a green roof. (PUSH Buffalo)

At the heart of many new stormwater policies is the concept of *green infrastructure*. The phrase has emerged as a catch-all term for approaches to managing stormwater with natural systems as an alternative to traditional gray drainage infrastructure, such as pumps and pipes. Green infrastructure is intended to capture stormwater, enhance water and air quality, and create attractive green spaces. Visible green infrastructure, such as rain gardens, bioswales, and green roofs, are accompanied by unseen technologies for water reuse, such as cisterns and rainwater recycling systems. Approaches to green infrastructure, on both the citywide and project scale, also enhance urban resilience by using flexible interventions to improve preparedness for both flooding and drought.

Whereas the concept of green infrastructure is not new, the notion of municipal policies creating a coordinated citywide green infrastructure network—including both public and privately owned sites—is. These networks require extensive participation from the private sector, enforced through policy requirements for newly developed and refurbished sites. In short, municipalities envision the public sector incorporating green design into public spaces, buildings, and rights-of-way while the private sector does the same for privately owned buildings, open spaces, and roofs.

Municipalities are increasingly requiring or incentivizing this approach in real estate projects and encouraging reductions in impervious surfaces such as concrete. Local governments are also providing frameworks supporting citizens, community groups, and institutions interested in incorporating green infrastructure into their properties, whether through grant programs, big data projects, demonstration projects, or idea competitions.

Many real estate developers are responding to new regulations by incorporating the requirements into their business models. Indeed, some developers have successfully leveraged stormwater management mechanisms not only to reduce and manage runoff, but also to add value to their buildings.

Whether by increasing potential development yield, introducing tangible amenities for residents, reducing operating costs, or building on a broader placemaking strategy, innovative stormwater management strategies can create value and contribute to quality of life and resilience in cities.

Case Studies

Developers across the United States are increasingly incorporating green infrastructure into their projects, whether on account of stormwater policy requirements or for other reasons that range from marketing value to compliance with green rating systems to cost savings.

Alongside an analysis of city policies, this report introduces the following real estate projects that have included green infrastructure and seen successful development outcomes:

- **Atlantic Wharf, Boston, Massachusetts**—a 31-story Class A office, retail, and residential development, described as “Boston’s first green skyscraper,” with a pioneering stormwater management system;
- **Burbank Water and Power EcoCampus, Burbank, California**—a campus for a community-owned utility site, which is the first power plant in the world to run on 100 percent recycled water;
- **Canal Park, Washington, D.C.**—a neighborhood park developed by a public/private partnership and located on the site of a former D.C. waterway, with 95 percent of the park’s irrigation, fountain, toilet-flushing, and ice-rink water provided through rainwater recycling;
- **Encore!, Tampa, Florida**—a 28-acre public/private, mixed-use, mixed-income development with an 8,000-square-foot stormwater retention harvesting system and a stormwater vault designed as the centerpiece of a public park;
- **High Point, Seattle, Washington**—a HOPE VI redevelopment, currently the Seattle Housing Authority’s largest residential project at 1,700 affordable and market-rate homes, with an extensive natural drainage system featuring bioswales and constructed wetlands;
- **Market at Colonnade, Raleigh, North Carolina**—a 57,000-square-foot commercial development capable of capturing up to 800,000 gallons of rainwater, including a Whole Foods Market that chose to include a visible cistern as part of its branding for the site;
- **Meier & Frank Delivery Depot, Portland, Oregon**—an office development in a National Register of Historic Places building in downtown Portland, with a rainwater recycling system that saves an estimated 193,000 gallons of water annually;
- **Penn Park, Philadelphia, Pennsylvania**—a community open space developed through public/private partnership by the University of Pennsylvania and designed in response to Philadelphia’s *Green City, Clean Waters* plan and the university’s Climate Action Plan;

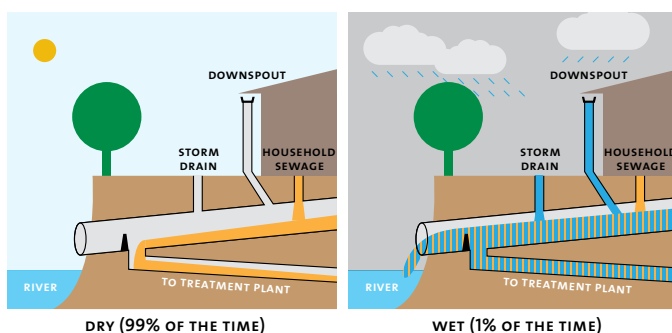
- **Stonebrook Estates, Harris County, Texas**—a Houston-area residential development with a low-impact development approach that stood up to catastrophic flooding during the Tax Day floods of 2016;
- **The Avenue, Washington, D.C.**—a mixed-use, transit-oriented development in downtown Washington that features a robust stormwater management system set in an inviting residential courtyard; and
- **The Rose, Minneapolis, Minnesota**—a 90-unit mixed-income residential project designed for on-site treatment of all stormwater, with features that include a rain garden and cisterns.

Lessons Learned

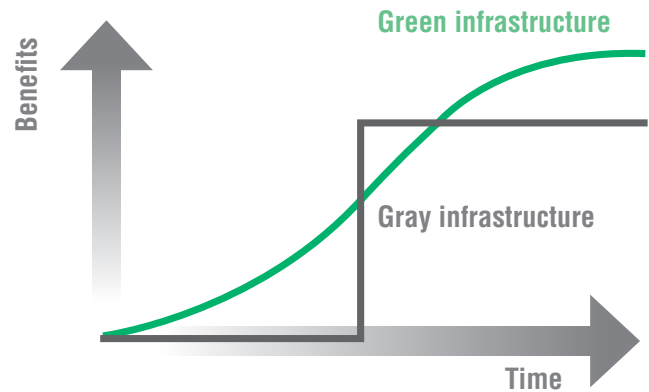
Cities often choose to incentivize or require stormwater management from the real estate sector because of top-down regulatory measures addressing water quality. Indeed, the U.S. Environmental Protection Agency (EPA) estimates that approximately 860 communities representing 40 million residents are affected by combined stormwater and sewage runoff in the United States.¹ Much of the municipal interest in enhanced stormwater management originates from regulatory measures addressing these water quality problems, such as the EPA's consent decrees to mitigate combined sewer overflows (CSOs). The 1972 Clean Water Act underpins these actions.

However, although the impetus to address stormwater management is often top-down, American cities' approaches to stormwater policy have differed across local markets, responding to differing markets conditions, annual rainfalls, and climate challenges. Conversations with real estate developers, designers, planners, and policy makers active in stormwater management shed light on numerous themes and lessons common to communities involving the real estate sector in stormwater management:

For cities, green infrastructure offers an opportunity to enhance environmental performance and save money, compared to costly gray infrastructure projects that do not offer other community benefits. Cities across the United States are embracing



Combined sewer systems overflow during heavy storms, discharging raw sewage into designated water sources. (Annemieke Beemster Leverenz/GrowNYC)



Over time, green infrastructure provides increasing benefits, in contrast with gray infrastructure. (NYC Green Infrastructure Plan, Executive Summary)

green infrastructure approaches because they offer social, economic, and environmental benefits while addressing water challenges. Green infrastructure cost-effectively reduces sewer system overflows and manages stormwater runoff, improves local water quality, decreases the use of potable water, reduces heat-island effects, improves public health, enhances recreational opportunities, increases employment, and stimulates economic growth—all at a lower cost than gray infrastructure solutions alone.

Unlike large-scale CSO pipe-and-tunnel mitigation projects, a green infrastructure approach allows small-scale interventions and participation by private landowners. Lower upfront and maintenance costs can also make green infrastructure more accessible, resilient, and cost-effective than large-scale gray infrastructure investments.

For real estate developers, green infrastructure provides opportunities for cost saving by freeing up more developable land than traditional water management solutions. Using

green infrastructure or low-impact development (LID) can be a more cost- and space-efficient means of achieving stormwater management requirements than gray infrastructure or traditional approaches such as detention ponds. Numerous projects profiled in this report chose to take innovative approaches to water management to free up space on constrained sites and achieve a larger developable area.

Green infrastructure can enhance the attractiveness and value of a property and reduce operating costs. Real estate developers, designers, and building operators interviewed for this report emphasized the multiple benefits that green infrastructure and stormwater management mechanisms have brought to their properties, often leading to increased real estate value.

From improving the design of the public realm to creating educational opportunities and amenities, many interviewees saw green infrastructure as offering social and community benefits

“When we look at the amount of work that needs to be done to manage stormwater in the District—the vast area of public and private land that needs to be retrofitted as well as the money and time involved—we realize that we can’t accomplish our water quality goals by only implementing public projects. Incentive programs that encourage voluntary retrofit are a huge piece of the puzzle.”

JEFFREY SELTZER, ASSOCIATE DIRECTOR, DEPARTMENT OF ENERGY & ENVIRONMENT, WASHINGTON, D.C.



that contribute to real estate value and marketing opportunities. Many also spoke of the opportunities to operationalize green infrastructure, generating savings on utilities, maintenance, water use, and upkeep.

The emerging range of green infrastructure policies and strategies works in different markets and contexts. Cities across the country have used policies in different combinations appropriate to their local market conditions and environmental needs. Real estate projects profiled in this report include historic buildings and high-density developments as well as open space-rich and suburban projects.

Green infrastructure mechanisms can be effectively implemented in scenarios when space is at a premium. Stormwater credit-trading systems, such as the system recently launched in Washington, D.C., offer an alternative strategy for achieving compliance in densely developed areas by supporting off-site green infrastructure within the same watershed.

Green infrastructure may require an initial learning curve, but the payoff can be large. Interviewed policy makers and city-planning practitioners indicated that the real estate community is often initially hesitant about new stormwater policies. Property developers and owners also indicated that design and operation of stormwater projects requires a learning curve, particularly in terms of landscape maintenance for green infrastructure installations such as bioswales and rain gardens.

Canal Park was a key part of a neighborhood-wide redevelopment strategy, enhancing attractiveness and adding a significant amenity for current and future residents and office workers. (© Bruce Damonte)

However, after local designers and developers had learned how to accommodate green infrastructure requirements and work them into the initial stages of the design process, incorporating green infrastructure became part of business as usual.

With this increasing familiarity, the real estate community also recognized the opportunities for improved amenities, aesthetics, and marketing appeal that can be derived from green infrastructure. As stormwater management policies continue to gain traction, cities and developers can learn from each other and gauge the success of different models through research and practitioner networking programs.

Real estate owners and operators value green infrastructure’s performance during peak weather events and the added security this brings to their investments.

Green infrastructure can be a particularly valuable investment during peak weather events such as floods, which can damage properties and shut down day-to-day activities across communities. In this way, investment in stormwater management can enhance the resilience of buildings, neighborhoods, and communities, thereby ensuring that lives and livelihoods are not interrupted while also improving quality of life and environmental performance on a day-to-day basis.

The Root of the Problem

Water is a critical natural resource, vital to human and environmental health. Water is essential for cities, many of which are situated on the coasts or at the confluence of major rivers or waterways.

For example, Chicago’s 2014 *Green Infrastructure Strategy* opens with commentary on the importance of water to Chicago, not only emphasizing the need for clean drinking water and water access, but also detailing the recreational, economic, tourism, and quality-of-life importance of having clean waterways.¹ Efforts to better manage stormwater are increasingly framed in this way, ensuring that citizens, policy makers, and members of the business community recognize stormwater as an issue bigger than the consequences of an occasional large rainfall.

A combination of environmental factors and built conditions has led to today’s concerns about stormwater. The increased frequency of rainfall in many parts of the country, urbanization, aging infrastructure, and the proliferation of impervious surfaces have all contributed to the severity of the problem. Budgetary concerns and the high cost of capital projects and day-to-day city maintenance of water infrastructure have led cities to seek opportunities for private sector action.

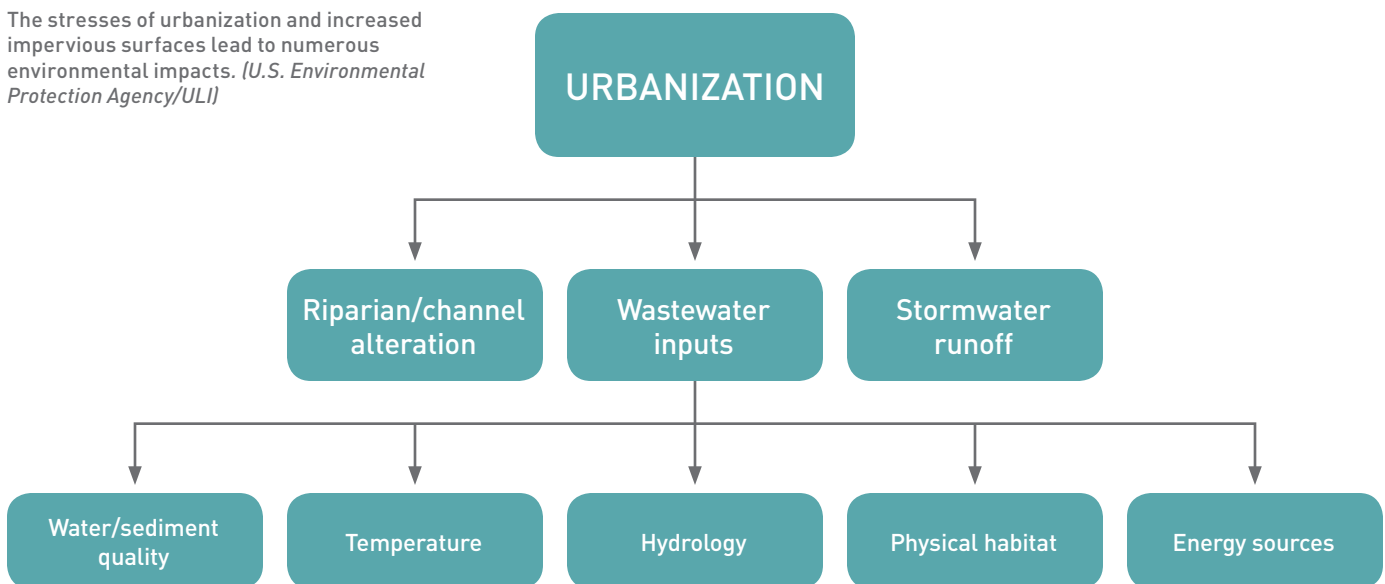
Cities and Water

By 2050, more than two-thirds of the world’s population will be living in urban areas.² North America is already one of the most urbanized areas in the world, with 82 percent of residents living in urban areas in 2014, according to the United Nations *World Urbanization Prospects* highlights.³

With urban development comes an increase in impervious surfaces, such as roads, sidewalks, parking lots, and roofs. Replacing the natural landscape with these surfaces leads to fewer opportunities for water infiltration, which in turn generates more runoff.⁴

The U.S. National Research Council has asserted that stormwater management is one of the more pressing environmental concerns for the country because stormwater is one of the most consistent pollution sources of rivers, lakes, and streams.⁵ The EPA also explains that an increase in impervious surfaces generally leads to “more frequent, larger magnitude and shorter duration” peak flows, ultimately altering urban stream-channel morphology, increasing erosion, and decreasing water quality.⁶

The stresses of urbanization and increased impervious surfaces lead to numerous environmental impacts. (U.S. Environmental Protection Agency/ULI)





Impervious surfaces, such as this sloped alleyway in Washington, D.C., reduce opportunities for infiltration, thereby increasing the speed of runoff and the likelihood of flooding while reducing water quality. (ULI Washington)

As stormwater carries pollutants such as oil, grease, fertilizer, sediment, and pesticides into the sewage system or nearby bodies of water, water quality is compromised.

An increased volume of runoff, if unmitigated, can lead to an increased likelihood of flooding, and in older combined sewer systems can result in frequent overflows of those systems and attendant surface-water quality concerns.

Infrastructure plays a key role. In the United States, contemporary water challenges can be traced at least in part to the legacy of car-centric planning, which transformed undeveloped, vegetated, and uneven land into impermeable flat surfaces.⁷ Building and financing new hard infrastructure to address flooding, rainfall, and sewage needs is a challenge for most American cities, particularly given that many struggle with the upkeep of their existing infrastructure.

In addition, many older cities were built with CSO systems that carry both sanitary wastewater and stormwater. These systems can overflow during rain events and discharge untreated sewage to nearby creeks, rivers, and lakes, potentially causing disease outbreaks and compromising water quality, wildlife habitats, and health.

Environmental Regulations

The management of stormwater quality in the United States began in 1987, when Congress amended the Federal Water Pollution Control Act of 1972 (more commonly known as the

Clean Water Act) to expand the regulation of stormwater runoff. Before then, nonpoint sources and industrial, construction, and municipal stormwater point sources were unregulated, despite being the cause of significant surface-water quality issues. Even small storms could dramatically affect water quality.⁸ After the 1987 amendment, the EPA promulgated a series of regulations, and, with the states, began issuing permits to industrial, construction, and municipal stormwater dischargers.

The Clean Water Act requires that any person must have a permit to discharge a pollutant to waters of the United States. The EPA and the states issue permits to a host of different entities, requiring that pollutants be managed before discharge to water bodies so that the nation's creeks, rivers, lakes, and beaches remain fishable and swimmable.

Wastewater from cities and factories is typically treated in a central wastewater treatment plant. Stormwater pollutants are usually addressed using a combination of education, operational approaches, good housekeeping practices, and some engineered systems.

The CSO issue began to get EPA's attention in 1994. Today, EPA consent decrees—which are legally binding agreements between a city, the EPA, and the U.S. Department of Justice—are forcing cities across the country to address their CSOs through a combination of sewer system improvements, large-diameter tunnel storage systems, and green infrastructure and LID to reduce the volume of stormwater runoff that enters the combined sewer.

More than 700 U.S. cities with such systems have entered into consent decrees.⁹ The EPA and states also issue cities Municipal Separate Storm Sewer System (MS4) Permits that often include LID or green infrastructure requirements.



The EPA tracks U.S. CSOs serving a population of 50,000 and provides the status of their consent decrees, if applicable. (U.S. Environmental Protection Agency)

STORMWATER AND HEALTH

Stormwater and health are inextricably linked. When stormwater is effectively managed as a community asset, a key benefit is a healthier environment for humans and animals, including improved air quality and cleaner water for consumption, recreation, and wildlife. Green infrastructure strategies provide opportunities for enhanced community parks and recreation areas, offer places to grow food, and help mitigate urban heat-island effects and their public health challenges.ⁱ

However, many communities struggle to manage stormwater. One key challenge is combined sewer overflow systems, which mix sewage with stormwater runoff during high rain events, thereby allowing untreated sewage to spill directly into waterways. The EPA estimates approximately 860 communities representing 40 million residents are impacted by combined stormwater and sewage runoff in the United States.ⁱⁱ

Localized flooding and inundation of roadways can lead to traffic accidents, increased mosquito breeding, and other issues. Flood water can carry pathogens and spread toxic materials, road oil, and pollutants as well as contaminate water sources. Waterborne contaminants from everyday

products such as fertilizers and pharmaceuticals pose public health concerns and are especially dangerous for pregnant women and children. Water that enters homes can compromise building structures, lead to mold and fungus growth, contaminate living spaces, and create the risk of electrical failure and shock.ⁱⁱⁱ

Poor communities are more likely to be affected by water challenges because they are often located in low-lying areas prone to flooding and close to high-capacity drainage and retention sites.^{iv} Their residents are more likely to swim or fish in polluted water sources. People with low incomes are also more likely to have chronic health challenges, such as asthma, which can be exacerbated by water issues. People of color and poor people are less likely to have the financial resources to quickly recover from the effects of disease and the loss of productivity that water-related challenges can bring.

Strategies explored in this report show how communities can avoid health-related hazards and maximize the potential of water management strategies that are win-wins for the environment and for health. For this potential to be realized, it is essential that stormwater solutions be equitably distributed.

i. V. Jennings et al., "Advancing Sustainability through Urban Green Space: Cultural Ecosystem Services, Equity, and Social Determinants of Health," *International Journal of Environmental Research and Public Health* 13, no. 2 (2016): 196.

ii. U.S. Environmental Protection Agency, "Combined Sewer Overflow Frequent Questions," National Pollutant Discharge Elimination System (NPDES) website.

iii. Adam Smith, "2016: A Historic Year for Billion-Dollar Weather and Climate Disasters in U.S.," U.S. National Oceanic and Atmospheric Administration, Climate, January 9, 2017.

iv. Cathleen Kelly and Tracey Ross, *One Storm Shy of Despair: A Climate-Smart Plan for the Administration to Help Low-Income Communities* (Center for American Progress, 2014).

"The 100-year storm event is really a misleading term because it implies that the event will happen only once every 100 years. Really, we should call it the 1 percent chance storm—because there is a 1 percent chance it will occur in a specific location every year. In the Houston region, the 1 percent storm is about 12 inches or 13 inches of rain in 24 hours."

RANDY JONES, PRINCIPAL, TERRA VISIONS LLC

Major rain events are becoming more likely to occur, creating an increased need to invest in alternative approaches to managing stormwater. (© Willowpix/iStock)

HEALTH BENEFITS OF SUSTAINABLE STORMWATER MANAGEMENT PRACTICES

How reducing and treating stormwater at its source—through bioswales, community gardens, porous pavement, and other measures—can benefit environmental, physical, and mental health

Environmental health	Physical health	Mental health
<ul style="list-style-type: none"> • Habitats are stabilized for pollinators, fish, and other wildlife, essential for biodiversity and food production, to thrive.^a • Air and water are filtered from contaminants found in mold, standing water, human-produced waste, toxic piping, and other sources of disease.^b • Local water supplies can be replenished through stormwater reuse and reclamation.^c 	<ul style="list-style-type: none"> • Recreational spaces are created for physical activity, which can reduce the prevalence of cardiovascular disease.^d • Access to healthy food is expanded through community and rooftop gardening and beekeeping.^e • Physical safety can be promoted through “greened, openly visible, and ordered spaces,” which may reduce opportunities for violence and crime.^d 	<ul style="list-style-type: none"> • Relaxation and feelings of well-being are enhanced by green spaces that mitigate stressful environmental factors, including noise, building vacancies, and pollution.^d • Civic participation can increase through urban greening projects that promote inclusive community involvement.^f • Neighborhood prosperity can be fostered by green jobs, increased property values, and decreased costs for infrastructure, heating, and cooling.^g

^aU.S. Environmental Protection Agency, “Problems with Stormwater Pollution,” Stormwater Program webpage.

^bWorld Health Organization, *Guidelines for Drinking-Water Quality*, 4th ed. (Geneva: WHO, 2011).

^cJ. Lee et al., *Arid Green Infrastructure for Water Control and Conservation: State of the Science and Research Needs for Arid/Semi-Arid Regions* (Washington, DC: EPA, 2016).

^dM.C. Kondo et al., “The Impact of Green Stormwater Infrastructure Installation on Surrounding Health and Safety,” *American Journal of Public Health* 105, no. 3 (2015): e114–e121.

^eR.J. McLain et al., “Gathering ‘Wild’ Food in the City: Rethinking the Role of Foraging in Urban Ecosystem Planning and Management,” *International Journal of Justice and Sustainability* 19, no. 2: 220–40 (2014).

^fV. Jennings et al., “Advancing Sustainability through Urban Green Space: Cultural Ecosystem Services, Equity, and Social Determinants of Health,” *International Journal of Environmental Research and Public Health* 13, no. 2 (2016): 196.

^gU.S. Environmental Protection Agency, “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices,” (Washington, DC: EPA, 2007).

The Climate Change Connection

Extreme rainfall is also more of a concern than it once was: for example, the number of days with heavy precipitation rose by 58 percent in the U.S. Northeast between 1958 and 2007.¹⁰ As the world warms, warmer air can hold increased moisture, meaning heavier precipitation is likely.¹¹

The EPA notes that among the impacts of climate change, precipitation has increased by an average of over an eighth of an inch per decade across the lower 48 states, with a higher percentage of precipitation coming through single-day events and eight of the top ten years for extreme one-day storm events occurring since 1990.¹²

Extreme storms are also likely to become more regular with climate change. In 2016, the Environmental Defense Fund noted that the United States saw four 1,000-year floods in five months in the diverse geographic areas of Texas, West Virginia, Maryland, and Louisiana.¹³ With this level of frequency, the term

1,000-year storm is becoming increasingly misleading: these storms are named for the statistical probability that they will occur, but the probability is computed using data from the past.

Even places plagued by drought face the risk of flooding because hard-packed soil can lead to its inability to absorb water and thus create flash floods. Climate change also brings the likelihood of increased heat to many regions of the country, meaning that intensified heat in cities, known as urban heat-island effect, is likely to continue to worsen.

In short, the challenges of urbanization and managing extreme precipitation, combined with the cost of aging infrastructure, strapped public budgets, and pressure from federal agencies such as the EPA, have led cities to look for alternative approaches to managing stormwater.

Defining Green Infrastructure

Green infrastructure offers an alternative to the gray infrastructure that cities have traditionally used to manage water during everyday and peak storm events.

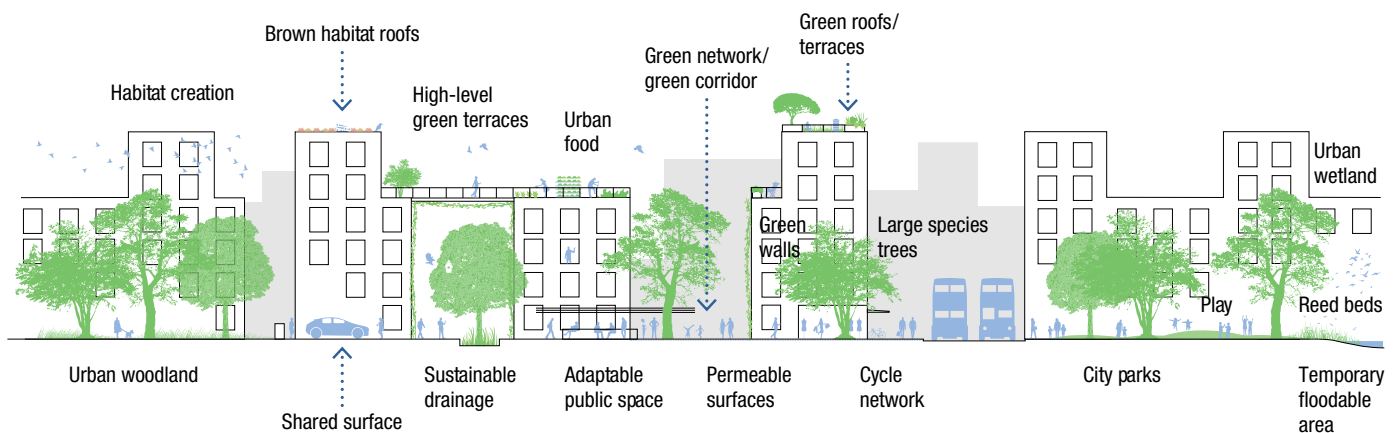
Gray infrastructure includes hard roofs, pavement, and pipes that are designed to convey stormwater away from a developed area. This approach treats water as a nuisance substance: a waste to be disposed of quickly and sent through pipes to detention basins.

Green infrastructure instead uses natural systems to slow water down, use it as a resource, convey it in landscape amenities, and as a result reduce potable water use. Natural drainage systems mimic the natural flow of water, creating bayous and corridors that can serve as attractive open spaces as well as water channels. According to the advocacy and conservation organization American Rivers, taking this approach can “provide clean water, conserve ecosystem values and functions, and provide a wide array of benefits to people and wildlife.”¹

A broad term, *green infrastructure* can refer both to site-specific measures and a community-wide or regional green network. The American Planning Association explains that “at the city and regional scales, [green infrastructure] has been defined as a multifunctional open-space network. At the local and site scales, it has been defined as a stormwater management approach that mimics natural hydrologic processes.”²

The EPA describes green infrastructure as a strategy to achieve triple-bottom-line benefits, explaining: “Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray stormwater infrastructure—conventional piped drainage and water treatment systems—is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits.”³

At the scale of a real estate project, green infrastructure often refers to design features that can capture, retain, and slow the release of stormwater during routine and peak events, using the



Green infrastructure can take on a range of forms, shapes, and sizes depending on the stormwater management goals, building types, and surrounding development context. (© ARUP)



Paseo Verde, a 120-unit mixed-income development in North Philadelphia, has a green roof over the first level that minimizes runoff and doubles as garden courtyards, an attractive amenity for residents. (Halkin Mason Photography)

storage, infiltration, evaporation, and carrying capacity of distributed elements rather than buried pipes and centralized, end-of-pipe detention basins. These distributed system elements can include green roofs, bioswales, berms, rain gardens, permeable paving, cisterns, and other aspects of a “rain chain.”

Whether implemented together or separately, on building surfaces or in outdoor spaces, these design mechanisms can capture water, support natural infiltration, and enhance local ecosystems. Frequently, green infrastructure reduces the need for buried storm sewer systems and end-of-pipe detention systems, thus lowering infrastructure costs and providing more developable land.

These design interventions can also be a key aspect of park and public space design, creating spaces that are both attractive gathering places and capable stormwater management systems. Creating these types of balanced spaces, which can both hum with human activity and support cycles of natural ecosystems, is the specialty of many of today’s landscape architects.

Benefits of Green Infrastructure

Implementing green infrastructure, particularly in conjunction with the private development community, is first and foremost attractive to cities because it costs less than traditional

stormwater management approaches. For example, before initiating the ambitious *Green City, Clean Waters* plan, decision makers in Philadelphia learned that a new sewage pipe under the Delaware River would likely cost \$10 billion.⁴

Likewise, New York City evaluated two stormwater management strategies and found that a green infrastructure plan, including green roofs, stream restoration, and bioswales, would save \$1.5 billion compared to a gray infrastructure plan composed of tunnels, pumps, and storm drains.⁵ The green infrastructure plan was projected to offer more long-term environmental, social, and economic benefits to the city.⁶ The World Resources Institute has reported that decision makers in Idaho and North Carolina came to similar conclusions after evaluating comparable scenarios.⁷

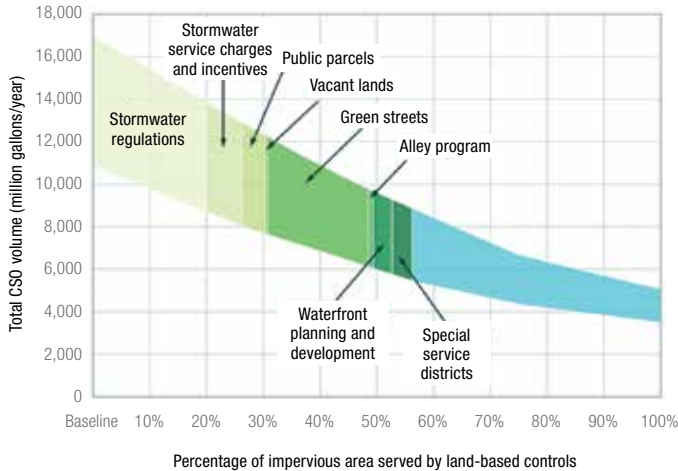
Philadelphia, Washington, D.C., and Seattle are national leaders in crafting policies to promote and create green infrastructure, with many other cities following suit. In most cases, the policies will eventually create a patchwork of green interventions across the city, implemented by both the private and public

GREEN INFRASTRUCTURE BENEFITS

The U.S. Environmental Protection Agency’s 2016 report on green infrastructure solutions for downtown sites, *City Green*, cites the following potential benefits of green infrastructure:

- Improved water quality
- Reduced municipal water use
- Groundwater recharge
- Flood risk mitigation for small storms
- Increased resilience to climate change impacts such as heavier rainfalls and higher temperatures
- Reduced ground-level ozone
- Reduced particulate pollution
- Reduced air temperatures in developed areas
- Reduced energy use and associated greenhouse gas emissions
- Increased or improved wildlife habitat
- Improved public health from reduced air pollution and increased physical activity
- Increased recreation space
- Improved community aesthetics
- Cost savings
- Green jobs
- Increased property values

U.S. Environmental Protection Agency, *City Green: Innovative Green Infrastructure Solutions for Downtowns and Infill Locations* (Washington, DC: EPA, 2016), 1, Exhibit 1, https://www.epa.gov/sites/production/files/2016-06/documents/city_green_0.pdf.



Philadelphia is using a wide range of policies and programs to decrease the amount of impervious area in the city and encourage the use of green infrastructure to decrease the volume of combined sewer overflow and achieve other benefits. (U.S. Environmental Protection Agency)

sectors, forming full green networks that can manage stormwater on a citywide scale.

Beyond cost savings, a citywide network of green infrastructure can generate many nonfinancial benefits. As green infrastructure has become a more common approach, numerous public sector and research groups have sought to quantify and monetize its environmental, social, and economic impacts beyond typical cost/benefit analyses. Studying the citywide impact of green infrastructure investments is a burgeoning field.

Some studies have monetized the reductions in energy use associated with green infrastructure, as well as benefits such as improved air quality and reduced levels of atmospheric carbon dioxide,⁸ and explored other benefits, including community cohesion, improved public health, carbon sequestration, real estate uplift, and economic development.

Philadelphia uses a triple-bottom-line approach, considering social and environmental benefits alongside financial benefits.⁹ Five years into Philadelphia's 25-year *Green City, Clean Waters* plan, a Sustainable Business Network study found that the green infrastructure industry catalyzed by the plan represented a \$60 million positive economic impact, supporting 430 jobs and \$1 million in tax revenue.¹⁰ Beyond this, the city's public investment in green infrastructure has made a \$3.1 billion positive impact, supporting 1,000 jobs.¹¹

GREEN INFRASTRUCTURE AND WATER MANAGEMENT STRATEGIES

Many of today's stormwater policies encourage or require a range of water management and green infrastructure strategies. Real estate developers who are conversant with the full suite of options will be able to leverage the tools most beneficial to their work. Key green infrastructure tools include the following:

Bioswales

Green areas that are similar to rain gardens, bioswales are used to reduce stormwater runoff through infiltration, storage, or both. However, unlike rain gardens, bioswales are designed to manage runoff from a large impervious area like a parking lot or street. Bioswales are deeper than rain gardens and often require engineered soils that can filter and handle larger stormwater flow rates.ⁱ



(© Aaron Volkering, Flickr)

Blue roofs

Blue roofs are designed to store rainwater within detention systems on roofs, thus preventing stormwater from initially entering the sewer system after a storm.

Cisterns

Large storage facilities, often built below ground, at ground level, in parking facilities, or on rooftops, cisterns store stormwater, often for reuse.



(© Regency Centers)

Curb cuts

A curb cut is part of a street curb removed to connect the street level with another surface, often a stormwater management or green infrastructure mechanism that can absorb water in place of the traditional drainage system.



(© Center for Neighborhood Technology, Flickr)

Green roofs

Green roofs use rooftop vegetation to absorb rainwater and heat. In addition to managing stormwater and cooling surrounding ambient air, green roofs help decrease energy needs for the building and improve overall air quality.ⁱⁱ



(© Joyfnp/Stock)

Permeable surfaces

Permeable surfaces include porous asphalt, porous concrete, and porous interlocking paving bricks that allow flowing water to infiltrate through the surface into the ground below. Permeable surfaces can be used for sidewalks, parking lots, alleys, and streets and have cooling properties caused by their reduced heat storage compared to regular pavement.ⁱⁱⁱ The porous asphalt, concrete, and interlocking paver industries offer design and installation credentialing programs.



(© Giodoalf/Stock)

Rain gardens

Rain gardens are small plots of vegetation that are designed to reduce stormwater runoff through infiltration, storage, or both. They are typically placed where stormwater naturally flows and are commonly incorporated in other landscape designs or streetscapes.^{iv} In parts of the country where soils do not allow natural infiltration because of their clay content, underdrains or pipes can send cleaned water into nearby creeks, bayous, or storm sewers.



(© Chris Hamby, Flickr)

Rainwater harvesting

Rainwater harvesting is the collection and storage of rainwater in containers; the water is then released into the stormwater management system or desired location for filtration. Rainwater harvesting systems can be created on a small scale, for example, by using roof downspouts, or on a large scale, depending on the needs of the stormwater management system.



(© Kodachrome25/Stock)

Stormwater vaults

This type of detention basin or subsurface facility, commonly made of concrete, steel, or fiberglass, manages stormwater in an urban setting.



(© Arbitrarily0)

Tree pits

Tree pits perform like small reservoirs, capturing and purifying runoff that flows into the uncompacted soil, which then diverts the water into a stormwater management system.^v

The following frameworks for real estate development and design advocate for many of the preceding green infrastructure tools:

- **Low-impact development (LID):** A land planning and design approach that emphasizes mimicking natural system processes to store, infiltrate, retain, and detain precipitation and rainfall as close to its source as possible; and
- **Stormwater best management practices (BMPs):** Methods that have proven to be the most effective, practical means of preventing or reducing pollution from a source that needs to be controlled, such as stormwater runoff.^{vi} BMPs provide a basis for estimating the performance, costs, and economic impacts of achieving management quotas and policies.

i. Soil Science Society of America website, "Rain Gardens and Bioswales," <https://www.soils.org/discover-soils/soils-in-the-city/green-infrastructure/important-terms/rain-gardens-bioswales>.

ii. Georgetown Climate Center, *Green Infrastructure Toolkit*, www.georgetown-climate.org/adaptation/toolkits/green-infrastructure-toolkit/green-infrastructure-strategies-and-techniques.html.


iii. Soil Science Society of America, "Rain Gardens and Bioswales."

iv. Ibid.

v. Lisa Nisenson, *Using Smart Growth Techniques as Stormwater Best Management Practices* (Washington, DC: U.S. Environmental Protection Agency, 2014), <https://www.epa.gov/sites/production/files/2014-04/documents/stormwater-best-management-practices.pdf>.

vi. Ibid.

Opportunities for Real Estate



Atlantic Wharf in Boston gained significant market recognition on account of its green and water management features. *(Ed Wonsek)*

“In Philadelphia, developers became leaders in advocating for the market value that green infrastructure could provide to projects. We saw progressive developers able to educate other developers, their financial backers, and the market. Their work showed that green infrastructure could provide for both the bottom line and for their sense of corporate identity and placemaking.” | MAMI HARA, GENERAL MANAGER/CEO,

SEATTLE PUBLIC UTILITIES, FORMER DEPUTY COMMISSIONER, PHILADELPHIA
WATER DEPARTMENT

As cities increasingly require private developments to incorporate stormwater management mechanisms, green infrastructure is likely to become part of business as usual. Real estate projects that harness the opportunities presented by stormwater management systems will see the benefits, particularly in terms of the design of public and outdoor spaces and opportunities for operational and land use efficiencies.

Many developers who have responded to stringent stormwater regulations have had an overall positive experience, according to a recent study.¹ Whereas most indicated that the new policies required creative thinking and led to some complexities, the overall results were positive because of market interest in green design and the lower costs of green infrastructure in comparison with conventional stormwater controls.

None indicated that stormwater requirements would deter them from involvement in future projects, particularly given that each considered “the cost of implementing stormwater controls [to be] minor compared to the other economic factors they considered in deciding whether or not to pursue a project.”²

Financial Opportunities

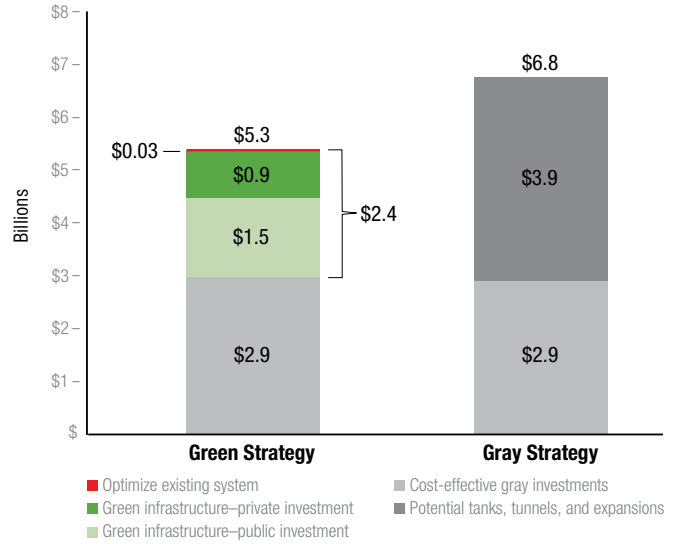
The cost of stormwater controls is extremely variable, particularly for redevelopment or infill projects.³ Indeed, developers interviewed for the study cited above were “unable or unwilling to provide specific ‘rules of thumb’ for either the proportional costs of stormwater relative to overall development costs or the difference in costs to implement stormwater controls between redevelopment and greenfield projects.”⁴

Many of the real estate developers interviewed for this report found that the investment in green infrastructure allowed them to free developable land on constrained sites, making the costs of the stormwater technologies a sound investment. This was particularly the case for projects that would have traditionally accommodated stormwater requirements by creating detention ponds.

Houston-based engineer Michael Bloom explains that wisely placed green infrastructure “allows a development site to accommodate a higher number of homes or commercial buildings, reduces drainage system costs, and provides for an open-space amenity, such as parks or trails.”⁵

MAXIMIZING WATER VALUE

Developers familiar with green infrastructure emphasized in interviews that, if executed well, an investment in stormwater management should be able to improve the bottom line for real estate projects. A 2013 report by the National Resources Defense Council (NRDC) describes how green infrastructure can become a “quality benchmark for the private sector,” contributing to



The estimated costs for managing New York City’s CSO scenarios were far lower using a green rather than a gray strategy, according to the New York City Green Infrastructure Plan. (NYC Green Infrastructure Strategy, p. 9/ULI)

properties that command higher rents, enhancing property values, decreasing energy and water costs, reducing maintenance costs, and improving occupant health.⁶

Case study prototypes in the NRDC report include a 40,000-square-foot retail center with green infrastructure that is capable of generating \$24.7 million in benefits over a 40-year analysis period, including roughly \$23 million in improved sales for tenants, and a 33,700-square-foot apartment building, generating \$1.7 million in benefits for the building owner.⁷ For constrained urban sites, this value may come from attractive landscaping; for suburban or green sites, the value may come from the integration of open spaces and trails designed with LID techniques.

A key design implication of green infrastructure policies is a focus on green rather than impervious surfaces. Roofs, community spaces, street frontages, and parking lots feature native plantings, bioswales, and permeable surfaces. These aspects may contribute to the aesthetics and marketing for a development project and can form key parts of a development’s amenity package.

In Boston, the 1330 Boylston apartment complex developed by Samuels & Associates saw rent increases of \$300 to \$500 per month for units overlooking a \$112,500 green roof, soon netting about \$120,000 per year. Accordingly, potential exists for revenue enhancement if the landscape aspects can be marketed as added value. “How you incorporate stormwater management into a home or community land plan can be a huge aesthetic boon, turning the property into a visual asset for the community,” notes Chuck Ellison, past chair of the National Association of Home Builders Resiliency Working Group.

STORMWATER AND DESIGN: USC VILLAGE



The USC Village expansion project uses dry wells to capture 85 percent of rainwater runoff on its densely developed site. (USC/Harley Ellis Deveraux)

USC Village at the University of Southern California (USC) in Los Angeles is an ambitious campus expansion project, including a total of nine residential, retail, and academic buildings on a 15-acre site adjacent to the main campus.

The first phase includes six buildings comprising 2,600 beds of undergraduate housing, situated on a 130,000-square-foot retail podium including Trader Joe's, Target, Starbucks, and Bank of America. The first phase of the \$650 million project will open in fall 2017.

The project was USC's first development to respond to the city of Los Angeles's new LID requirements mandating that 85 percent of rainwater be captured on site. These requirements, along with others from CalGreen, the state's green building code, were critical to the project's design process and arrival at the stormwater solution: six 26,000-cubic-foot dry wells, each of which is roughly six feet in diameter and 55 to 60 feet deep. Each dry well captures water and sends it into the groundwater aquifer, with water first running through a filter, followed by a 20-foot manhole, and then through 35 to 40 feet of rock filtration. The system is unlike anything the university has built previously.

Director of capital construction development William Marsh explains that the design team initially considered

finding a way to recycle and reuse the captured water, but "it didn't pencil out from an economic point of view. When you look at all nine buildings and the amount of landscaping and plant material we would have needed, we just did not have enough groundcover."

The dry wells proved to be the best solution for the desired density, as well as the best option from a utility and cost perspective. According to Marsh, the dry wells ultimately had "a very low dollar impact on the project," given that the university was already laying the utilities for the site. However, Marsh notes that the approach would not have been appropriate for a constrained urban environment with existing infrastructure.

Ultimately, the dry wells became a critical part of the USC Village concept, including during the construction process, when the team set up temporary dry wells to manage construction runoff. "During the design, NOAA [National Oceanic and Atmospheric Administration] was predicting one of the largest El Niños to hit southern California in history," explains Marsh. "We were looking at dry wells and realizing that they might become really valuable to us sooner than we realized."

STORMWATER AND DESIGN: THE STANDARD

The Standard is a \$75 million condominium building developed by the Domain Companies in New Orleans's new South Market District. The five-block area sits at the intersection of the Central Business, Warehouse/Arts, Sports/Entertainment, and Medical districts. The Medical District is experiencing redevelopment with the creation of two top cutting-edge hospital facilities.

Domain Companies has an extensive development portfolio in New Orleans, but the Standard was the company's first project built after the city revised its Comprehensive Zoning Ordinance, which includes a stormwater retention requirement. According to Chris Papamichael, principal at Domain Companies, "This was the first project where we had these new guidelines in place . . . To find a cost-effective solution, we needed to think about it in the early stages of planning."

The development team decided to use an already planned amenity deck to manage the stormwater detention requirement, incorporating a blue roof designed to store water. Papamichael describes this approach as "an easy and cost-effective way to do it . . . Given the large amenity deck footprint that we had—about 30,000 square feet of a 45,000-square-foot site—we were able to use a good portion of the amenity deck as a detention area." The development team had used similar approaches for projects in New York City and had experience with the necessary technologies, which Papamichael estimated added \$200,000 to \$250,000 to the project cost.

For the Domain Companies, complying with the stormwater management requirements was ultimately a case of determining what worked best for its particular site and project. "Each site is different, and each building is different," explains Papamichael, noting that cost-effective approaches will vary widely for new construction versus redevelopment projects. However, in all cases, managing stormwater on site will ensure that the building and residents are less vulnerable to flash flooding, which is of particular concern in New Orleans.

Tyler Antrup, urban water program manager for the city of New Orleans, notes that integration of stormwater management best practice is taking off in the city but is "still somewhat experimental for us." However, the stormwater provisions in the zoning ordinance have led local and national firms to find creative ways to incorporate green infrastructure into real estate projects, thus increasing the capacity of the local construction industry and transforming water management into business as usual. "We are starting to finally see what we had hoped to see," says Antrup. "Designers are really thinking about stormwater management at the beginning of a project and designing their projects in a way that integrates stormwater [management] into the development."

A rendering of the Standard's amenity deck, which uses a blue roof to meet new city of New Orleans detention requirements. (Domain Companies)





This redesigned space at Symantec's Research and Development Complex in Chengdu, China, incorporates an extensive filtration garden while creating a functional outdoor space that connects the complex to the surrounding city. (© SWA by Tom Fox)

DESIGN SOLUTIONS

Landscape architects and designers thrive on finding ways to derive value and create inviting environments through green infrastructure, achieving stormwater management targets along the way. Laura Maret, a senior associate at landscape architects Sasaki, explains: "As stormwater regulations become more stringent in many of the cities where we work, we find that stormwater management is increasingly a driver of implementation for landscape projects. Clients often assume that incorporating best management practices will increase the cost of a project; however, often system-level stormwater approaches offer both environmental benefit and a better return on investment than conventional approaches."

Yet incorporation of stormwater controls could lead to an opportunity cost if potential amenities are lost to the requirement for green, permeable spaces. Cisterns may take up space once reserved for underground parking, or permeable green roof space may occupy what might have been a purely recreation-driven roof deck.

However, creative and resourceful design can address some of these concerns. Well-designed green infrastructure elements should create attractive green spaces and lower costs through savings in long-term operations and maintenance. For example, green roofs should absorb heat and lower energy costs and long-term roof maintenance costs, and bioswales and absorbent natural landscaping should both improve the aesthetics of a building and shift long-term landscape costs, potentially resulting in cost reductions. Zach Christo, a principal at Sasaki, describes the new stormwater policies as encouraging innovation and efficiency by "forcing designers to think about the dual

purposes of different surfaces. A sidewalk is no longer just a sidewalk for walking; it's also taking on a function for stormwater management."

Green Infrastructure Learning Curve

Although implementation of green infrastructure requires a learning curve for maintenance, the costs and amount of time required are generally lower than those for maintenance of gray infrastructure systems.

Gardeners and maintenance staff may need training to manage new types of landscaping, particularly given that it often requires more selective weeding and watering practices. For example, bioswale maintenance would entail weeding and landscaping, rather than parking lot sweeping, sediment removal, and grouting and sealing of concrete structures.

David Hollenberg, university architect for the University of Pennsylvania, explains that training for the management of the bioswales and meadows of Penn Park required a substantial learning curve for the campus maintenance crew. "These are landscape typologies that we had not had on the campus before," explains Hollenberg. "They are quite beautiful, but they initially were not in our management vocabulary."

Describing the New York City experience with stormwater management-focused green streets, Nette Compton notes that contractors managing the city's first green streets with a stormwater management component quickly recognized that the sites required reduced maintenance compared with other green streets.

Use of reclaimed water on site can also reduce long-term maintenance costs, as is done at the Residences at La Cantera, a residential project in San Antonio that incorporated a rainwater recycling system to water the development's signature central park.⁸

In short, after an initial investment in training, the cost and maintenance time required for green infrastructure systems is typically lower than that for traditional, turf-based landscapes that require frequent mowing.

Some developers indicated that incorporating green infrastructure is likely to become easier over time, because of the increased number of approaches likely to be developed and the potential for more widespread availability and greater affordability of materials, such as porous pavers and cisterns.⁹

CREATIVE PLACEMAKING AND WATER

Creative placemaking, an approach that engages art and culture in place-based design, can enhance the value of green infrastructure solutions. Artful approaches can not only address the practical issue of stormwater management, but also enhance aesthetics, which may lead to greater economic value. Creative placemaking for water can help establish a sense of place that is appealing and attractive, inviting people to engage with their surroundings, community, and environmental values.

When aligned with cultural landscape preferences, creative stormwater management features can serve the purposes of public relations, recreation, education, and social interaction as well as drainage and filtration. These elements, in turn, increase the success and longevity of the projects themselves.

Stuart Echols and Eliza Pennypacker, professors of landscape architecture at Pennsylvania State University, are proponents of artful rainwater design (ARD). ARD aims to prompt a shift in mindset: rather than viewing stormwater as a problem, designers, developers, and others think of it as an opportunity. Within this framework, rainwater is celebrated as a resource, and rainwater management is embraced as a chance to provide an aesthetic or artful experience.

Some of the main principles of ARD include daylighting (bringing out in the open rather than hiding) features such as basins, bioswales, and green roofs; integrating educational materials into the design; and using stormwater

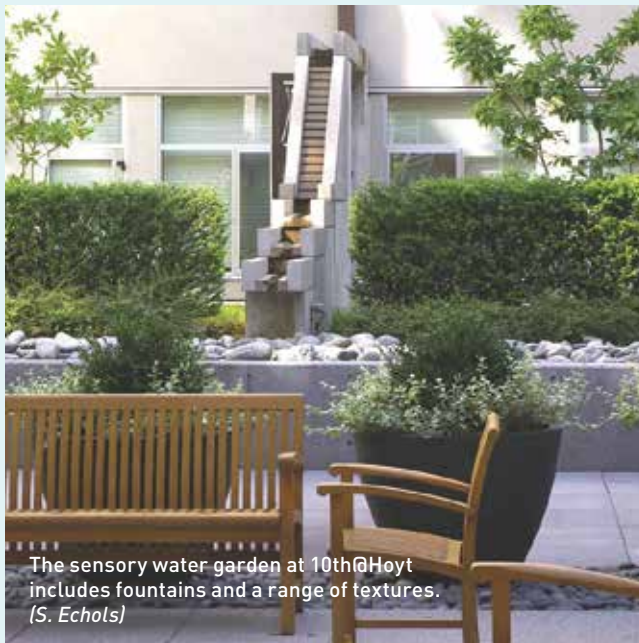
management as the basis of public relations, which generates interest and increases the likelihood of tenant retention.

A few examples bring ARD principles to light. At the High Point residential community in Seattle, Washington, developed by the Seattle Housing Authority, drainage, filtration, and transference occur throughout the site in creative ways, with markers that explain the function and importance of each element.

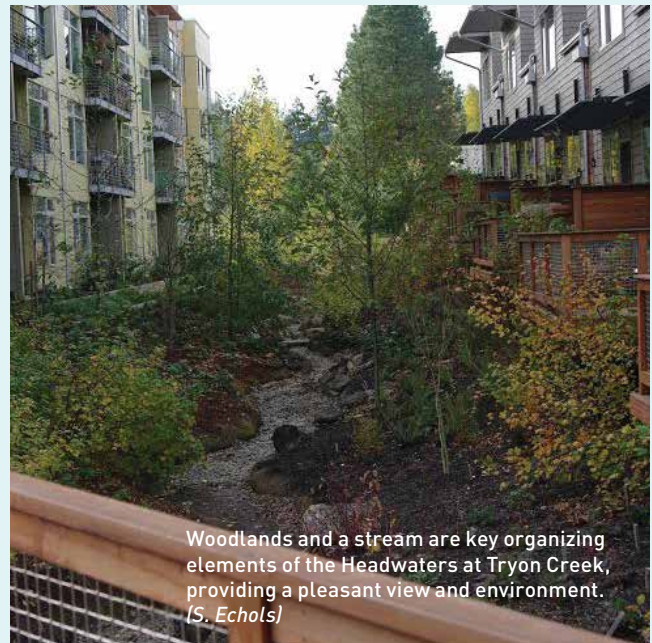
At 10th@Hoyt, an apartment complex developed by Prometheus Real Estate Group, located in Portland, Oregon, roof runoff is mitigated by transforming an interior courtyard into a sensory water garden. A carefully crafted rain-receiving system guides water from roof to garden and then is reused in playful fountains. Plantings offer texture, color, and filtration simultaneously. The developer of 10th@Hoyt made the courtyard into a selling point, turning the complex into a lucrative investment.

At Headwaters at Tryon Creek, a multifamily development in Portland, Oregon, a connecting stream both conveys rainwater and ties together various buildings within the same site, thus creating a sense of cohesiveness and community.

Creative and thoughtful designs increase well-being, facilitate communication, and provide a connection to place and community. Through close attention to aesthetics and creative placemaking, stormwater management becomes a conduit for much more than rain.



The sensory water garden at 10th@Hoyt includes fountains and a range of textures. (S. Echols)



Woodlands and a stream are key organizing elements of the Headwaters at Tryon Creek, providing a pleasant view and environment. (S. Echols)

Case Studies in Green Infrastructure

Real estate developers across the United States are increasingly incorporating green infrastructure into their projects, driven by stormwater regulations, marketing value, green rating systems, cost savings, or other reasons.

This chapter introduces a selection of real estate projects that have prioritized green infrastructure with successful development outcomes, such as the following:

- Increased developable land;
- Increased market value, sometimes described as a “sustainability premium”;
- Enhanced marketing opportunities;
- Placemaking opportunities, amenity value, and improved building user experience;
- A smooth permitting process;

- Avoided losses in peak weather events;
- Reduced operating and maintenance costs; and
- Decreased potable water use.

These projects comprise a variety of densities and uses, including mixed-use, urban developments; master-planned residential projects; commercial and office developments; parks and institutional projects; and affordable or mixed-income projects. All have used green infrastructure and stormwater management technologies with varying approaches, depending on the building types, locations, and climates.

Although the context and development conditions for these projects are diverse, many common themes and lessons learned have emerged. A key message is the value proposition: innovative approaches to stormwater management created value, improved building user experience, and differentiated the product from others in the local market.

GREEN STORMWATER INFRASTRUCTURE^a

Property	Bioretention swales	Detention basin	Efficient fixtures or irrigation	Filtration systems ^b	Green roofs	Monitoring system
Atlantic Wharf			•	•	•	
Burbank Water and Power EcoCampus		•		•	•	
Canal Park	•			•	•	
Encore!				•		
High Point	•					
Market at Colonnade	•	•	•	•		•
Meier & Frank Delivery Depot	•		•	•	•	•
Penn Park	•					•
Stonebrook Estates	•	•		•		
The Avenue				•	•	
The Rose			•	•		

^aSee Glossary on page 60 for definition of green stormwater infrastructure terms.

^bFiltration systems include biofiltration, filtration planters, automatic filtration systems, baffle boxes, and subsurface infiltration systems.



Native plants and trees	Natural drainage system	Permeable pavers	Rain gardens	Rainwater cistern	Retention pond or ice rink	Reuse systems	Stormwater vault	Tree boxes
•				•		•		
•		•				•		•
			•	•	•	•		•
•		•				•	•	
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Atlantic Wharf

QUICK FACTS

Location: Boston, Massachusetts

Project type: Mixed-use redevelopment

Status: Purchased in 2007, opened in 2011

Project cost: \$280 million

Site size: 2.1 acres

Development size: 27.5 acres

Development program: 16,000 square feet of indoor public space, 23,300-square-foot urban park, 776,000 square feet of office space, 25,000 square feet of ground-floor retail/restaurant space, 88 market-rate residential units

Developer: Boston Properties

Design team: Halvorson Design Partnership, CBT Architects

Water management features: Efficient fixtures, filtration system, green roofs, native plants or trees, rainwater cistern, reuse system

Atlantic Wharf's roof includes 18,000 square feet of rooftop gardens, formed of preplanted grids with native and adapted landscaping.

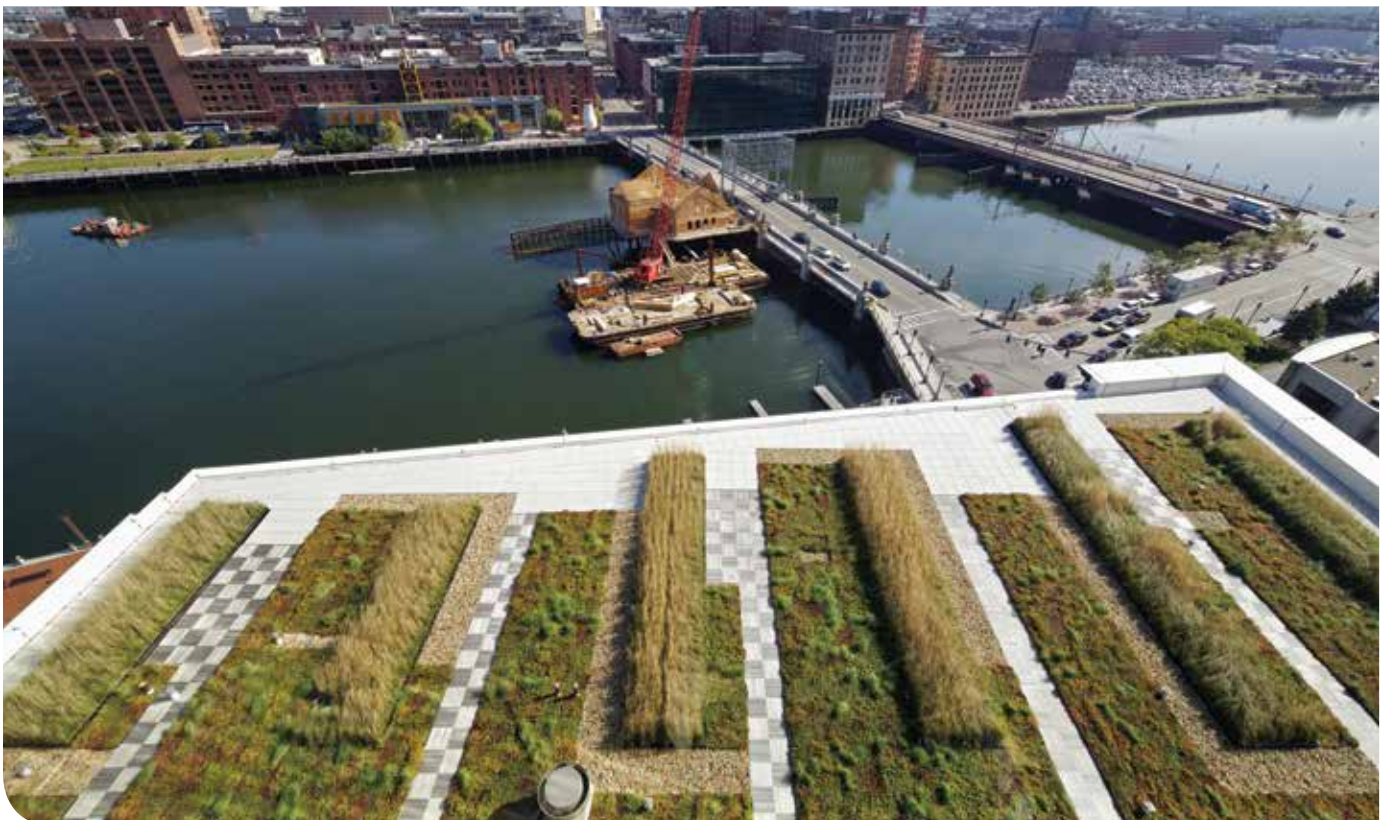
(© Ed Wonesek)

Atlantic Wharf is a 1.2 million-square-foot mixed-use redevelopment of the historic Russia Wharf in Boston's Waterfront District, adjacent to downtown. Developed by Boston Properties (BXP), Atlantic Wharf was 100 percent leased within the first year of opening, outperforming the local market for office, residential, and retail spaces. The development includes a mix of office, residential, retail, art, and public space and the restoration of three historic 19th-century facades.¹ Innovative stormwater management features helped it become known as Boston's first green skyscraper.

Context

In 2007, developer BXP used the nation's first green building standard, Article 37 of the Boston Municipal Zoning Code, to create Boston's first sustainable high rise, Atlantic Wharf, which opened in 2011.² Specifically, Article 37 incentivizes applicants with one Leadership in Energy and Environmental Design (LEED) credit if they submit calculations for groundwater area absorption and retention rates.³

Atlantic Wharf is situated between the historic Fort Point Channel, renowned for the Boston Tea Party; the downtown Financial District, home to Boston's financial centers; and the Rose Kennedy Greenway, a series of linear parks and gardens.^{4,5} The building's design preserves and integrates about 40 percent of the existing historic structures on the site and created 23,300 square feet of urban parks and plazas.⁶





Atlantic Wharf, Boston's first green skyscraper, renovated and integrated 42 percent of the existing historic structures, including streetscapes and facades. (Anton Grassl/Esto)

"We have been inspired by the mayor's vision to make Boston the greenest city in the country and our customers' commitment to a sustainable workplace," Bryan Koop of BXP said at the LEED plaque awards ceremony. "Atlantic Wharf is a model proving that development can be done with a conscious regard for the environment."⁷

Atlantic Wharf was certified as LEED Platinum shortly after its completion.⁸ BXP's commitment to sustainability and historic preservation has been recognized by a number of award programs: Atlantic Wharf was a 2012 finalist for the ULI Global Awards for Excellence, received the 2012 Brick in Architecture Award, and won the 2012 International Facility Management Association Large Project Award.⁹

Innovative Water Management Features

- **Rooftop garden.** An 18,000-square-foot garden of modular, preplanted grids with native and adapted landscaping allows stormwater filtration, permits easy repair and maintenance access to the roof, reduces the heat-island effect, and minimizes impact on the microclimate.¹⁰
- **Rainwater cistern.** Seventy-one drainage points and over a half mile of piping funnel stormwater from the roof to a 40,000-gallon-capacity storage tank.
- **Automatic filtration system.** Environmental pollutants in the stormwater are cleaned and collected from the rooftop rainwater harvesting system.
- **Rooftop cooling tower.** Filtered stormwater is used for irrigating the rooftop garden and for replacing water lost because of evaporation, leaks, or discharge in the cooling system.¹¹

- **Public parks and plazas.** Over 30 percent of the site area contains native and adapted planting, not only on the green roof, but also in the public Waterfront Plaza and promenade, where programming is provided throughout the year.
- **Water-efficient fixtures.** Low-flow plumbing fixtures, such as shower heads, sinks, and dual-flush toilets, are included in all units, and similar fixtures are required for all office tenants.¹²

Value Proposition

Atlantic Wharf's LEED Platinum certification level has translated into significant operational savings and increased market demand for its commercial and residential units. Within the first year of opening, Atlantic Wharf was 100 percent leased, outperforming the local market for office, residential, and retail spaces.¹³ By July 2012, residential rental rates were some of the highest in the city, averaging \$4.24 per square foot, and all four restaurants reported higher-than-forecast sales.¹⁴

Atlantic Wharf's resource- and water-efficient design has also led to cost and resource savings. Potable water use for irrigation has been reduced by more than 60 percent through native planting and rainwater harvesting systems on the rooftop and in the public spaces.¹⁵ The development's rooftop cooling tower, which uses rainwater, saves 15 percent in process water compared to conventional HVAC systems.¹⁶

LESSONS LEARNED

- **Innovative water and environmental features can aid in leasing high-density developments and provide marketing value.** Within its first year of opening, Atlantic Wharf was 100 percent leased and had some of the highest residential rents in the city.
- **Historic preservation can be achieved while realizing gains in water efficiency.** Atlantic Wharf, Boston's first green skyscraper, renovated and integrated 42 percent of the existing historic structures, including streetscapes and facades. The innovative water management system decreased potable water use for on-site irrigation by over 60 percent and saved 15 percent in process water in its cooling systems.
- **Public space is an asset for filtering stormwater runoff and increasing the marketability of a site.** At Atlantic Wharf, 23,300 square feet of urban parks and plazas absorb and filter stormwater between the modern Financial District and the historic Fort Point Channel.

Burbank Water and Power EcoCampus

QUICK FACTS

Location: Burbank, California

Project type: Community-owned public utility site

Status: Completed

Site size: 3.2 acres

Developer: City of Burbank (community owned)

Designers: ADBE Landscape Architects, Tyler Gonzalez Architects, Leo A Daly Civil Engineering, Fuscoe Engineering

Water management features: Detention basin, filtration system, green roof, native plants or trees, permeable pavers, reuse system, tree boxes

A community-owned public utility site, the Magnolia Power Project at Burbank Water and Power (BWP) EcoCampus is the first power plant in the world to operate on 100 percent recycled water. The surrounding landscaping of the 3.2-acre campus, designed by ADBE Landscape Architects, incorporates a wide range of green infrastructure techniques that retain and manage stormwater, filtering it through a treatment system that recycles the water to assist in efficient, cost-effective electricity generation for the municipality. At a time of drought in California, BWP's leadership in water management has set an example and shown that sustainable design can thrive in an urban industrial context.

Context

Burbank Water and Power has served Burbank for more than 100 years. In the late 1990s, facilities were aging, increasing maintenance costs and resulting in inefficiencies and higher utility rates for residents and businesses. In fact, rates in 2000 were near the top in the region as compared to other municipal-owned utilities.¹⁷ The site was also more than 79 percent impervious surfaces and the high temperatures and low precipitation meant that few plants could survive on site.¹⁸

The campus invested in a major redesign in 2000 to modernize to an efficient utility operation incorporating green infrastructure to achieve goals of lower operating costs and keep rate increases under the rate of inflation while creating

The SITES-certified courtyard is a space for community building among employees and has served as a recruiting tool. *(Helio-135)*



“[BWP] realized that new generations were in tune with the environment and that the younger generation wanted to work for an organization that had values similar to theirs.”

JOE FLORES, MARKETING AND PUBLIC INFORMATION OFFICER, BURBANK WATER AND POWER



An aerial view of Burbank Water and Power shows the dynamic campus, which includes green roofs, solar panels, and an interior courtyard. *(Helio-135)*

a competitive employment advantage. Today, BWP boasts some of the lowest rates for utilities in southern California. The utility also sees the campus redevelopment project as enhancing its brand, improving its recruitment capabilities, particularly given the utility's high visibility on an urban site.

The campus redesign responded to the new city development codes, including on-site mitigation requirements, requiring projects to retain 0.75 inches during a 24-hour rain event. The 15-year project adjusted its design based on the industry's understanding of sustainability to maintain efficient operations.

Innovative Water Management Features

Today's BWP's EcoCampus ecologically manages stormwater, uses solar power, reduces urban heat-island effects, and reuses materials throughout the campus. In total, the campus uses five different water filtration technologies: detention, rainwater capture, infiltration, flow-through cells, and tree root cells.¹⁹

Key aspects of the campus landscape redesign included primary landscaping, a green street implemented in 2010, and an employee courtyard that repurposes old industrial structures from a decommissioned electrical substation. Campus facilities include three LEED Platinum buildings topped with white and green roofs. Water management features within the EcoCampus include the following:

- **Recycled water treatment system.** The Magnolia Power Project's recycled water treatment system eliminates use of more than 1 million gallons a day for cooling towers and steam turbine generation with no discharge into the Pacific Ocean.
- **Green street.** Lake Street was initially a green street demonstration project, serving as an educational tool about sustainable design and demonstrating how green infrastructure can be artfully incorporated. The street includes permeable pavers and filtration planters.

Value Proposition

The key success factor for BWP was the improved operations, which led to more affordable utility rates for the citizens of Burbank, who are customer-owners of the utility. Burbank's investment in green infrastructure has also led to net-zero stormwater runoff from the campus and 100 percent recycled water use for all landscaping, reducing piped water use by as much as 100,000 gallons per day. Green roofs, which absorb up to 70 percent of rainwater, help the facility save an estimated \$14,000 per year.

Burbank's leadership has linked improved morale and recruiting to the campus enhancements. Previously, the campus lacked green space and spaces for employees to gather and exchange ideas. The improved campus has contributed to success in recruiting a younger generation of talent and generated substantial publicity for the utility, including numerous awards, certification by the Sustainable Sites Initiative, and regular visits from the global business community.

LESSONS LEARNED

- **Investment in a green facility positively affected the bottom line and prices for consumers.** Burbank's investment in using recycled water and sustainable design measures has been incorporated into operational efficiencies that contribute to the bottom line and ultimately to some of the lowest utility rates in southern California.
- **Green design can contribute to corporate identity, branding, and talent retention.** BWP has attributed recent recruiting and talent attraction to the brand recognition that in part has come from the green campus.
- **Green infrastructure can be effectively incorporated into a tightly constrained urban site.** The project sought to not only educate the public on green infrastructure, but also show what could be possible in both an urban and industrial context, preserving industrial structures within the campus.
- **BWP's leadership in green design and water management has helped the city at a time of water scarcity.** Burbank met the "billion-gallon challenge" for water savings ahead of schedule after Governor Jerry Brown's call for water conservation in the face of the state's drought crisis.²⁰ BWP's example has been part of this city and statewide focus on water conservation and stewardship.

Canal Park

QUICK FACTS

Location: Washington, D.C.

Project type: Park, adjacent to office and residential development sites

Status: Completed in 2012

Project cost: \$20 million

Site size: 3 acres

Developer: WC Smith

Designers: OLIN, Studios Architecture, Vika Capitol, Nitsch Engineering, SK&A Structural Engineering, Atelier Ten, Joseph Loring & Associates

Water management features: Bioretention swales, filtration system, green roof, rain gardens, rainwater cistern, ice rink, reuse system, tree boxes

Located along a portion of Washington, D.C.'s historic canal system, Canal Park uses innovative water management practices and has been a catalyst for the broader revitalization of the bustling Navy Yard neighborhood. A stormwater system including cisterns, rain gardens, and bioretention tree pits captures, treats, and reuses water for up to 95 percent of the park's needs, including irrigation, splash park-style fountains, and an ice rink. The park has become a key focal point of activity in the city, hosting regular events and seasonal festivities.

Context

Developer and property manager WC Smith led the creation of the park as a component of the District of Columbia's Anacostia Waterfront Initiative, which sought to reinvigorate the neighborhood and improve water quality in the Anacostia watershed. Today, WC Smith retains interest in the park and anticipates that the park will mitigate stormwater for the development of an adjacent multi-family property to be developed by the company.

Canal Park's origins date to 1999, when WC Smith was acquiring properties in the neighborhood. At the time, the paved site was a parking lot for school buses, but it was once part of the Washington City Canal System that connected the Potomac and Anacostia rivers and ran through the National Mall.²¹ The park proposal later became a key part of the Anacostia Waterfront Initiative and a demonstration project for the District's Department of Energy & Environment.

A view from WC Smith's office building shows Canal Park (on the lower diagonal) and the adjacent parking lot, which will also be developed by WC Smith. (© Olin/Karl-Rainer Blumenthal)



“Canal Park is a popular meeting spot for residents, workers, and visitors. The project would not have been successful without the partnerships with private developers, the city and federal governments, and the Capitol Riverfront BID.” | BRAD FENNELL, SENIOR VICE PRESIDENT OF DEVELOPMENT, WC SMITH



In winter months, rainwater collected in underground cisterns is used to replenish the park's ice-skating rink. (© OLIN/Sahar Coston-Hardy)

To pursue a public/private partnership for the park construction, WC Smith formed the Canal Park Development Association (CPDA) in 2000, which ultimately secured the site from the city and led the development process. A design competition led by CPDA, along with the Anacostia Waterfront Corporation and the District's deputy mayor for planning and economic development, chose OLIN as the design team to advance the project.²²

Given the site's history and the ongoing water quality concerns with the Anacostia River (partially because of combined sewer overflow), water management was a top priority in the design competition. "The park naturally became a focal point of sustainability and a regional stormwater facility," explains Brad Fennell, senior vice president of development at WC Smith. The potential for the site as a community and social hub also evolved as a number of catalytic developments occurred in the area, including the Washington Nationals ballpark, the U.S. Department of Transportation headquarters, and the redevelopment of an adjacent public housing site.

Today, WC Smith maintains connections to the park, while the local business improvement district (BID), Capitol Riverfront, manages day-to-day maintenance and programming. WC Smith has continued development momentum around the park and anticipates using the water management capabilities of the park to adhere to the District's on-site water retention requirements for the development of an adjacent parcel. "We are really excited for the next ten years, when you will see more buildings fronting on the park and the development of new retail in the area," says Fennell.

Innovative Water Management Features

- **Stormwater collection and reuse system.** Stormwater that falls on site is collected and treated through a bioretention, ultraviolet disinfection, and filtration system that removes 100 percent of biological pollutants and reduces total

suspended solids.²³ Collected stormwater then meets up to 95 percent of the park's needs for irrigation, its ice rink, and its fountain, saving an estimated 1.5 million gallons per year.

- **Rain gardens and bioretention tree pits.** Rain gardens run along the eastern edge of the park, and captured rain is subsequently filtered and reused. Forty-six bioretention tree pits also filter out contaminants.²⁴
- **Cisterns.** Two underground cisterns hold 80,000 gallons of water, in addition to the roughly 8,500 gallons that the rain gardens can hold.
- **Ice rink and water features.** The ice rink and 42-jet fountain splash park are among the most popular aspects of the park—and their water needs are met entirely by stormwater.

Value Proposition

Canal Park has greatly contributed to the revival of the Capitol Riverfront neighborhood. Perceptions of the neighborhood have changed with this revitalization; for example, a survey by the BID found that 90 percent of local residents considered the area "clean and safe" in 2015, compared with 30 percent in 2009. For WC Smith, the investment in Canal Park has enhanced the value of adjacent properties, which now overlook a valuable and vibrant public amenity. The park's ability to manage stormwater for a future adjacent development has been an added bonus.

LESSONS LEARNED

- **Public/private partnerships can be excellent vehicles for delivering innovation in stormwater management.** The Anacostia Waterfront Initiative provided the initial vision for the area's revitalization, and Canal Park came to fruition through a public/private partnership with funds from tax increment financing and New Markets Tax Credits. Today, the Capitol Riverfront BID manages a robust program of activities that draw people to the park from both the neighborhood and the city at large. Fennell describes the BID's work as contributing to the "energy that helps make the park a special place."
- **Water management can inspire community engagement and local conservation.** "The whole concept of environmental conservation in the park is what has captured people who live around here," explains Janet Weston, the park manager at WC Smith. The design and development team proactively developed educational signage about the park's stormwater management functions and has worked with the BID to get the message out to a wider audience.

Encore!

QUICK FACTS

Location: Tampa, Florida

Project type: Mixed-use, mixed-income, master-planned community

Status: Underway

Project cost: \$425 million

Site size: 28 acres with a planned total of 180,000 square feet of office space, 300-plus hotel rooms, 1,500-plus residential units, and 50,000 square feet of retail space; 662 units in four buildings and the stormwater infrastructure at the Technology Park have been built to date

Developer: Public/private partnership between the Tampa Housing Authority and Bank of America Community Development Corporation

Designers: Baker Barrios Architect, Cardno TBE

Water management features: Filtration systems, native plants or trees, permeable pavers, reuse system, stormwater vault

Topped with solar panels and green space, the vault is the centerpiece of Technology Park. *(Tampa Housing Authority)*

Encore! is a mixed-use, mixed-income development including multifamily housing, senior housing, retail, and office space on the site of a previously isolated public housing development. Developed through a public/private partnership between Bank of America Community Development Corporation and the Tampa Housing Authority, Encore! incorporates advanced stormwater management as part of its efforts to achieve Leadership in Energy and Environmental Design for Neighborhood Development (LEED ND) certification. Water management has been a key component of the development strategy, with early infrastructural investments including an 18,000-square-foot water retention vault.

Context

Situated between Old Tampa Bay and Hillsborough Bay, Tampa is surrounded by water, which ultimately flows into Tampa Bay and the Gulf of Mexico. Although Tampa does not have combined sewers or the requirements of a federal consent decree, stormwater management is a priority given the city's frequent flooding and low elevation of three or four feet above sea level.²⁵

Encore! sought to protect residents from flooding through the incorporation of district-scale water management that would capture all stormwater on site. "When you control runoff and cut down on erosion problems, . . . you don't have that fear of standing water and flooding," explains Leroy Moore, the Tampa Housing Authority



"We decided to put our dollars into infrastructure that would allow us to go vertical on our buildings when the market turned back." | LEROY MOORE, SENIOR VICE PRESIDENT AND CHIEF OPERATING OFFICER, TAMPA HOUSING AUTHORITY



Encore! is a mixed-use, mixed-income development in Tampa's Central Avenue business district. (Tampa Housing Authority)

senior vice president and chief operating officer. "It keeps the site safe, clean, and healthy."

The centerpiece of the water management system is a water-retention vault that accommodates 33,000 cubic feet of water. The chamber is roughly 12 feet below ground, with a three-foot rock layer below the chambers. "It is the slickest, coolest feature that we've done from a sustainability perspective. . . . It is one of the most unique stormwater management systems in the state on account of its size," explains Marc Mariano, then assistant director of site development for Cardno TBE. All surface stormwater is collected from the site in the vault and then treated through a system of nutrient-separating baffle boxes and sediment chambers that capture pollutants. Water is then stored for irrigation use. When the vault is at capacity, stormwater runoff is filtered through sand before reaching Tampa Bay. Over several years, water has yet to leave the site or be piped in for irrigation.

The project also reduces stormwater runoff through permeable pavers, native plants, and other elements. Land above the water-retention vault has been transformed into Technology Park, a passive educational park that serves to explain Encore!'s green building practices to area residents.

Innovative Water Management Features

- **Stormwater vault and baffle boxes.** The 18,000-square-foot stormwater vault is structured with five-foot individual cubes that together hold up to 33,000 cubic feet of stormwater. Stormwater then flows through two baffle boxes for pretreatment before being used for landscaping irrigation.
- **Permeable pavers and native plants.** Encore! manages stormwater in an urban setting by using permeable pavers and native plants that are not irrigation intensive. Pavers on the hardscapes and the median of the central street through Encore! contribute to stormwater management and create visibility for the stormwater system. The landscape palette is estimated to reduce water needs for landscaping by 50 percent.
- **Park with educational signage.** Technology Park, a 16,000-square-foot park located above the stormwater vault, features

educational kiosks, solar public art, and the district chiller. Visitors often watch the fluctuation of water in and out. "Once you draw people to the vault, you can educate them about it and the many sustainability features built into Encore!," explains Moore.

Value Proposition

The investment in cutting-edge stormwater management features allowed Encore! to maximize the developable land on the site. A traditional retention pond and water collection system would have required six acres: the net gain of developable land from having used a half-acre vault is three city blocks, or about a quarter of the full site. Moore explains, "We were motivated by not having to consume a lot of that land with surface retention." Investing in stormwater technologies allowed Encore! to be "a more valuable project and an urban scale," according to Moore.

Encore! also benefited greatly from federal government funding available at the time of development. As Moore explains, "The recession hit and everything was put on hold, but we had the most shovel-ready site in the country." The development team initially committed to district-scale green and stormwater infrastructure when it planned to use tax increment financing. However, instead of using that approach, the development team leveraged a \$28 million stimulus grant to complete the site's district-scale infrastructure.

Today, the Tampa Housing Authority is investigating district-scale infrastructure opportunities for another public/private redevelopment, the \$2 billion Tampa Live project.

LESSONS LEARNED

- **District-scale stormwater management can free up developable land and create a more urban development product.** Using a stormwater vault rather than a retention pond not only ensured that the maximum portion of the site was available for development, but also fostered the creation of a better-connected street network.
- **District-scale sustainable utilities were a part of the marketing draw for the site.** The market-rate units at Encore! were leased up before the affordable units, which the development team attributes to the location, competitive pricing, and branding. "All of our indications show that market-rate residents want to live in sustainable communities," explains Moore.
- **Stormwater infrastructure provides an opportunity to educate and inspire.** Stormwater infrastructure is celebrated in the park topping the stormwater vault.

High Point

QUICK FACTS

Location: Seattle, Washington

Project type: Mixed-income housing; redevelopment

Status: Opened 2004, planned completion 2018

Project cost: \$550 million

Site size: 129 acres

Development size: 80 acres

Development program: 1,529 units (798 market rate, 731 affordable) for sale and rent for seniors, low-income and very low-income households

Developer: Seattle Housing Authority

Design team: Mithun, SvR Design Company, Nakano Associates

Water management features: Bioretention swales, native plants or trees, natural drainage system, permeable pavers, rain gardens, retention pond

Four miles of bioretention swales, like this one on 30th Avenue SW, improve water quality and protect wildlife at High Point, which was formerly 65 percent impervious. (MIG | SvR)

High Point creates a vibrant mixed-income community of 1,529 market-rate and affordable homes on a former public housing complex once marked by crime and unemployment. A HOPE VI redevelopment, High Point is noted for being the first dense urban development in the nation to achieve sustainable, low-impact design at a large scale.²⁶ On a site that was formerly 65 percent impervious, High Point's natural drainage system infiltrates 75 to 80 percent of stormwater runoff.²⁷

Context

High Point has been cited as “a new model of cooperation” between residents, private developers, and government agencies to create a more sustainable and inclusive community for one of Seattle's most demographically diverse neighborhoods.²⁸ This innovative partnership between the Seattle Housing Authority; the departments of Planning, Development, and Transportation; and Seattle Public Utilities was formed to improve water quality for residents of this mixed-income community while protecting the endangered salmon run downstream in Longfellow Creek—one of the last four runs remaining in the city.²⁹

To accommodate this cross-sector partnership, in 2003, Seattle passed a special ordinance to permit low-impact-development features throughout the redevelopment of High Point, which would expand to include 1,529 units, 48 percent



“There was a magical match between people who embraced the ideals and virtues of green living and those who desired to live in a community that looked like America—not segregated, not one color, but a real mix of peoples, cultures, backgrounds, income levels, and so on. That was one of the drivers of pushing, from a marketing perspective, for a green, sustainable community. We saw that those buyers had more than one reason to take note of this new community.” | GEORGE NÉMETH, SENIOR HOUSING DEVELOPER,

SEATTLE HOUSING AUTHORITY



Located on the site of a former public housing complex once marked by crime and unemployment, High Point includes more than 1,500 homes, of which 48 percent are affordable for low-income families. (© Juan Hernandez for Mithun)

of which were affordable to low-income families to buy or rent.³⁰ To balance concerns for neighborhood green space, pedestrian safety, and water quality, the entire street grid was raised and replaced by a natural drainage system that uses a new street network including pedestrian circulation, bioswales, a storm-water pond, porous streets and sidewalks, and multifunctional open spaces to create a positive net impact on the environment.³¹

Innovative Water Management Features

- **Pedestrian-friendly streets.** Narrowed streets, shortened blocks, strategic alley connections, porches, hidden parking lots, landscaped sidewalks, new utilities, mature and newly planted street trees, and walking groups highlight the aesthetics of stormwater features and promote physical activity.
- **Integrated stormwater management system.** High Point was the first community in the state to feature permeable pavements in residential streets, sidewalks, parking lots, sidewalks, and basketball courts. A quarter-mile walking trail and gathering space was constructed around a 22-acre-foot retention pond and connected by four miles of grass and vegetated bioswales to naturally manage stormwater, improve water quality, and protect the wildlife habitat on site and nearby.
- **Sustainable landscaping.** Organic landscaping methods were introduced on more than 20 acres of open space, including front and back yards, gardens, and pocket and neighborhood parks. Over 100 mature trees have been saved at High Point, valued at more than \$1.5 million. Approximately 3,000 trees were planted in High Point as part of the site's redevelopment.
- **Green building standards.** Public and private developers were held to Built Green standards, a construction checklist

and rating system verified by the local Master Builders Association, which included the use of recycled or reused building materials, topsoil, and pavement in the construction of housing and trenches. At a small incremental cost, energy-efficient appliances, windows, doors, and insulation were installed in all units. High Point features 60 Breathe Easy Homes®, independently verified units structurally enhanced to improve interior air quality for residents suffering from asthma.

Value Proposition

After integrating innovative stormwater features, High Point's public and private developers achieved faster-than-anticipated sales and lease-up rates. Market-rate home and land sale proceeds have added revenue back to the city for neighborhood improvements through property taxes and to the Seattle Housing Authority for the construction of low-income housing through a profit-sharing model with private developers.

High Point's success in improving the physical, mental, and environmental health of its residents has been reported by several National Institutes of Health studies and served as the model for green building standards in future developments at the Seattle Housing Authority.³² The community's commitment to sustainable design and community development for residents of all incomes has garnered numerous awards and documentaries, including a 2007 ULI Global Award for Excellence.

LESSONS LEARNED

- **Large-scale affordable and market-rate housing developments can integrate a high-quality, low-impact design.** High Point achieved faster-than-anticipated sales and lease-up rates for over 1,500 mixed-income homes while developing a natural drainage system that infiltrates 75 to 80 percent of stormwater runoff.
- **Street grids can manage stormwater runoff while creating a safer pedestrian environment.** High Point created an entirely new street grid lined by four miles of vegetated bioswales, more than 2,000 new trees, porous sidewalks, a quarter-mile recreational trail, and multiple traffic-calming measures, supported by walking groups.
- **Endangered species can be protected from contaminants through stormwater management.** On a site that was formerly 65 percent impervious, High Point contributed to the protection of one of the last four salmon runs in Seattle, Longfellow Creek.

Market at Colonnade

QUICK FACTS

Location: Raleigh, North Carolina

Project type: Retail

Status: Completed

Project cost: \$16.5 million, including about \$727,000 toward stormwater management

Site size: 6.25 acres

Development program: 57,000 square feet of commercial space, including a Whole Foods Market

Developer: Regency Centers

Designers: CMH Architects Inc., Kimley-Horn & Associates Inc., Soil & Environmental Consultants PA

Water management features: Bioretention swales, detention basin, efficient irrigation system, filtration systems, monitoring system, rainwater cistern, reuse system

The above-ground cistern, next to tenant Whole Foods Market, benefits the development as a marketing tool in addition to collecting rainwater. (© Regency Centers)

An infill retail project developed by Regency Centers, the Market at Colonnade uses water management and reuse technologies on a largely impervious site in North Carolina's Research Triangle area. The development's innovative stormwater management approach was a key part of achieving a rezoning for commercial development and became part of the project's branding, as tenant Whole Foods Market embraced an above-ground cistern.

Context

The Colonnade site is located adjacent to the Falls Lake watershed, which is largely restricted from commercial development. The site required rezoning from office and institutional to commercial use, and stormwater runoff and water quality were key concerns for community members. "What led us down this path was the zoning and the desire for community support and support from the elected officials," explains Chris Widmayer, vice president of investments for Regency Centers. The small site also did not have space to accommodate a traditional stormwater management device such as a surface stormwater pond or wetland and still achieve the development objectives.

The engineering solution was a rain chain, linking a number of stormwater management practices to capture, detain, treat, infiltrate, and reuse stormwater. The approach reduced runoff from the predevelopment condition by roughly 98 percent. "The holy grail of stormwater is that a drop of rain infiltrates the



"This shopping center has less stormwater runoff than my house—and, actually, a lot less. Almost all of it gets captured by the system on site. Not only do you have the volume captured, but also the associated pollutants that have a negative impact on our drinking water." | CHRIS WIDMAYER, VICE PRESIDENT OF INVESTMENTS, REGENCY CENTERS

ground generally where it falls . . . and recharges the aquifer there. That was the ultimate goal,” explains Widmayer. The team sought to capture all runoff from a one-inch rain event and infiltrate it into the underlying soils and detain runoff from both two-year and ten-year design storms. By infiltrating the “first-flush” runoff, the stormwater system exceeds water quality requirements. The system was also designed to reuse harvested rooftop rainwater for both landscape irrigation and indoor use in the toilet system.

Regency Centers used a North Carolina Clean Water Management Trust Fund grant for the project’s green infrastructure features. This grant contributed toward the cost of the stormwater components of the project, which totaled roughly \$727,000.

Innovative Water Management Features

- **Cisterns.** Three rainwater-harvesting cisterns—one above ground and two subsurface—can collect up to 43,000 gallons of stormwater runoff. Water from the above-ground cistern is reused within Whole Foods Market for toilet flushing, while water from the below-ground cisterns is used for landscaping.
- **Subsurface infiltration system.** The subsurface infiltration system includes 2,500 linear feet of gravel and pipe trench, typically four feet wide and 3.5 feet deep. The system allows approximately 15,000 cubic feet of temporary storage, permitting infiltration into the underlying sandy loam soils.
- **Bioswales and bioretention space.** A 250-square-foot grass-lined bioretention area and 450 feet of bioswale capture and treat runoff from the shopping center’s parking lot and further promote infiltration.
- **Landscape irrigation system.** The landscape irrigation system uses harvested water from the underground cisterns to irrigate turf and landscaped areas on the site, as well as provides for additional infiltration and groundwater recharge within the remaining wooded area on site.
- **Underground detention chamber.** An additional 350,000 gallons of rainwater can be temporarily stored in the 48,100-cubic-foot underground detention chamber.

Value Proposition

Although proud of the environmental accomplishments of the site, the development team also describes its investment in stormwater technology as a savvy means of achieving the land’s highest and best use. Mark Peternell, Regency Centers vice president for sustainability, explains that “by avoiding the need for an above-ground pond, we had the buildable space we needed to construct a profitable retail center.” Widmayer also emphasizes

that the approach works “to enhance development rights and provide density with much cleaner outcomes and cleaner water.”

The Regency Centers team credits its environmental consultants for developing a sophisticated and innovative response to the needs of the constrained site. The team has since received detailed information on how the stormwater management mechanisms have functioned from North Carolina State University researchers, who monitored the site 12 months after its installation and compared its performance to that of sites with similar development conditions. The researchers found that the system took in approximately 130 percent more stormwater than a traditional system, with less than 5 percent of water flowing out, compared to a traditional system. Monitoring results indicated that in the first year a total of 30.6 inches of rainfall was measured on the site, of which only 0.6 inches was released from the site, the difference being infiltrated or reused on site.

LESSONS LEARNED

- **Visible green infrastructure can be a marketing boon for a sustainability-minded tenant.** Whole Foods chose to feature the above-ground cistern next to its entrance. The cistern became a memorable symbol of the retailer’s values and commitment to sustainability.
- **Stormwater can be harvested and managed even on highly impervious sites.** Although the site was 80 percent impervious after development, the stormwater management system captures the one-inch rainfall without discharge and can detain up to a ten-year design storm. Researchers from North Carolina State found that the site greatly outperforms nearby sites with higher percentages of permeable surface.
- **Green infrastructure can save space and free up developable land, particularly in comparison to a retention pond alternative.** Green infrastructure made retail development feasible on this 6.25-acre site, which could not have accommodated a traditional wet detention pond, the retail facilities, and parking.
- **Water management mechanisms can be an effective part of a real estate project’s community engagement strategy, particularly in environmentally sensitive areas.** The need for rezoning initially inspired the development team to take an innovative approach to stormwater management. Using stormwater technologies allowed the site to meet environmental requirements and achieve support from the surrounding community.

Meier & Frank Delivery Depot

QUICK FACTS

Location: Portland, Oregon

Project type: Commercial office building

Status: Completed; LEED Platinum certified

Project cost: \$66 million

Site size: 200-by-200-foot city block

Developer: Gerding Edlen

Designer/construction team: GBD Architects, Skanska, Ankrom Moisan Architects, Howard S. Wright Construction, Glumac Engineers

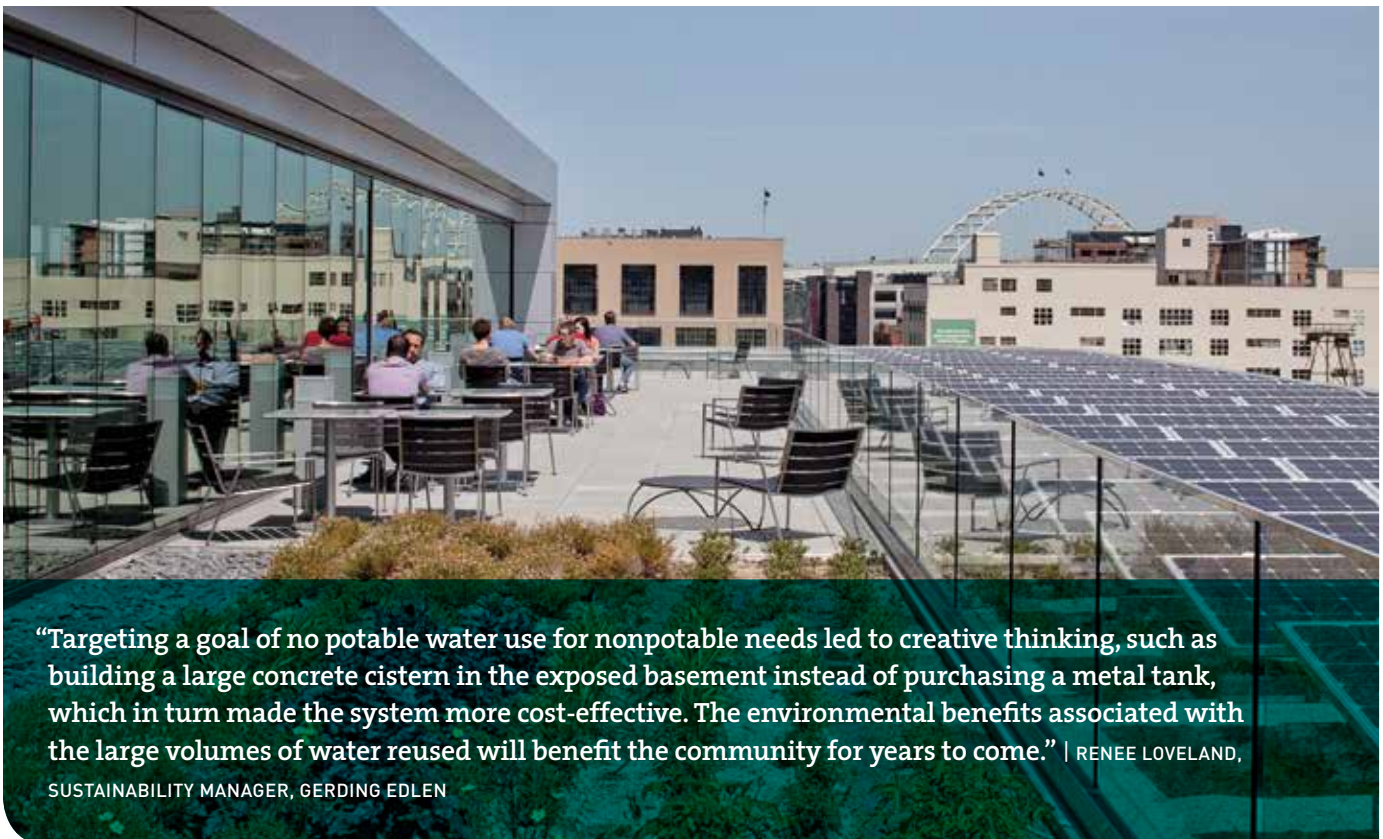
Water management features: Bioretention swales, efficient fixtures, filtration systems, green roof, monitoring system, rainwater cistern, reuse system

On the National Register of Historic Places, the Meier & Frank Delivery Depot now houses the North American headquarters of Vestas, a global energy company specializing in wind power, as well as Gerding Edlen's headquarters and tech firm Urban Airship. Redeveloped to showcase energy and water efficiency, the building has a very robust stormwater management system. Water is collected from the green roof and captured in a 169,000-gallon concrete cistern, which saves an estimated 193,000 gallons³³ of water per year and provides 100 percent of the water needed for irrigation, cooling tower makeup, and toilet flushing.³⁴ Filtration planters and bioswales surround the perimeter of the building and filter runoff directly into the ground.

Context

The combined sewer system in Portland strains the area's watersheds, forcing the city to invest in pipe expansion projects in hopes of protecting its rivers for salmon and other sensitive local species.³⁵ Renee Loveland, the sustainability manager at Gerding Edlen, explains that "dealing with stormwater has always been a sensitive issue and a priority for the city." Redevelopment of the historic Meier & Frank depot was an opportunity for the redevelopment team and the building's tenants to promote green infrastructure and endorse best practices in stormwater

The green roof adds aesthetic value to the outdoor terrace and collects stormwater that is eventually reused throughout the building. *(Photography by Jeremy Bittermann)*



"Targeting a goal of no potable water use for nonpotable needs led to creative thinking, such as building a large concrete cistern in the exposed basement instead of purchasing a metal tank, which in turn made the system more cost-effective. The environmental benefits associated with the large volumes of water reused will benefit the community for years to come." | RENEE LOVELAND,

SUSTAINABILITY MANAGER, GERDING EDLEN

management. Construction was completed in 2012, resulting in an extremely high-functioning building and LEED Platinum certification.³⁶ Although going above LEED Gold standards cost roughly 2 percent of the total construction budget, incentives related to energy and water efficiency, which accrued to the project, resulted in a payback period of only seven and a half years.

Located in the Pearl District of downtown Portland, today's Meier & Frank depot is a beautiful blend of historic preservation and innovative stormwater management technologies. A top priority was maintaining the integrity of the building's 1928 facade through the retrofit process. To that end, double-paned, energy-efficient replicas of the old single-paned historic windows were commissioned from a local glazing fabricator, and the original penthouse addition on level five was scaled back to comply with historic sightline requirements.

Vestas, a renewable energy system producer, manages and occupies most of the building, which is home to its North American headquarters.

Innovative Water Management Features

- **Concrete cistern.** The 169,000-gallon cistern collects water from the green roof for reuse both outside and within the building. A new floor had to be poured at grade after interior demolition was complete, so using the space below to install a basic concrete cistern was a cost-effective and practical strategy.
- **Real-time monitoring.** Vestas installed extensive submetering to track equipment performance and follow the building's consumption patterns. The monitoring system allowed the company to identify at least one contractor error early on, resulting in significant avoided losses compared to identifying the problem from a spike in utility bills.
- **Bioswales and urban landscaping.** The building comprises a full 200-by-200-foot city block and is surrounded by bioswales on all four sides. These were partially funded by a Green Investment Fund operating through the local Bureau of Environmental Services.

Value Proposition

Gerding Edlen asserts that investment in green infrastructure and the building's energy-efficient design have added value to the Meier & Frank depot and introduced opportunities for operational cost savings. The real-time monitoring has helped track energy and water consumption patterns for the building, keeping extra costs associated with high resource use to a minimum. Reusing captured water for three major nonpotable uses also lowers operational costs.

The redevelopment of the Meier & Frank depot and the arrival of Vestas also represented a value proposition for Portland. The city sought to attract the tenant and was partially successful because of its offer of the historic Meier & Frank depot as a headquarters building. After making the decision to open its North American headquarters in Portland, Vestas was heavily involved in the redevelopment process, taking a more hands-on role than a typical commercial tenant.

LESSONS LEARNED

- **Innovative water management and recycling techniques can be achieved in the context of a historic building.** The Meier & Frank Delivery Depot maintains its historic facade and charm while incorporating innovative water management technologies, some of which are invisible to passers-by.
- **Stormwater management can be part of a holistic workplace health philosophy.** According to Loveland, Vestas "took a European approach to healthy workplaces, which is becoming more and more the type of design approach for highly sustainable buildings in this market." Along with water management, healthy workplace practices include prioritizing natural light; incorporating visible, enticing staircases; and providing employees with direct views of the outdoors.
- **Water reuse strategies need to consider the building occupant.** When the building first opened, reused water in the building was treated according to code requirements but was discolored, making users uncomfortable. The building switched to piped water for about a month while the tank was cleaned, which removed residue that had accumulated during construction. Since then, only minor variations in color have occurred and no further complaints have been heard. Building management also markets the green efforts, including signs reading "We flush with rainwater" to raise awareness about this environmental accomplishment at the building.
- **The opportunity for a green, resource-efficient building won Portland a high-profile new company.** The vision for the Meier & Frank depot, including the water management strategy, ultimately was a successful economic development tool for the city. The water and energy-efficient vision for the Meier & Frank depot paralleled priorities of a high-profile company, becoming a successful economic development tool for the city.

Penn Park

QUICK FACTS

Location: Philadelphia, Pennsylvania

Project type: Public park on a university campus within a larger public/private partnership development

Status: Completed

Project cost: \$46.5 million

Site size: 24 acres

Developer: University of Pennsylvania

Designer: Michael van Valkenburgh Associates

Water management features: Bioretention swales, monitoring system, native plants or trees, rain gardens, rainwater cistern, reuse system

Penn Park has transformed an unappealing “leftover space” into an active part of the University of Pennsylvania campus and a green visual connection to Center City Philadelphia. The university developed the park as part of the *Penn Connects* master plan, and its innovative green infrastructure goes beyond the city of Philadelphia’s *Green City, Clean Waters* plan requirements for stormwater absorption. The stormwater management features not only serve an environmental function, but also contribute to the park’s sense of place while presenting research and educational opportunities. “It’s a natural environment in what we all remember as a vast and inaccessible Postal Service parking and storage yard,” says university architect David Hollenberg. “It really is an incredible thing.”

Context

The University of Pennsylvania acquired the Penn Park site primarily from the U.S. Postal Service (USPS). The park site was part of a larger surplus property disposal deal with the USPS, when the agency downgraded its landholdings in Philadelphia. The park site was previously used for a vehicle maintenance facility and parking lot and included or bordered a web of infrastructure, including a high-speed-rail track, a commuter-train line, freight-train tracks, and two major downtown connections.

The meadow in Penn Park includes over 500 trees and reclaims about an inch and a half of rainwater. (Michael Van Valkenburgh Associates)



“We could manage our stormwater requirements on campus by putting everything out of sight and underground. But we recognize that the rain gardens and the visible green roofs are a way to convey to people that we are taking water seriously even to the extent of introducing new landscape typologies to the campus.” | DAVID HOLLENBERG, UNIVERSITY ARCHITECT, UNIVERSITY OF PENNSYLVANIA

USPS disposed of its 30th Street holdings as one parcel rather than subdividing contiguous properties. The university retained and developed the open parking and storage component of the disposed properties as Penn Park. For the remainder, the university entered into a ground lease arrangement with Brandywine Realty Trust, which has constructed a residential tower, a garage rooftop park, and the mixed-use corporate FMC Tower. Finally, the historic circa 1930 post office was fully turned over from Penn to the trust, which has restored and rehabilitated it for use as offices for the Internal Revenue Service.

The new park would support adjacent recreational and athletic facilities and also presented the opportunity to innovate with water management. “Penn Park was one of a handful of early examples of following Philadelphia Water’s stormwater regulations,” explains Hollenberg. “We were a big and visible early example of the kind of stormwater management the Philadelphia Water Department wanted to implement.” The design of the park would also respond to the university’s first Climate Action Plan, which included water management objectives. In addition, a separate Stormwater Management Plan explored possible sites, tools, and best practices for the entire campus.

Today, Penn Park includes passive park space, two multi-purpose turf fields, 12 tennis courts, a natural-grass hockey field, a softball field, concessions space, a press box, spectator stands, a food orchard, and a student-run apiary. The entire park is open to the public, and community members can rent field and recreational space. Sculptural landforms connect the different functions and grade levels, creating a pedestrian circulation network that showcases the historic infrastructural forms remaining—in particular, the CSX train trestle overhead, still in active use on the site.

Innovative Water Management Features

- **Bioswales, rain gardens, and meadows.** The park can reclaim about an inch and a half of rainwater. Natural features of the park designed to capture stormwater include meadow plantings, bioswales that cover roughly three-quarters of an acre, and nearly 570 newly planted trees. The meadow aesthetic was new to the campus.
- **Cistern and associated underground infrastructure.** An underground 300,000-gallon cistern collects runoff from the adjacent turf athletic fields, which are porous and collect roughly 2 million gallons of stormwater per year.³⁷ In the first five years of use, the cistern has never needed to be emptied manually on account of filling to capacity. The park also includes further underground infrastructure to accommodate its location: for example, an underground support system ensures that the weight from the berms and meadow plantings is evenly distributed and does not disrupt the adjacent rail line.

Value Proposition

The park has helped the university achieve some of its master-planning goals, creating new open space and better connecting the campus and the community. Today, the park hums with activity and offers commuters a scenic link across a previously fenced-off, inaccessible site. The park has also become a site for student and faculty environmental research and pilot projects such as the orchard and apiary. Faculty members and students are continuing to identify new opportunities for on-site research and are currently looking into adding groundwater monitoring wells.

A first test of the park’s water management mechanisms came in 2011 in the month before the ribbon-cutting, when Philadelphia experienced 13.6 inches of rain, a city record for rainfall in a month. Shortly afterward, Hurricane Irene brought nearly six inches of rainfall in 12 hours, bringing the Schuylkill River to its highest level in 140 years.³⁸ University president Amy Guttman notes that “our state-of-the-art drainage system had obviously worked. . . . It was put to the ultimate test with Irene far sooner than we could have expected, and it passed with flying colors.”³⁹

LESSONS LEARNED

- **Maintenance required a significant learning curve.**

The water-rich bioswales of Penn Park, as well as the monitoring systems in place, were new to the campus and initially presented challenges to the university’s grounds crew. “It’s a full-time job to keep it managed and operated,” explains Bob Lundgren, the university landscape architect. “We’re always learning more.” Challenges have included:

- **Monitoring systems.** Instruments that measure the dryness and wetness of soil require fluency with the system for all involved. “It’s great to have a smart system, but you have to remember to turn things on and off, and if you don’t reboot it, it’s not going to work,” explains Lundgren, recounting an instance when a stuck-open valve led to significant water loss.
- **Bioswale and meadow landscapes.** Bioswales, which hold water and allow it to seep into the earth, require a very different maintenance approach from grass surfaces. Penn Park’s bioswales sit within a meadow, featuring a range of upland plantings. When disturbances occur and soils erode, weeds can become prevalent and spread, which is a particular challenge for the university, given policies against pesticides or herbicides.
- **Deicing.** The university uses EnvironMelt, a less caustic deicing material, instead of rock salts that might contaminate the water in the cistern.

Stonebrook Estates

QUICK FACTS

Location: Harris County, Texas

Project type: Residential community

Status: Civil infrastructure and lots completed; homes currently under construction (approximately 52 percent completed)

Project cost: \$11.4 million

Site size: 51.4 acres

Development size: 135 lots (lot sizes included two offerings: one 70 feet wide by 125 feet deep and the other 80 feet wide by 130 feet deep)

Developer: Terra Visions LLC

Designers: Aguirre & Fields LP (LID component), R.G. Miller Engineers Inc.

Stormwater management features: Bioretention swales, detention basin, filtration systems, natural drainage system

A key feature of Stonebrook Estates' low-impact-design approach is a bioswale, which creates a welcoming green space at the entrance to the development. *(Terra Visions LLC)*

Stonebrook Estates is a 51.4-acre, single-family residential, low-impact development located north of Houston in Harris County. The 135-lot community, currently made up of about 70 completed homes averaging sale prices upward of \$500,000 each, offers an example of a hybrid stormwater management system that uses both natural drainage systems and traditional storm sewers to effectively convey stormwater around and away from homes. In addition to adding green amenities to the community, the investment in low-impact development has ensured avoided losses by proving to effectively handle the Tax Day and Memorial Day floods of 2016.

Context

Adopted in 2011, Harris County's Low Impact Development and Green Infrastructure (LID/GI) Design Criteria provide detailed guidelines and requirements that enable real estate development projects using LID/GI techniques to obtain development permits in the unincorporated portions of the county. Stonebrook Estates was among the first in the Houston area to implement LID principles.

Stonebrook Estates developer Terra Visions LLC could have managed drainage on the site by using a six- to seven-acre detention pond, but instead chose to pursue the LID techniques as part of the overall amenity offering for the development. The development entry features a green, landscaped drainage corridor designed to serve as a gateway to the homes. LID features also provide residents with more



“We could have put a six- to seven-acre detention pond on the far side of the development and gone off without thinking about using the drainage system as an amenity. But the idea was to be different. We chose to use the facility as landscaping and give it a look that’s not an ugly ditch.” | RANDY JONES, PRINCIPAL, TERRA VISIONS LLC



Stonebrook Estates' natural drainage system managed the waters from the Tax Day Flood of 2016, which severely affected Houston. (Terra Visions LLC)

green space, a trail system, and a water feature that naturally guides stormwater to two 50-foot-wide detention channels that then filter the flows to an interior detention basin. The basin manages the release of water at a rate and quality that is safe for the surrounding environment.

Innovative Water Management Features

- **Natural drainage system.** The natural drainage system at Stonebrook mimics the natural flow of water across a green landscape, directing stormwater into linear and lake-style detention basins; from there, stormwater is slowly released to nearby channels and bayous.
- **Engineered soils.** The first inch of stormwater runoff from the development is routed through engineered soil filters that remove pollutants from the runoff and ensure that the development complies with local postconstruction stormwater quality management regulations. The engineered soil filters (known as biofiltration) are designed to provide a very high filtration rate, thus avoiding surface ponding.⁴⁰
- **Curb cuts and false-back inlets.** Roadways are sloped and use "false-back inlets" on the curbs to drain stormwater into bioswales instead of traditional precast concrete storm sewer pipes.

Value Proposition

Randy Jones, Terra Visions LLC principal, describes the LID features as a key part of the development's sense of place. After Houston's 2014 downturn caused by falling oil prices, the developer worried the homes would be priced too high for the market. However, although sales volume and absorption were

initially lower, the development fared well, with average home prices about 25 percent higher than expected. Jones describes the community as a "complete blend" that was attractive to the suburban Houston market. "It's on a private street, a gated neighborhood, and well landscaped with LID components right at the front door. When you put all the pieces together, the market likes it," he explains.

The site engineer, Michael Bloom with R.G. Miller Engineers, estimates that the natural drainage system, which is used only in a portion of the development, reduced the site detention requirement by 24 percent, which increased lot yield.⁴¹

Stonebrook's natural drainage system was put to the test during the Tax Day Flood of April 2016. Stonebrook received approximately 12 inches of rainfall in a 24-hour period, which is about equal to the 100-year rainfall for the area. The stormwater management system at Stonebrook "functioned better than anticipated given the rain storm intensity," says Jones. "I was absolutely amazed that the stormwater stayed in the system and didn't flow into the streets or yards." The natural drainage system was able to capture then convey the rainfall and runoff, and both the linear and lake-style detention basins successfully released the design flow to the nearby channels and bayous.

LESSONS LEARNED

- **A low-impact development framework presents an opportunity to fulfill market demand for environmentally friendly communities.** LID principles inherently include natural amenities that are attractive to homeowners, such as trail systems and open space. Jones described green infrastructure as a key component of a well-rounded community desirable to homebuyers.
- **Natural drainage systems can cut costs of drainage facilities.** Stonebrook Estates' drainage corridor is part of the landscape of the community—and is a more cost-effective alternative for the community's utilities, given the limited access to the drainage piping system.
- **Green infrastructure can mitigate risk and avoid losses.** Stonebrook Estates has already survived a major storm, the Tax Day Flood. Infrastructure in this community has proven to be resilient and protected its community members.

The Avenue

QUICK FACTS

Location: Washington, D.C.

Project type: Mixed use

Status: Completed

Project cost: \$336 million

Site size: 3.5 acres

Developer: Boston Properties Inc.; site now owned by Boston Properties (commercial) and Bozzuto (residential)

Designers: Sasaki Associates Inc., Pelli Clarke Pelli Architects/Landscape, Hickok Warner Cole Architects, Thornton-Tomasetti Group, TOLK, KTA Group, Wiles Mensch Corporation, Clark Construction

Water management features: Filtration systems, green roof, rainwater cistern, retention pond, reuse systems

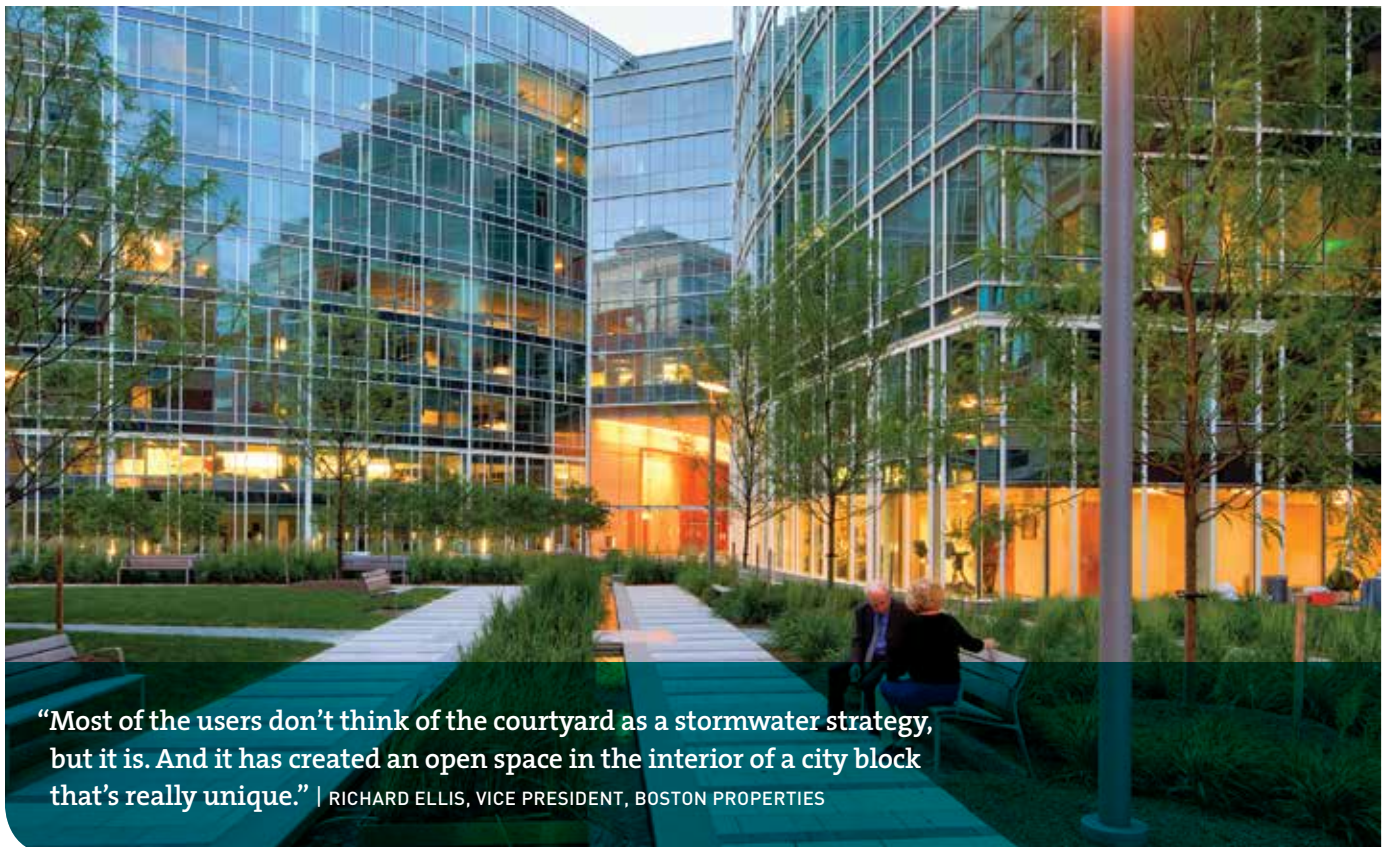
The Avenue's courtyard is an inviting space for visitors, office workers, residents, and others. *(Sasaki)*

The Avenue is a mixed-use, transit-oriented development steps away from the George Washington University campus and hospital in Washington, D.C. The 3.5-acre development includes 335 residential units, 460,000 square feet of commercial office space, a Whole Foods Market, six eateries, and public and private green space. Upon completion in 2011, the residential building achieved the highest rents in the city for a project of its size and leased up in 11 months. Central to the residential and office space is an attractive interior courtyard, with a water feature that operates with a stormwater management system and uses 100 percent reclaimed water.

Context

Completed in 2011, the Avenue has an active streetscape that has become a popular destination for visitors, office workers, residents, and students in downtown Washington. The project came out of an urban design study for the disused parcel that previously held the George Washington University Hospital, which was also Square 54 of the original Washington plan.

The project is the result of a partnership between George Washington University and Boston Properties Inc. under a 60-year lease that has since provided funding for the construction of the university's Science and Engineering Hall and contributed an estimated \$11.5 million in annual city tax revenues.^{42,43} The ground



“Most of the users don’t think of the courtyard as a stormwater strategy, but it is. And it has created an open space in the interior of a city block that’s really unique.” | RICHARD ELLIS, VICE PRESIDENT, BOSTON PROPERTIES



The attractive courtyard water feature holds captured runoff from the roof after it has been cleansed by the treatment system. (Sasaki)

lease terms were based on the amount of developable space rather than the possible floor/area ratio (FAR), which led the development team to create a courtyard concept slightly below FAR opportunities. A key requirement for the design of the building was a below-grade loading dock, which also created the opportunity for an interior courtyard above it.

Sustainable design can be found throughout the Avenue. Green and lightly colored roofs absorb less heat than conventional black roofs, thereby decreasing peak roof surface temperature by approximately 40 degrees Fahrenheit. The Avenue also uses a high-efficiency irrigation system and native and drought-tolerant plants, which reduce the amount of water needed by an estimated 62 percent.⁴⁴

Innovative Water Management Features

- **Green roofs.** An extensive 8,000-square-foot green roof is spread equally across the office and residential buildings. This green roof system comprises a water retention layer, a drainage layer, filter fabric, engineered soil, and succulent plantings. On the residential roof, more than 300 linear feet of raised planters with tall evergreen hedges shield the pool and terraces from sight and wind.
- **Stormwater treatment and reuse system.** Water is absorbed by the green roofs and then sent through interior piping into the stormwater filter, which includes two sand filters, an ultraviolet sterilizer, and an ionizer that kills algae, bacteria, and viruses without the use of extra chemicals. This system allows plants to grow directly in the water feature and requires less maintenance than a standard infiltration system.⁴⁵ Water is then recirculated into the 7,500-gallon cistern, which is located underneath the courtyard, within the five-level parking garage below. Irrigation water is pumped directly from the cistern, and all other stored rainwater is continuously pumped through the courtyard water feature and treatment system.

The development's robust stormwater management system for collecting, treating, and reusing rainwater in an inviting courtyard is able to manage an estimated 76,000 gallons of stormwater.⁴⁶

- **Courtyard water feature.** The attractive water feature doubles as a stormwater container, holding roughly 15,000 gallons of water that has been recirculated through the cistern and treatment system. The courtyard's water feature is 100 percent supplied by reclaimed stormwater. The water feature includes aquatic vegetation in perforated planters that allow the roots to provide supplemental filtration.

Value Proposition

The Avenue has been a resounding commercial success. It achieved the highest residential rents in the city for a project of its size and had a relatively fast lease-up: 11 months for 335 apartments. The commercial space also attracted tenants quickly. "By every metric, the project has exceeded expectations," says Richard Ellis of Boston Properties. Ellis attributes this success to a variety of factors, including the location, the quality of construction, and the design of the courtyard space.

Beyond serving as an attractive public space, the courtyard has enhanced views throughout the development. "There's no such thing as a bad or back view," explains Ellis. "Some people look at a green courtyard; some look at a busy commercial corridor."

LESSONS LEARNED

- **The courtyard water feature has provided residents with significant amenity value.** The courtyard is an extremely popular amenity for residents, office workers, and members of the public. Beyond improving public spaces, the courtyard also enhances views for residences and offices, thereby contributing to the desirability of the project and the real estate value.
- **Innovative design can create additional water storage capacity.** The design team was interested in creating more water storage than was available in the 7,500-gallon cistern. "We were constrained by the size of the cistern because of the premium for parking," explains designer Matt Langan of Sasaki. Instead of proposing a larger cistern in the parking structure, the landscape architects designed the water feature to be unusually deep, with water circulating in and out from the cistern and infiltration system.

The Rose

QUICK FACTS

Location: Minneapolis, Minnesota

Project type: Mixed-income multifamily redevelopment

Status: Completed in 2015

Project cost: \$36.2 million

Site size: 1.65 acres

Development program: 145,000 square feet; 90 units (43 market rate and 48 affordable)

Development team: Aeon, Hope Community

Design team: MSR Design (lead), Emmons O'Rourke and Associates, Karges-Faulconbridge, Meyer Borgman Johnson, Elert and Associates

Water management features: Efficient fixtures, filtration systems, native plants or trees, rain gardens, rainwater cistern, reuse systems, stormwater vault

The Rose is a 145,000-square-foot mixed-income redevelopment in the final phase of Minneapolis's South Quarter. Stormwater management was a key strategy to remediate contamination present in one of most ethnically diverse neighborhoods in Minneapolis. The development features 33 percent green space and is designed with rain gardens that infiltrate and reuse about 90 percent of rainwater for community gardens. In 2013, the Rose became one of the first affordable housing developments in the nation to be selected as a Living Building Challenge™ pilot for its stringent commitment to sustainable design and its achievement of nearly net-zero water, waste, and energy.

Context

Creative partnerships were the cornerstone to achieving high sustainability standards while preserving affordability at the Rose, located in one of Minneapolis's lowest-income and most ethnically diverse neighborhoods. The Rose created 90 units of market-rate housing, affordable housing, and supportive housing for the long-term homeless as part of the final phase of the South Quarter district's redevelopment. The complex is located on a 1.65-acre former brownfield site surrounded by freeways, spanning nearly a block of South Minneapolis.

Lead developer Aeon partnered with another nonprofit developer, Hope Community, whose strong ties to the neighborhood ensured the development

Children enjoy a landscape feature in one of the Rose's courtyards. (Aeon/MSR Design)



“We focused on finding the highest return on investment for each design strategy. For example, every design element had a goal to provide more than one benefit; it also had to bolster the performance of another system or component. Thus, we were able to evaluate on a building-wide basis the right balance of life-cycle cost, first cost, durability, and energy and water savings.” | LESLIE ROERING, PROJECT MANAGER IN HOUSING DEVELOPMENT, AEON



Built on a previously contaminated site surrounded by freeways, the Rose has integrated stormwater management mechanisms to cleanse and reuse 90 percent of captured rainwater. (Don Wong/MSR Design)

process was both inclusive and on target to meet local needs.⁴⁷ In 2013, the Rose became one of the first affordable housing developments to be selected as a pilot project for the Living Building Challenge, a rigorous certification standard for sustainable construction and design.⁴⁸

While aspirationally pursuing the Living Building Challenge, the development team complied with the Enterprise Green Communities Criteria, a point and checklist system with mandatory considerations for sustainability, required by the Minnesota Housing Finance Agency as a condition for public funding.⁴⁹ At the project's inception, the general contractor and the design team entered into an informal Integrated Design and Delivery process, a contract from American Institute of Architects that jointly establishes energy budgets, bidding cycles, and life-cycle costs of product alternatives.⁵⁰

Innovative Water Management Features

- **Rain gardens.** Up to 26,000 gallons flowing from the east quarter of the building roofs can be filtered through three rain gardens on site.⁵¹
- **Underground retention system.** A 48,500-gallon-capacity underground retention system captures the stormwater runoff from roofs that the rain gardens cannot capture.
- **Water quality unit.** Before runoff reaches the Mississippi River, oil, trash, and sediment are removed from stormwater runoff on site.
- **Rainwater cisterns.** Rainwater is captured in cisterns and reused in a 5,000-square-foot community garden that offers food-production programming on site.
- **Solar water-heating system.** On-site solar panels heat 35 percent of the water used in the project.
- **Water-efficient fixtures.** To reduce potable water use, the Rose installed 1.5-gallon-per-minute (gpm) maximum-flow showerheads, 1.5 gpm maximum-flow kitchen faucets, 0.5 gpm bathroom faucets, and 0.8-gallon-per-flush toilets.⁵²

Value Proposition

An independent third party, the Weidt Group, estimates the payback period for the Rose's sustainable features is 11.4 years.⁵³ Potable water use at the Rose has decreased by an estimated 47 percent since water-conserving features were installed.⁵⁴ By design, the Rose exceeds the city's water consumption standards nearly by half, with a system that uses up to 35.6 gallons of water per capita per day. After these sustainability and water management features were implemented and over half the units were set aside for low-income and formerly homeless tenants, construction costs still came to only \$156 per square foot.⁵⁵

Leslie Roering, project manager in housing development at Aeon, notes, "Our goal was to transform the blighted, contaminated site into a place of refuge. We incorporated 33 percent green space, fully accessible tree-lined walkways, and gathering spaces that serve as buffers to streets. Underground parking frees up space for use by people instead of cars, and a band of rain gardens infiltrates 90 percent of rainwater collected on the roof and site and feeds it into cisterns for reuse in the community garden."

The Rose's commitment to sustainable, healthy, and affordable housing has earned it numerous awards and accolades, including the ULI Jack Kemp Excellence in Affordable and Workforce Housing Award, the AIA Minnesota Honor Award, and the Environmental Initiatives Award, Energy & Climate category.

LESSONS LEARNED

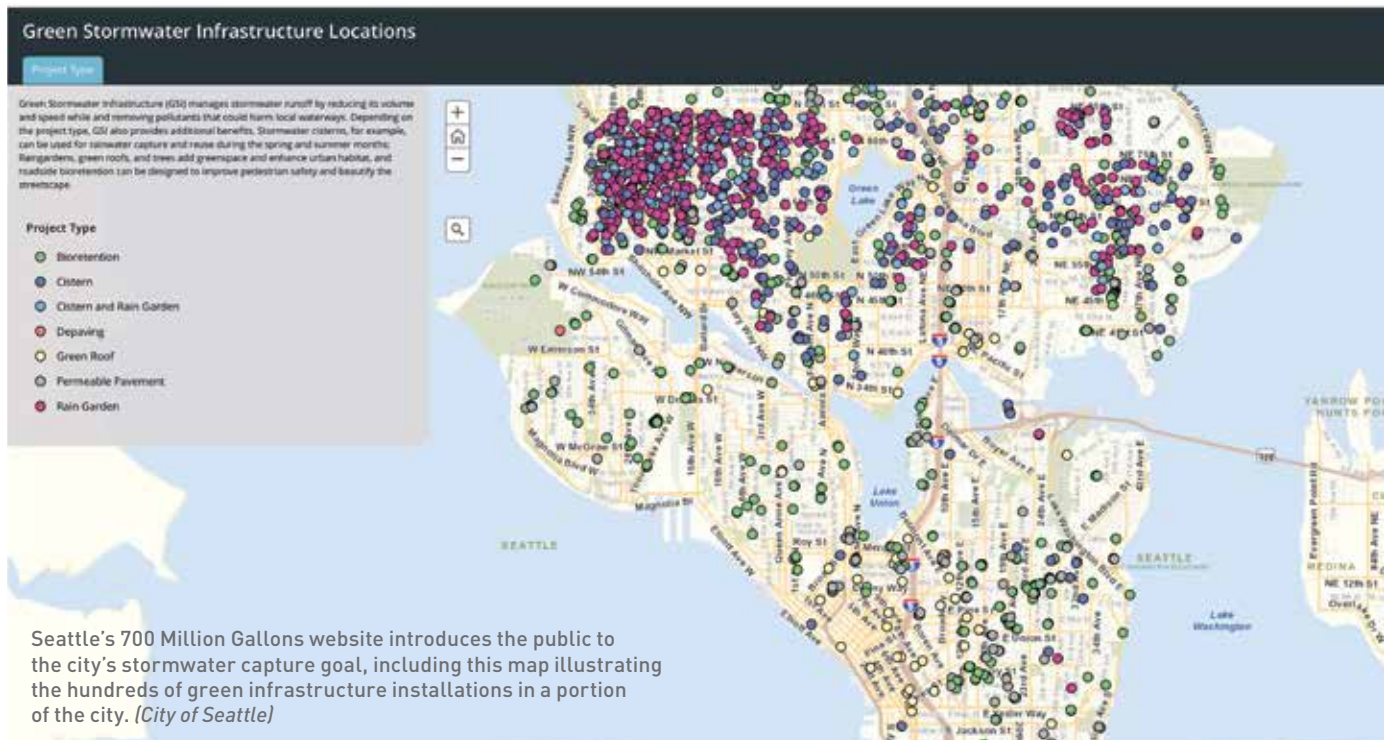
- **On-site contamination can be remediated when stormwater capture is integrated at different levels of design.** The Rose, developed on a former brownfield site surrounded by freeways, cleans stormwater runoff and conserves potable water through rainwater harvesting systems and water-efficient fixtures.
- **Affordable and supportive housing can be preserved while achieving a high level of sustainability.** The Rose's sustainability features have an estimated payback period of just over 11 years. This investment was viable for the project, although over half the units are for low-income families and formerly homeless people.
- **Creative partnerships between design and construction teams are essential to forecast and mitigate costs at the inception of a development.** The general contractor was informally integrated into the design team at the inception of the Rose's development, containing costs for construction to \$156 per square foot.

The Stormwater Policy Landscape

In cities across the United States, investments in green infrastructure are growing through both public sector programs and private sector involvement. New York City has committed to spending \$1.6 billion on green infrastructure in 20 years,¹ while Philadelphia has estimated that public investment in stormwater retrofits over the next 25 years will total \$1.2 billion.² Smaller but still substantial green infrastructure targets are also in place in Los Angeles; Detroit; Portland, Oregon; and Kansas City, Missouri.³ Along with these public investments, government policies often encourage or require private real estate sector participation.

“The goal [of a holistic green infrastructure strategy] is for all sectors and residents of cities to see the benefit to themselves personally and to their cities as a whole,” explains Mami Hara, general manager/chief executive officer of Seattle Public Utilities and former deputy commissioner of the Philadelphia Water Department. “These strategies should make the best use of every infrastructure dollar spent, to achieve the multiple ends that we need to in order to have a more sustainable society.”

Municipalities encourage private sector participation in green infrastructure development in multiple ways. Some cities have focused on putting new requirements in place, whereas others have focused primarily on development incentives. “While developing and paying for additional stormwater management systems is still an option [for cities], using existing tools to share risk with citizens and landowners in a way that achieves many



STORMWATER POLICY TOOLS

On-site water retention requirements	These policies require developments over a certain size threshold to capture a specific minimum volume of water on site, typically measured by inches of rain or percentage of a certain type of rain event.
Credit-trading schemes	Credit-trading schemes, such as the innovative new policy in Washington, D.C., offer real estate developers the opportunity to adhere to on-site mitigation policies or purchase credits from other sites that have voluntarily complied with the requirements.
Green area ratios	Green area ratios encourage the layered use of different stormwater mechanisms through the use of a score-based tool that requires a certain percentage of a site to be covered by green infrastructure, with different points awarded to different interventions.
Frameworks and design guidelines for low impact development	This largely bottom-up, market-driven approach offers developers the tools to use the LID approach for their projects, providing resources such as guidebooks, development incentives, and expedited permitting. LID refers to systems that mimic natural processes to manage water and protect water quality.
Stormwater fees	Stormwater fees are charged based on the amount or percentage of impervious surface on a site, encouraging the incorporation of impermeable or green surfaces. Sites that put larger burdens on the public drainage systems are required to contribute more.
Development incentives	Development incentives for green infrastructure have included FAR bonuses, tax abatements, and rebates.
Implementation of total maximum daily loads (TMDLs)	Calculated in watersheds discharging too much pollution, TMDL refers to the maximum amount of a pollutant that a body of water can receive while adhering to water quality standards. Reducing the volume of runoff from a development directly reduces the pollutant load and can help achieve the required pollutant load reduction.
Community grant programs and design competitions	Cities have sought to generate new ideas about green infrastructure and to inspire innovation through ideas competitions aimed at the design community. Community grant programs have supported citizen-led stormwater management and community greening projects.
Monitoring and open data programs	Green infrastructure is one of the many topics that can be analyzed through open data platforms, with cities releasing green infrastructure data to gain insights on effectiveness and performance.
Toolkits for households	Beyond policies affecting large-scale residential, mixed-use, commercial, and office development, cities have introduced policies, toolkits, and incentives to encourage private homeowners to make small-scale, low-cost alterations to their properties to reduce impervious surfaces.
Demonstration projects	Numerous municipalities have shown their commitment to green infrastructure by initiating demonstration projects in the public realm intended to spark discussion and inspire private sector action.

STORMWATER POLICY STRATEGIES: EXAMPLES FROM SIX CITIES

	New York Capture rainfall on 10% of impervious surfaces by 2030	Chicago Capture up to 250 million gallons/year by 2020	Philadelphia Capture rainfall on 34% of impervious surfaces by 2035	Seattle Capture up to 700 million gallons/year by 2025	Baltimore Capture rainfall on 20% of impervious surfaces by 2018	Washington, D.C. Capture rainfall on 75% of all surfaces by 2035
STRATEGIES						
On-site water retention requirements	•	•	•	•	•	•
Credit-trading schemes						•
Green area ratios				•		•
Fee structures	•	•	•	•	•	•
Development incentives	•	•	•	•		•
Community grant programs	•		•	•	•	•
Open data and monitoring programs	•	•	•		•	•
Design and idea competitions	•		•		•	•
Household toolkits	•	•	•	•	•	•
Demonstration projects	•		•	•	•	
Greening vacant land	•		•		•	
CONTEXT						
EPA consent decree	•	•				•
EPA settlement agreement	•			•	•	
EPA partnership agreement			•		•	•
Average rainfall	50" average rainfall/year	37" average rainfall/year	43" average rainfall/year	39" average rainfall/year	42" average rainfall/year	40" average rainfall/year
Public commitment	\$2.4 billion	\$50 million	\$1.6 billion	\$57.7 million	\$77.5 million	\$2.6 billion
Municipal plan	<i>2010 New York City Green Infrastructure Plan</i>	<i>2014 Chicago Green Stormwater Infrastructure Strategy</i>	<i>2009 Green City, Clean Waters: A Long Term Control Plan Update</i>	<i>2015 Seattle Green Stormwater Infrastructure, Implementation Strategy</i>	<i>2013 Baltimore City Watershed Implementation Plan</i>	<i>2012 Sustainable DC Plan</i>

Principal sources: EPA Statute Enforcement Database; 2010 New York City Green Infrastructure Plan; 2014 Chicago Green Stormwater Infrastructure Strategy; 2009 Green City, Clean Waters: A Long Term Control Plan Update; 2015 Seattle Green Stormwater Infrastructure, Implementation Strategy; 2015 Baltimore City MS4 and TMDL Watershed Implementation Plan; 2016 District of Columbia, Water Quality Assessment Integrated Report to the US Environmental Protection Agency and Congress Pursuant to Sections 305(B) and 303(D) Clean Water Act (P.L. 97-117); NOAA Online Weather Data.

Note: See appendix on page 64 for complete citations.

additional benefits is a resilient approach—and one cities around the world should consider trying,” explains Amy Armstrong, vice president for knowledge and impact at 100 Resilient Cities, a project of the Rockefeller Foundation.

Philadelphia and Washington, D.C., currently have particularly broad stormwater management programs, which are likely to inspire other cities if successful development outcomes are achieved. Both include on-site water retention requirements alongside a range of other programs and policies that have been mixed and matched by other cities establishing green infrastructure programs.

Some cities are increasingly looking to green infrastructure to address climate change–related issues, particularly concerns about flooding. Jeff Hebert, chief resilience officer, chief administrative officer, and deputy mayor for the city of New Orleans, notes that the city has found neighborhood-scale green infrastructure to be more effective at reducing flooding vulnerability than investments on individual properties. He explains: “The city of New Orleans did an analysis and decided that it was more advantageous for us to invest in green infrastructure with our hazard mitigation and severe repetitive loss area funds. The model showed that investing in even smaller green infrastructure in parks and other places actually reduced the risk across the board.” Today, the city has revised its approach to its repetitive loss funds and the Comprehensive Zoning Ordinance for the city of New Orleans requires on-site stormwater management.

Cities have also sought new strategies to track the success of their investments, considering costs in comparison to both gray infrastructure and the potential costs related to property damage from flooding. “For cities and property owners to make effective investments in sustainable stormwater management, they need to be able to evaluate its performance,” explains Steve Fifita, executive director of City Digital in Chicago, which recently launched a green infrastructure monitoring project.

The following section of this report introduces a range of approaches to stormwater management policy and explores their relevance to real estate.

On-Site Stormwater Retention Requirements

On-site mitigation policies require real estate projects to retain a certain volume of water on site. In 2013, 18 states and the District of Columbia had on-site standards for stormwater infiltration or evapotranspiration—the process by which moisture is carried from plant roots to tips for release into the atmosphere.⁴ Typically, these standards are measured in terms of volume of stormwater that must be captured (for instance, the first inch of stormwater) or percentage of stormwater from a certain type of rain event that must be captured.

Developers achieve these goals by incorporating into their projects green infrastructure, such as green roofs, cisterns, rain



Los Angeles's LID Road Map offers residents and developers clear guidance on how to navigate LID requirements. (City of Los Angeles)

gardens, bioswales, or other design approaches. The goal is to keep stormwater out of drainage and sewer systems by minimizing impervious surfaces on the site as well as between the site and adjacent sites.

The following cities currently have such standards:

- **Philadelphia:** Among the most progressive in the country, Philadelphia's stormwater requirements are likely to set a standard for other cities seeking new approaches to managing runoff. One of the most stringent requirements is for new development to capture the first 1.5 inches of stormwater from all directly connected impervious areas using green infrastructure.⁵ If infiltration is not possible or is environmentally harmful for any reason, the method of compliance is then derived from the sewershed where the project is located.⁶
- **Washington, D.C.:** The District of Columbia requires new development to retain on site the first 1.2 inches of rainfall from a 24-hour storm for all projects over 5,000 square feet, with evapotranspiration, retention, or rainwater harvesting occurring during the following 72 hours, if no additional rain occurs.⁷ Building retrofits that cost more than half the structure's prerenovation value are required to capture 0.8 inches of rainfall.⁸ The organization Clean Water Action heralded this permit standard as an opportunity to improve water quality in the District.
- **New Orleans:** Following recommendations from the post-Katrina recovery blueprint, *The Unified New Orleans Plan*, the city of New Orleans updated its Comprehensive Zoning Ordinance (CZO), adopting a new CZO in 2015. A place-based development code, the CZO advocates for a denser urban pattern and addresses stormwater management by focusing on landscape, stormwater management, and screening. The CZO requires that new development detain and filter the first 1.25 inches of water using stormwater best management practices.⁹ Stormwater management plans must be prepared by a registered landscape architect and analyze pre- and postdevelopment runoff rates.¹⁰
- **Los Angeles:** Los Angeles introduced an LID ordinance in 2012 that requires projects of a range of sizes, including small-scale developments, to capture stormwater at the source.¹¹ The ordinance describes these stormwater management requirements as critical to achieving the city's revitalization plans for the Los Angeles River.¹² The ordinance aims to apply "an integrated approach to incorporate wastewater, stormwater and runoff, and recycled water management," citing an increase in impervious area, which has increased runoff and decreased water quality because of the transport of pollutants downstream.¹³ The city's LID ordinance was particularly innovative in its inclusion of smaller properties, including housing developments of ten or more units, single-family hillside residential developments, commercial

or industrial developments with one acre or more of impervious area, and others. Nearby Santa Monica also requires that all new development or retrofitted development capture runoff from impervious surfaces for a storm dropping 0.75 inch of rain.¹⁴

Credit-Trading Programs

Washington, D.C.'s new stormwater policies introduced a credit-trading program for stormwater volume, a first-of-its-kind concept in the United States and internationally.¹⁵ Washington's program offers developers the choice of either capturing the required volume of stormwater on site by implementing green infrastructure or purchasing stormwater volume credits from other sites that have voluntarily exceeded the volume capture requirements and have additional stormwater volume credits to sell. The city of Los Angeles is considering adopting a similar program, as are a number of other cities across the country.¹⁶

A credit-trading program can be particularly attractive to real estate developers leading high-density downtown development projects. For example, the developer of a high-rise building with limited green space may choose to purchase credits rather than forgo rooftop amenities to make way for green infrastructure, or forgo some of the underground parking or space for utilities to make space for cisterns. Conversely, developers with larger sites and more flexibility regarding green infrastructure implementation may retain a higher volume of stormwater by using additional green infrastructure and sell the credits at a profit.

Credit-trading systems also create a role for suppliers and aggregators who can build green infrastructure and sell the capacity to developers, such as District Stormwater LLC, a startup launched in 2016 through the Nature Conservancy's impact investment arm, NatureVest, drawing a \$1.7 million investment from Prudential Financial.¹⁷ "We are a large-scale aggregator in the market," explains managing director Craig Holland. "We will continue to build credits on behalf of the development community in D.C. that would offer a long-term compliance alternative."

In Washington, one stormwater retention credit is equal to one gallon of retention capacity for one year, meaning that a project developer can purchase one credit instead of implementing one gallon of the stormwater retention requirements. Developers are eligible to use credits to achieve up to half of their stormwater capture requirements.¹⁸ The D.C. Department of Energy & Environment is administering the credit scheme and sought to accelerate adoption through a \$12.75 million Purchase Agreement Program launched in May 2016, which created the option of selling the credits to the department to create a price floor in the early days of the program.

USING THE D.C. STORMWATER CREDIT MARKET

The former Shaed Elementary School is located on a small site in northeast Washington, D.C. In 2014, the nonprofit Building Hope leased the school, which had closed because of low enrollment, and an extensive renovation of the building began. This improvement project triggered the city's stormwater regulations and led to the first Stormwater Retention Credit (SRC) trade in Washington, D.C., when the District Department of Energy & Environment approved the transfer of 11,013 SRCs for a value of approximately \$25,000.

"It was a tradeoff," Tom Porter of Building Hope explains, "between carrying out a complex and expensive green infrastructure project and buying credits." The school's modest size and structural limitations made it difficult for Building Hope to meet the required 11,013 credits on site. Almost 31,000 square feet of this 39,413-square-foot lot is composed of impervious surfaces, and the foundational work required for a green roof or bioswale would increase the initial costs of green infrastructure to over \$100,000.

The Shaed Elementary School bought credits from the Westchester, a co-op apartment complex located in northwest Washington. A person involved in the trade says the initial cost of installing rain gardens on the property, including engineering plans, was close to \$75,000. Thus far, the

Westchester has generated more than \$70,000 in income by selling SRCs. "Revenue from this trade will help cover the costs of designing, installing, and maintaining the rain gardens that generated the SRCs," the seller of the credits says. "Now we're looking at other ways to install practices on our property to generate additional SRCs." In addition, the Westchester is entitled to receive a discount for the stormwater portion of its monthly water bill, which is quite a significant savings for a property of 11 acres.ⁱ

Ecologically, the trade fits nicely into the city's plan to encourage more green infrastructure where it is most needed. The Westchester is located in an area served by a municipal separate storm sewer system, or MS4, where stormwater runs directly into the city's waterways without any filtration or treatment. Green infrastructure is especially important for water quality in these areas. The Shaed Elementary School, by contrast, is served by a combined sewer system that brings both sewage and rainwater to the city's Blue Plains Advanced Water Treatment Plant. The SRC trade between the Shaed Elementary School and the Westchester, therefore, is a successful example of the main purpose of the SRC program: to shift investment in green infrastructure to MS4 areas of the District.

Washington, D.C.'s stormwater credit market database website includes data on recent sales and purchase prices. (D.C. Department of Energy & Environment)

Transfer Date	Watershed where SRCs are generated	Sewershed where SRCs are generated	Purchase price per SRC	Number of SRCs (tot)	Total value of transfer (tot)
10-13-2016	Potomac	MS4	\$1.90	11,013	\$20,925
09-26-2016	Rock Creek	CSS	\$1.70	4,648	\$7,902
09-08-2016	Rock Creek	CSS	\$2.00	2,142	\$4,284
08-10-2016	Rock Creek	CSS	\$1.80	108	\$194
08-08-2016	Potomac	MS4	\$1.90	2,115	\$4,019
08-03-2016	Rock Creek	CSS	\$1.80	3,105	\$5,589
07-08-2016	Rock Creek	CSS	\$1.90	584	\$1,110
07-08-2016	Rock Creek	CSS	\$1.80	1,257	\$2,263
10-02-2015	Potomac	MS4	\$1.90	11,013	\$20,925
09-18-2014	Potomac	MS4	\$2.27	11,013	\$25,000
Totals (10 groups)				46,998	\$92,209

i. J. Strong, "D.C. Introduces Cap and Trade System to Keep Dirty Water out of Local Streams," WAMU 88.5 American University, June 19, 2015, http://wamu.org/programs/metro_connection/15/06/19/dc_introduces_cap_and_trade_system_to_keep_dirty_water_out_of_local_streams.

To function well, stormwater credit-trading systems must create different markets for different watersheds and ensure that the volume of stormwater captured through credit trades is all within a single watershed. The optimal outcome occurs when more properties are managing stormwater, including projects in full compliance and other projects in partial compliance, covering a broader geographic area. Having a high number of runoff management systems allows communities to capture more water over time than they might have with fewer systems designed for larger rain events.

Ideally, the system will not only offer alternative means of compliance for the real estate community, but also encourage development of environmental infrastructure in underinvested parts of the watershed. According to Craig Holland, managing principal of District Stormwater LLC, "The places where you are most likely to want to build stormwater management credit

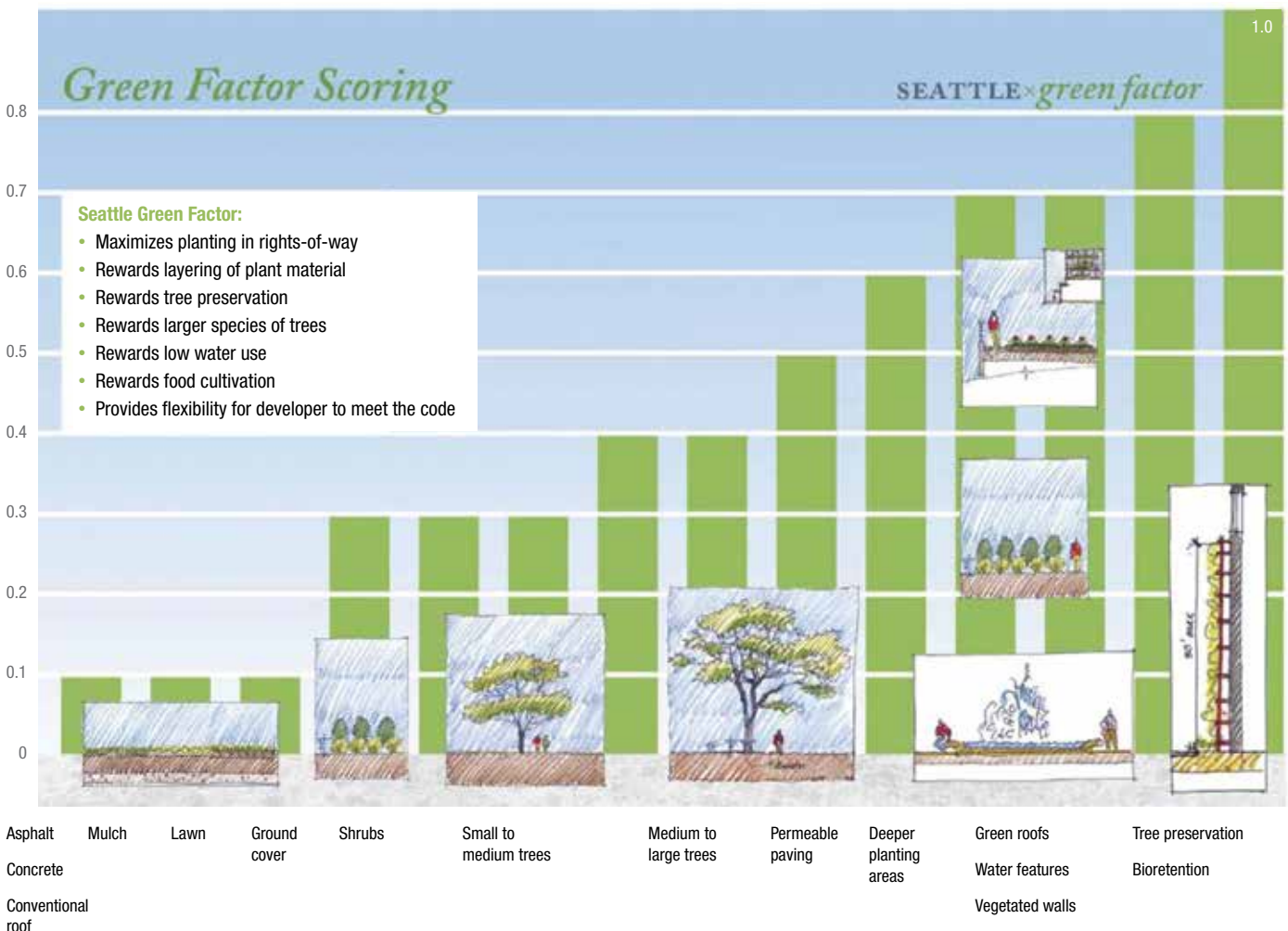
supply are often areas where not a lot of development is occurring. These also happen to be places where oftentimes there is a lack of public infrastructure investment. Credit-trading systems incentivize suppliers to go out and build in places where the investment is most needed."

On a statewide scale, Oregon's Department of Environmental Quality runs a Water Quality Trading system that is designed to allow facilities that discharge wastewater to streams and rivers to address regulatory requirements by buying pollution reduction credits from other sources or by participating in wetland and riparian area restorations.¹⁹

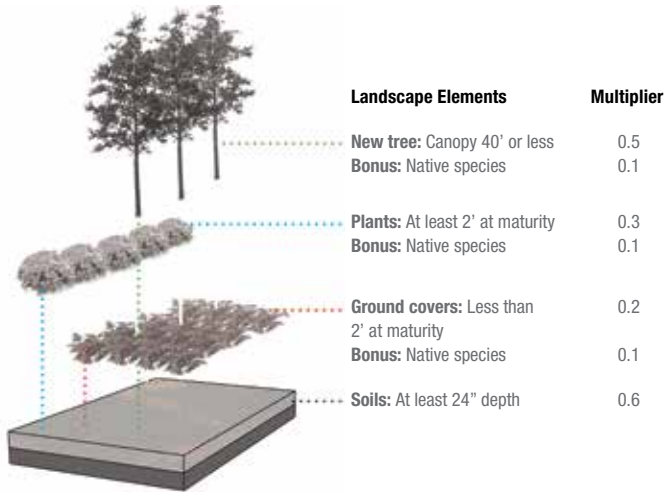
Green Area Ratio

The green area ratio, an alternative metric to on-site mitigation requirements, encourages the layered use of a range of stormwater capture mechanisms. The tool is intended to provide real

Seattle's Green Factor establishes a score for different types of green infrastructure; properties must then meet a minimum score tied to a lot's zoning. (City of Seattle)



Bonus +0.1: Drought-tolerant or native plants, rainwater harvesting, features visible to the public, and food cultivation.



Washington, D.C.'s Green Area Ratio includes a range of landscape elements with different multipliers. (D.C. Department of Energy & Environment)

estate developers with a menu of options for compliance with green infrastructure and stormwater capture requirements.

Pioneered in Berlin, Germany, in 1997 as the "biotope area factor," the green area ratio awards points for different types of green infrastructure, creating a score that considers the design interventions in the context of a site.²⁰ Malmö, Sweden, has used a similar system, as has Hamburg, Germany.²¹

Seattle was the first U.S. city to adopt a green area ratio, known there as the Seattle Green Factor (SGF). The city describes the SGF as a "score-based code requirement that increases the amount and improves the quality of landscaping in new development," aiming to manage stormwater runoff as well as improve habitat and aesthetically enhance a neighborhood.²² Seattle adopted the SGF in 2006 and expanded the program in 2009, with the priorities being livability, ecosystem services, and climate change adaptation.²³ Fife, Washington, a suburb of Tacoma near Seattle, also adopted a Green Factor as part of an LID ordinance in 2009.²⁴

Development projects must achieve a minimum SGF score indicated by zoning, with different standards set for commercial and residential properties. To achieve the score, developers can choose from a menu of options that provide credits, including rain gardens, native landscaping, vegetated walls, green roofs, and food gardens. Each provides a number of points weighted by green infrastructure size, functionality, and aesthetics,²⁵ with the total then divided by the parcel size to create the SGF score.²⁶

The system encourages the layered use of different stormwater mechanisms to increase absorption capacity and create rich and varied aesthetics. Landscaping in the public right-of-way is considered with landscaping on the site itself, and bonus points are awarded for landscape aspects visible to the public.²⁷

According to the American Society of Landscape Architects, "because SGF significantly raises the bar for landscaping in affected zones, landscape design now starts in the initial stages of site planning, allowing more collaboration between design professionals; the resulting landscapes are more attractive and better integrated into site programs and amenity areas."²⁸

Washington, D.C.'s Green Area Ratio (GAR) is a system very similar to the Seattle SGF. The GAR applies to all new buildings that require certificates of occupancy as well as to any additions or renovations with construction costs that exceed 100 percent of the building value within a one-year period.²⁹ Different GARs are required for different zone districts within the city, with the specific ratios determined in line with land use expectations.³⁰ Single-family residences, some designated historic properties, some properties with historic roofs, and wastewater treatment plants are exempt.³¹

Development Incentives

Development incentives offer another strategy for encouraging the development of green infrastructure on sites controlled by the private sector. The following cities are among those that offer development incentives correlated with stormwater management strategies:

- **Austin, Texas:** In 2009, the Austin City Council established a stakeholder group, including the renowned Lady Bird Johnson Wildflower Center,³² to study green infrastructure incentive programs elsewhere in the country, including San Diego, Chicago, and Portland.³³ Today, the city offers developers additional square feet of floor area for each square foot of planted bed on a vegetated roof, measuring the percentage of vegetated roof cover as a ratio of planted bed divided by total roof area.³⁴ The program also offers additional square feet of floor area if the green roof is publicly accessible and if it achieves the city's "downtown public plaza standards."³⁵
- **Portland, Oregon:** Portland offers developers an ecoroof FAR bonus for properties within the Central City Plan District.³⁶ The program allows developers of large-scale projects, such as commercial, industrial, and multifamily units, to create additional floor area beyond what is allowed

Percentage vegetated roof cover	Bonus area granted	Bonus area granted for publicly accessible green roofs	Bonus area granted for green roofs meeting the downtown public plaza standards
30%–49%	2 bonus square feet	2 additional bonus square feet	2 additional bonus square feet
50% or greater	3 bonus square feet		

Austin's green roof density program is an example of a development incentive tied to green infrastructure. (City of Austin, Green Roof Existing Credit Fact Sheet)

by zoning codes if they include a green roof that adheres to specific requirements.³⁷

- **New York, New York:** In 2008, New York City and New York state passed legislation creating a one-year tax abatement for property owners who incorporate green roofs.³⁸ The program, which was amended in 2013, offers tax relief of \$4.50 per square foot of green roof, or up to \$100,000 of the building's tax liability.³⁹ Participating property owners must certify their green roof projects, ensuring that the green roof's vegetation layer offers 80 percent coverage.⁴⁰ The abatement is currently in place through March 2018.⁴¹
- **Nashville, Tennessee:** In response to a 2009 EPA consent decree acknowledging the 765 million gallons of combined sewer overflow sent into the Cumberland River in 2007,⁴² the city of Nashville initiated a range of stormwater management projects and policies, including a citywide Green Infrastructure Master Plan and development incentives such as Green Roof Credit Program. The Green Roof Credit program is for private properties within the combined sewer system area and offers a maximum credit of \$10 per square foot of green roof, applied to the monthly sewer charges for the property for up to 60 months.⁴³
- **Chicago, Illinois:** In Chicago, permit applications for projects with stormwater management BMPs, such as rainwater harvesting and green roofs, as well as other green technologies, such as wind turbines, photovoltaic panels, and geothermal systems, are processed through the Green Permits program.⁴⁴ Eligible buildings must also achieve LEED or Green Globes certification, or LEED for Homes for residential properties. Qualifying projects receive expedited permitting and potential for reduced permit fees.

LID Frameworks and Design Guidelines

LID frameworks and design guidelines offer the real estate community the tools to implement green infrastructure systems with market-based application. In general, low-impact development refers to practices that use natural processes for filtration and evapotranspiration, which typically preserve natural landscape features and minimize impervious surfaces. Cities with LID frameworks, guidelines, and programs often offer expedited permitting, reduced permitting fees, and other incentives to those that participate. LID toolkits are now popular across the United States and have been developed for the state, county, and city levels. In many cases, LID approaches are not mandated but are encouraged and incentivized.

Harris County, which surrounds and includes the city of Houston, was the first in Texas to offer an LID framework. John Blount, Harris County's engineer, says interest in the Houston region is largely driven by consumer interest in low-impact-style amenities. "People use [LID] to be successful," he explains.

THE PHILADELPHIA STORY: THE GREEN CITY, CLEAN WATERS PLAN

Philadelphia's *Green City, Clean Waters* plan has been lauded for its pioneering approach to using sustainable landscaping and green technologies to collectively retrofit its over-100-year-old stormwater and sewage system at a neighborhood scale and at a low incremental cost.ⁱ The plan features many of the policy tools profiled in this report, promoting green infrastructure at the citywide level and actively involving the private sector.

Green City, Clean Waters represents a holistic approach to incorporating green infrastructure across the city at a cost affordable to taxpayers. Mami Hara, former deputy commissioner of the Philadelphia Water Department, who initially pioneered the project with design firm WRT, explains that the plan did not emerge "with a wide-eyed perspective that we should use this stuff to make things pretty. It's really from a perspective of trying to make the very best use of all of our investments. In certain places, green infrastructure is the best value, and I think that holds true for developers as well."

In the 1990s, the expiration of the federal Construction Grants Program and the threat of lawsuits over contaminated stormwater runoff spurred the Philadelphia Water Department to completely overhaul the city's aging network of underground pipes, pumps, and treatment facilities.ⁱⁱ In 2012, Philadelphia reached a consent agreement with the U.S. EPA to finalize a series of decentralized investments over a period of 25 years.ⁱⁱⁱ These investments and the related policies are outlined in *Green City, Clean Waters*.

Green City, Clean Waters is estimated to cost \$1.6 billion over the lifetime of the project. An independent economic analysis of this plan estimates that, without the *Green City, Clean Waters* program, the city of Philadelphia would have needed \$8 billion to \$10 billion and several decades to upgrade and expand its conventional combined sewer overflow system.^{iv}

Today, the Philadelphia Water Department displays the progress of its stormwater management strategies, spanning 45 percent of city land, on an online interactive map, which includes 409 privately constructed and 474 publicly constructed features to date.^v

Currently, the following projects are under design or construction:

- 742 stormwater tree trenches;
- 195 stormwater planters;
- 49 stormwater bump outs;
- 179 rain gardens;
- 6 stormwater basins;
- 268 infiltration/storage trenches;

- 63 porous paving projects;
- 48 bioswales;
- 2 stormwater wetlands;
- 33 downspout planters; and
- 25 other projects.

Environmental Benefits

The Philadelphia Water Department is tracking environmental outcomes of its stormwater management services, particularly as they relate to air quality, soil erosion, the cost avoidance of sick days, and health care costs associated with asthma and heart attacks.^{vi}

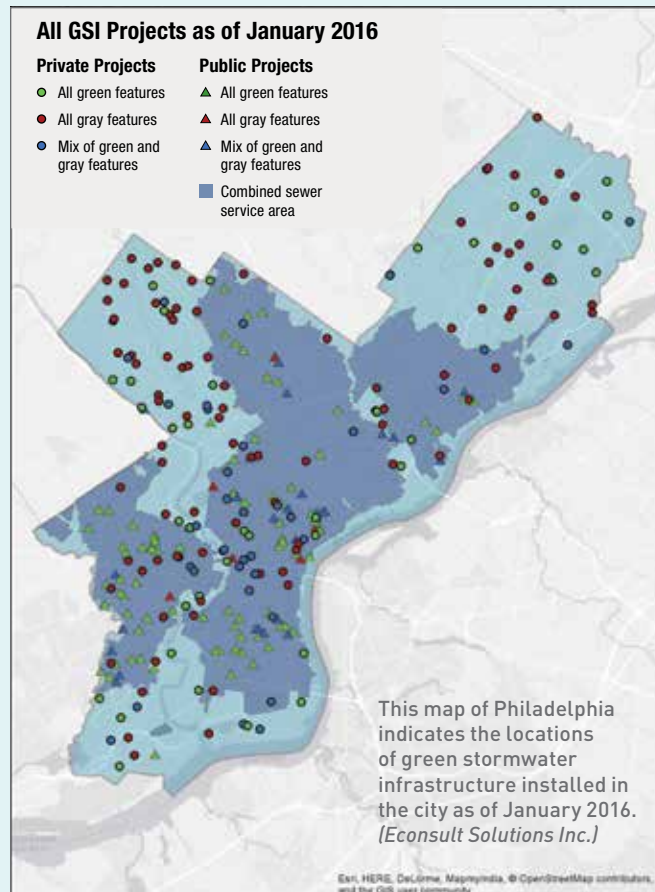
A 2011 report estimated Philadelphia waterways will have up to 85 percent fewer pollutants and 1.5 billion pounds of avoided or sequestered greenhouse gases through the plants and trees distributed throughout the city.^{vii} The program has also catalyzed up to \$8.5 million in investments over the next 40 years to restore habitats and support biodiversity in targeted locations, including the preservation of 45 acres of existing wetlands, the creation of 148 acres of new wetlands, and the restoration of 7.7 miles of streams in the Cobbs Creek watershed and 3.4 miles of streams in the Tookany/Tacony Frankford watershed.^{viii}

Economic Benefits

Conservatively, Philadelphia’s sustainable stormwater practices are estimated to have a nearly \$60 million economic impact, sustaining 430 local jobs and generating \$1 million in local tax revenue.^{ix} Local firms in the fields of architecture, engineering, and landscaping have been able to export their innovative stormwater management technologies and services to other cities, such as Washington, D.C., and New York City, which seek to emulate Philadelphia’s model policies.^x From 2013 to 2014, public and private firms related to stormwater management grew 14 percent, with revenues totaling more than \$146 million.^{xi}

Social Equity Benefits

Philadelphia’s Green City, Clean Waters program has concentrated the majority of public and private stormwater management amenities and services in low-income communities to improve environmental and physical health.^{xii} The stormwater management programs completed in the first five years of the program alone are estimated to have resulted in a total of \$9.9 million invested in local schools and \$8.1 million invested in city services through property tax revenue.^{xiii}



i. Philadelphia Water Department, *Green City, Clean Waters: The City of Philadelphia’s Program for Combined Sewer Overflow Control, Program Summary, Amended* (Philadelphia, 2011), www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf.

ii. Sarah Madden, “Choosing Green over Gray: Philadelphia’s Innovative Stormwater Infrastructure Plan” (master’s thesis, Massachusetts Institute of Technology, 2010), 24, http://web.mit.edu/cron/Backup/project/urban-sustainability/Stormwater_Sarah%20Madden/sarahmadden_thesis_MIT.pdf.

iii. Philadelphia Water, *Green City, Clean Waters*.

iv. Econsult Solutions, *The Economic Impact of Green City, Clean Waters: The First Five Years* (Philadelphia: Sustainable Business Network of Greater Philadelphia, 2016), [www.sbnphiladelphia.org/images/uploads/Green%20City,%20Clean%20Waters-The%20First%20Five%20Years\(1\).pdf](http://www.sbnphiladelphia.org/images/uploads/Green%20City,%20Clean%20Waters-The%20First%20Five%20Years(1).pdf).

v. Philadelphia Water, Green Stormwater Infrastructure Project Map, www.phillywatersheds.org/BigGreenMap.

vi. Econsult Solutions, *The Economic Impact of Green City, Clean Waters*.

vii. Philadelphia Water, *Green City, Clean Waters*.

viii. Ibid.

ix. Econsult Solutions, *The Economic Impact of Green City, Clean Waters*.

x. Ibid.

xi. Ibid.

xii. Ibid.

xiii. Ibid.



A low-impact-development approach, as seen here in Stonebrook Estates outside Houston, can create space for parks and trail access. (Terra Visions LLC)

“Whether that means gaining residential lots for development or having space for park use . . . the suburban market really wants to have access to parks and trails within the neighborhood.”

Different approaches to LID frameworks include the following:

- **Harris County, Texas:** Harris County’s LID criteria address swales, permeable pavement, stormwater planters, green roofs, rainwater harvesting, soil amendments, and other stormwater management practices. The LID manual was developed after a low-impact development design competition in the region piqued the interest of the real estate development and design community. Projects that follow LID criteria often can provide a lower volume of detention because LID techniques slow down stormwater runoff and reduce downstream impacts.
- **Nashville–Davidson County, Tennessee:** Nashville–Davidson County introduced its LID manual in response to the requirements of its municipal stormwater quality permit, which required the use of green infrastructure. The manual details the design approaches of LID and confirms which incentives are available at the county level, including green roof credits, reduced detention credits, and stormwater user fee credits, for sites designed using the approach detailed in the manual.

Stormwater Fees

Stormwater fees are a stormwater management approach likely to be familiar to any member of the real estate development community. Although not particularly innovative, stormwater fees are becoming increasingly commonplace, particularly as the cost of improving and maintaining aging infrastructure rises.

These fees typically encourage the implementation of permeable surfaces by assessing fees based on percentage of impervious area on a site, which is directly related to the amount of stormwater runoff the site discharges to the public drainage system.

More than 1,400 local jurisdictions assess stormwater user fees (proportional to each site’s burden on the public drainage system), applied toward the capital and operating expenses for public stormwater infrastructure.⁴⁵ These programs often offer credits for those incorporating green infrastructure, which reduces the site’s burden on the public system.

Models for stormwater user fees and credits can be found in the following cities:

- **Portland, Maine:** Portland has a stormwater service charge, applied to all properties with rooftops or paved areas on site.⁴⁶ However, property owners can earn credits, applied to the relevant portion of the site’s impervious area, if green infrastructure elements are incorporated.⁴⁷

CITY STORMWATER MANAGEMENT RESOURCE: NACTO'S *URBAN STREET STORMWATER GUIDE*

Following in the footsteps of the National Association of City Transportation Officials (NACTO) *Urban Street Design Guide*, the forthcoming *Urban Street Stormwater Guide* is a collaboration between city transportation, public works, and water departments to advance the discussion about how to design and construct sustainable streets that responsibly manage stormwater. Across North America, cities are meeting the dual mission of providing safe and vibrant streets for people while leveraging streets and public rights-of-way to develop resilient infrastructure.

The *Urban Street Stormwater Guide* provides cities with national best practices for sustainable stormwater management in the public right-of-way, including core principles about the purpose of streets, strategies for building interdepartmental partnerships around sustainable infrastructure, technical design details for siting and building bioretention facilities, and a visual language for communicating the benefits of such projects. The guide sheds light on effective policy and programmatic approaches to starting and scaling up green infrastructure, provides insight on innovative street design strategies, and proposes a framework for measuring performance of streets comprehensively.

Green stormwater infrastructure can be a bridge between environmental and mobility goals. Rain gardens can be

integrated in curb bulbs, enabling shorter and safer street crossings while beautifying the sidewalk. Bioswales can line bikeway and transitway buffers, making active travel modes more attractive to use and effective in function. The guide highlights case studies at many scales to give cities practical examples of success, like the Metro Green Line project in the Twin Cities, a large capital transit project serving a million transit riders each month that has catalyzed \$3 billion in commercial and residential development and uses green infrastructure to manage half the stormwater on the 11-mile corridor. On a smaller scale, a retrofit project on Newcomb Avenue in San Francisco is lowering the burden on aging stormwater infrastructure by reducing the peak stormwater flow from the street into the existing drainage system by nearly 80 percent while calming vehicle traffic and making a safer environment for residents and families.

The *Urban Street Stormwater Guide* illustrates a vision of how cities can use one of their best assets—streets—to address resiliency and climate change while creating public spaces that are truly public and nurturing streets that deliver social and economic value while protecting resources and reconnecting natural ecological processes.



Green infrastructure runs alongside Minneapolis's Metro Green Line corridor. (Metro Transit)

- **Minneapolis, Minnesota:** Minneapolis's Stormwater Credit Program encourages developers to implement stormwater management practices through an incentive program, with separate credits available for stormwater quality and quantity.⁴⁸ Building owners can reduce their stormwater fees by up to 50 percent for stormwater quality interventions and by 50 to 100 percent with interventions that address the quantity of stormwater absorbed.⁴⁹
- **Charlottesville, Virginia:** In 2013, Charlottesville implemented a Water Resources Protection program to “comply with federal and state stormwater regulations, rehabilitate the city’s aging stormwater system, address drainage and flooding programs, and pursue environmental stewardship.”⁵⁰ A stormwater utility fee provides a funding source for the program and is levied according to the amount of impervious surface on each property.⁵¹ Property owners can reduce their utility fees by either reducing impervious surfaces on site or operating and maintaining stormwater management facilities.⁵²

Monitoring and Open Data Programs

As more cities encourage data sharing and civic hacking initiatives to evaluate municipal services, green infrastructure is likely to become one of the areas analyzed. Green infrastructure is one of many topics that has been and can be studied through open data platforms. Accordingly, cities are likely to use open data as a strategy to measure the effectiveness of city investments and policies encouraging green infrastructure.

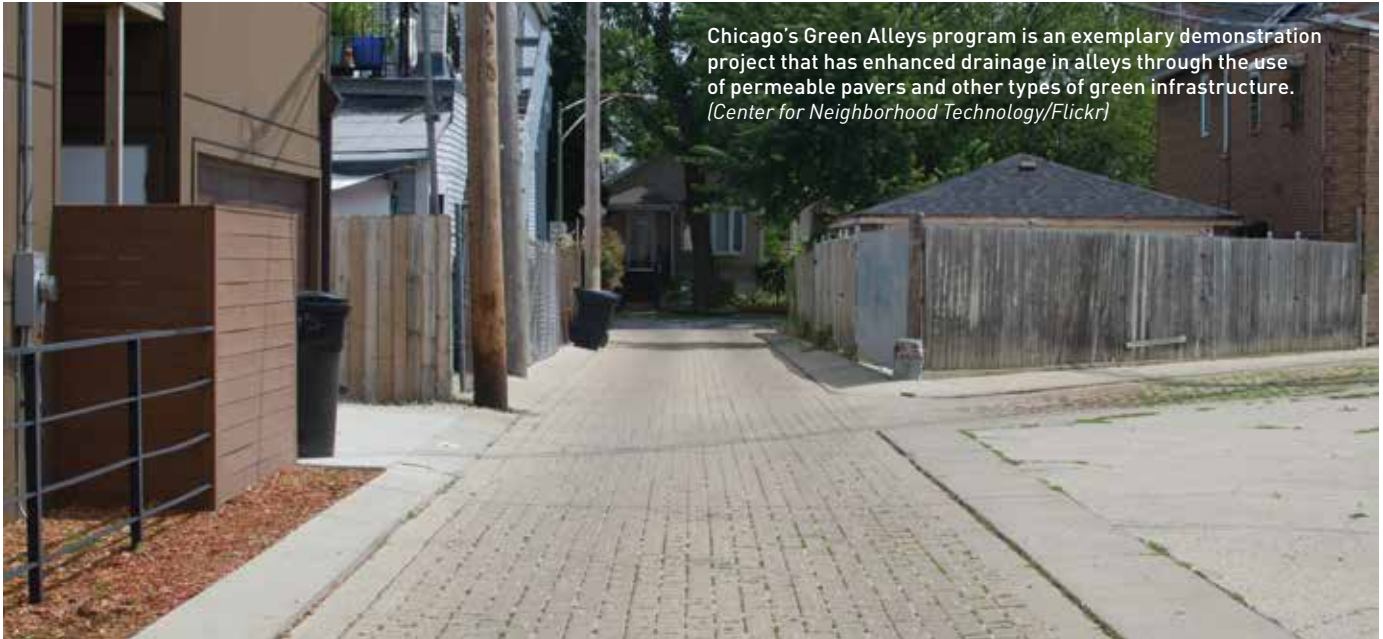
Cities using open data for analysis of green infrastructure programs include the following:

- **New York:** Open data was a key strategic initiative for the Bloomberg administration. Bloomberg initiated a citywide open data policy in 2012, which led to an Open Data Portal intended to share information on city services. The de Blasio administration has since built on these initial policies, including a 2015 initiative called Open Data for All, intended to make data sets more user-friendly and accessible.⁵³

Today, New York City’s Open Data Portal features a data set from the New York City Department of Environmental Protection on the location of sites within the NYC Green

Underground sensors at the UI LABS bioswale in Chicago collect data on soil moisture and groundwater levels, while an above-ground weather station collects data on precipitation, wind, humidity, solar radiation, and temperature. (© 2017 by UI LABS)





Chicago's Green Alleys program is an exemplary demonstration project that has enhanced drainage in alleys through the use of permeable pavers and other types of green infrastructure. (Center for Neighborhood Technology/Flickr)

Infrastructure initiative, including green roofs and bioswales. Between September 2014 and late 2016, the data set was downloaded more than 1,350 times and viewed 2,400 times.⁵⁴

- **Chicago:** Smart Green Infrastructure Monitoring, a project launched in late 2016 by Chicago-based consortium UI LABS, is using sensors and cloud computing to study the impact of green infrastructure projects. Sensors on a bioswale and a green street featuring permeable pavement and native plants are tracking soil moisture, humidity, precipitation, air pressure, and chemical absorption.⁵⁵ The project will ultimately include six green infrastructure sites, with sensors monitoring over 20,000 data streams.⁵⁶

Steve Fifita, the executive director of City Digital, explains, "The Smart Green Infrastructure Monitoring pilot combines our partners' technology into a new product—a platform that will help us make smarter decisions about stormwater management and water infrastructure maintenance, and ultimately reduce property damage caused by urban flooding."

City officials are seeking to both understand where green infrastructure has been the most effective and explore different models for data transmission, analysis, and modeling. The data will then be available on the city's open data portal in 2017. A goal is to have data on different types of green infrastructure performance in different locations and data points about which investments have been the most effective.⁵⁷

Demonstration Projects

Beyond implementing new regulations, taxes, and incentives, U.S. municipalities are also showing their commitment to green

infrastructure by investing in demonstration stormwater management projects. Although the private sector is not responsible for these costs, the projects often involve prominent sites in the public realm that can set new expectations for stormwater management. Well-designed demonstration projects can also showcase the aesthetic and community-building opportunities that green infrastructure can bring. Notable demonstration projects include the following:

- **Green Alleys, Chicago:** With 1,900 miles of alleys, Chicago has more miles of alleyways than anywhere else in the world, totaling about 3,500 acres,⁵⁸ or the paved equivalent of five medium-sized airports.⁵⁹ Initially unpaved,⁶⁰ many of these public streetscapes lack a connection to the city's combined sewer and stormwater system, making flooding a frequent problem.⁶¹

Chicago's Green Alley program, launched in 2006, promotes the incorporation of green infrastructure to avoid flooding, including permeable pavement, open-bottom catch basins, and high-albedo pavement.⁶² The city describes the cost of the program as competitive with traditional alleyway design when the decreased long-term maintenance costs are taken into account.⁶³

- **Greenstreets program, New York City:** PlaNYC, New York City's ambitious 30-year plan from 2007, committed the city to green infrastructure, including through tree plantings, stormwater management "bluebelts" (natural drainage corridors), and its Greenstreets program.⁶⁴ The subsequent *NYC Green Infrastructure Plan* provided further detail on implementation, seeking combined sewer overflow reductions and cleaner

waterways.⁶⁵ Although these long-term plans proposed a variety of new green infrastructure policies, Greenstreets was one of the smaller-scale investments that became particularly visible across the city.

Launched in 1996 by the New York City Department of Parks and Recreation as a citywide beautification project, the Greenstreets program was a popular initiative that also had tremendous potential for stormwater management.⁶⁶ The program, which is now funded by the city's Department of Environmental Protection, transforms paved medians and vacant traffic islands into green spaces designed to capture stormwater.⁶⁷

PlaNYC committed to the creation of an additional 80 green streets each year, including a \$15 million funding commitment for street design and implementation of the Greenstreets program between 2007 and 2017.⁶⁸ Researchers estimate that a 1,500-square-foot green street captures nearly 1,900 gallons of stormwater per year, with the total capturing more than 9.4 million gallons annually.⁶⁹

Community Grant Programs and Design Competitions

Design and idea competitions are an increasingly popular means of engaging the design community in solving complex environmental and community problems. Rebuild by Design, the design competition to increase resilience in the New York metropolitan area post-Sandy, is arguably the highest-profile example, particularly given that the U.S. Department of Housing and Urban Development (HUD) released \$920 million to fund the winning designs.⁷⁰ At a more local level, several cities have initiated competitions to encourage local designers and community groups to develop holistic design and land use concepts that address water management.

Numerous cities have used design and idea competitions to address critical stormwater needs and seek multidisciplinary approaches to project delivery. Community grant competitions also address a different need by encouraging local community groups to develop and initiate innovative stormwater projects. Both idea competitions aimed at the design community and grant competitions aimed at community groups raise local awareness and create opportunities to identify more efficient ways of designing and implementing green infrastructure.

- **Philadelphia, Pennsylvania:** Philadelphia's *Green City, Clean Waters* plan is one of the most ambitious in the country and uses many policy tools to advance the city's goals of reducing impervious surfaces. In June 2016, the city added an idea competition sponsored by the Philadelphia Water Department and the city's Office of the Chief Administrative Officer to the mix. The Green Stormwater Infrastructure Innovation Challenge sought to find ways to increase the effectiveness

of the *Green City, Clean Waters* plan by reducing the cost of green stormwater infrastructure projects.⁷¹ The competition sought a new strategy for assessing the subsurface conditions at potential green infrastructure sites, seeking new approaches for studying soil conditions, analyzing subsurface data, and mapping locations.⁷²

- **Portland, Oregon:** Portland's Community Watershed Stewardship Program is a community-focused stormwater grant program that offers grants of up to \$10,000 for civic groups.⁷³ Projects may address topics such as community gardens, pavement replacements, stream and park restorations, environmental education, youth leadership, and job training.⁷⁴ A recent winner of the Jimmy and Rosalynn Carter Foundation Campus Community Partnership Award, the program has been celebrated as an example of best practice in community engagement, university-city partnerships, and initiatives to advance social equity.⁷⁵ Washington, D.C., launched its own Riversmart Innovation Grant award in 2016, modeling the program after Portland's example.
- **Baltimore, Maryland:** Partnering with the Chesapeake Bay Trust and the U.S. EPA, the city of Baltimore encouraged its design community to think green through the Growing Green Design Competition in 2014. The competition focused on designs for vacant lot transformations following the guidelines in the city's *Green Pattern Book*. Seven winning projects won a total of approximately \$300,000 to design and construct the concepts.⁷⁶ The winning proposals, submitted by community groups, nonprofits, and design firms, included pocket parks, a fruit recovery garden, native plant restoration, and an urban cut flower farm.⁷⁷

Toolkits for Households

Stormwater policies focusing on larger developments, including commercial, mixed-use, and institutional projects, are often complemented with policies and tools aimed at homeowners. These programs typically offer a combination of grants, tax subsidies, and educational programming aimed at reducing impervious cover in residential properties. Cities with notable or innovative household stormwater management programs include the following:

- **Seattle, Washington:** Seattle seeks to manage 700 million gallons of annual runoff through green infrastructure by 2025, up from a current 100 million gallons.⁷⁸ Seattle's RainWise Program, which is run by Seattle Public Utilities, offers tools to encourage residents to manage stormwater at home by planting trees, composting, reducing the paved areas on their properties, and installing water management tools such as cisterns, rain gardens, and rock trenches.⁷⁹ RainWise resources include rebates for contractors, how-to booklets and videos, and lists of local suppliers.



- **Washington, D.C.:** D.C.'s Department of Energy & Environment's RiverSmart Homes program provides incentives for on-site stormwater mitigation by homeowners. Homeowners are eligible to receive up to \$2,400 worth of improvements, including incorporation of rain barrels, rain gardens, shade trees, or permeable pavers.⁸⁰

The department also runs the RiverSmart Schools program to promote schoolyard greening, including educational materials, and the RiverSmart Communities program, which provides incentives for apartments, condominiums, co-ops, locally owned businesses, and places of worship. Participants in RiverSmart Communities are eligible for rebates or for design/build LID projects in high-priority watersheds.
- **Norfolk, Virginia:** In addition to Norfolk's stormwater management planning and policies, a recent initiative sought to encourage homeowners to implement short-term, "tactical" projects to manage stormwater. The Retain Your Rain project, sponsored by the city of Norfolk, Downtown Norfolk Council, and the Rockefeller Foundation's 100 Resilient Cities program, encourages homeowners to address flooding by using rain barrels, planter boxes, and rain gardens. The workshop hosted homeowners and taught them how to build and install these facilities at a low cost, encouraging small-scale flood mitigation because "Norfolk's resilience depends on all of us."⁸¹

Many cities have adopted policies encouraging homeowners to install rain barrels and other easy-to-assemble stormwater management techniques. (© Barb Howe/Flickr)

Conclusion

Considered together, this wide range of policies, requirements, and incentives offers cities a variety of ways to work with the private development community on the implementation of green infrastructure. Examples of real estate development projects that have responded to the requirements innovatively, exhibiting best practices in stormwater management while offering successful development outcomes, are provided in the Case Studies section of this report.

GLOSSARY

Aquifer

An underground surface or geological formation that holds or conducts groundwater.

Baffle box

A concrete or fiberglass structure used to removal pollutants from stormwater by slowing the flow velocity through sediment settling chambers. It also contains a screen that skims the top, capturing floating materials and trash.¹

Basin

A landform or area draining to a point of interest. A stormwater basin collects water to reduce the risk of flooding.

Berm

A constructed area of compacted earth, designed to direct water or restrict flow.

Best management practices (BMPs)

Methods that have proven to be the most effective, practical means of preventing or reducing pollution from a source that needs to be controlled, such as stormwater runoff.² BMPs provide a basis for estimating the performance, costs, and economic impacts of achieving management quotas or policies.

Bioinfiltration

A stormwater management practice that uses vegetative land cover to filter and cleanse stormwater runoff into an aquifer.³

Bioretention

The process by which water is collected in a treatment area to advance infiltration and remove sediment.

Bioswale

A green infrastructure technique that captures stormwater runoff from a large impervious surface in a sloped vegetated area. Slopes usually use native species and allow the water to infiltrate into the ground slowly.⁴

Breathe Easy Home

Construction standards that use particular features to decrease risk factors that cause asthma and other respiratory illnesses.⁵

Carbon sequestration

The uptake of atmospheric carbon by plants and soils.

Cistern

A large storage facility, often built below ground, at ground level, or on rooftops, that stores stormwater.

Clean Water Act

An act passed by the U.S. Congress and enforced by the EPA that established the structure for regulating pollutant discharge into U.S. bodies of water. The act implements pollution control programs and water quality standards.

Combined sewer overflow (CSO)

During rain or snow events, drainage systems in a combined sewer system exceed the capacity of the collection system, discharging untreated sewage and stormwater into designated lakes, streams, and other bodies of water.⁶

Combined sewer system

Wastewater collection system that is designated to carry both sanitary sewage and stormwater in a single piping system to a treatment facility.⁷

Consent decree

A legal document used to formalize an agreement reached between the U.S. EPA and another party to correct or halt certain actions that violate the Clean Water Act or other EPA-initiated regulations; it also outlines financial penalties.⁸

Credit-trading scheme

A program policy that offers real estate developers the opportunity to purchase or sell credits for stormwater compliance in an open market. Those who own credits have met regulatory requirements for retaining stormwater.

Curb cut

A part of a street curb removed to connect the street level with another surface, often a stormwater management or green infrastructure mechanism that can absorb water in place of the traditional drainage system.

Daylighting

The process of uncovering a waterflow that was previously piped, covered, or buried to create an open channel, which improves aesthetics and allows biological activity and infiltration.

Detention pond/basin

A low-lying, porous, sometimes vegetated, area that is designed to hold water for a temporary amount of time after a weather event. Although effective at holding stormwater, detention basins do not traditionally offer water quality treatment.

Evapotranspiration

The process by which moisture is carried from the plant roots to tips for release into the atmosphere.⁹

Fee structure

A program that requires financial payments based on the amount of impervious surface on a site, encouraging investment in permeable surfaces or green infrastructure methods.

Filter medium

A material, often consisting of sand and organic matter, that removes pollutants through filtration.

Green area ratio

A score-based tool that encourages including multiple stormwater management techniques by awarding points for different mechanisms.

Green Globes

An online rating system and certification tool that also provides guidance on green building design, operations, and management. Three modules include new construction/significant renovations, commercial interiors, and existing buildings.¹⁰

Green infrastructure

Mechanisms that enable natural systems to capture stormwater runoff, enhance water and air quality, and create green space. Some examples are bioswales, green roofs, permeable pavement, rainwater harvesting, rain gardens, and tree pits.

Green roof

A green infrastructure technique that uses rooftop vegetative plantings to absorb rainwater and heat, in addition to improving air quality and decreasing energy needs for the building below.

Groundwater

Water flowing beneath the earth's surface, between rock, sand, and soil. Groundwater is the source of water for wells and springs.

Impervious surface

A hard surface that prevents or impedes the flow of water to the soil mantle, such as concrete.¹¹

Infiltration

The process by which water percolates from the land's surface into the ground.

Leadership in Energy and Environmental Design (LEED)

A rating system administered by the U.S. Green Building Council that provides the development and building industry with quantitative standards for sustainable design. The system takes into consideration five key areas: sustainable site development, water savings, energy efficiency, material selection, and indoor environmental quality.¹²

Low-impact development (LID)

A land planning and design approach that emphasizes mimicking natural system processes to store, infiltrate, retain, and detain precipitation and rainfall as close to its source as possible.

Makeup

The amount of water necessary to replenish losses caused by evaporation, leaks, or discharge in a cooling tower system.¹³

Municipal Separate Storm Sewer System (MS4) Permit

A permit required to develop stormwater management programs to prevent harmful contamination to the watershed, required for publicly owned conveyance that discharges into federal or state waters.

National Pollutant Discharge Elimination System (NPDES)

Provision of the Clean Water Act that forbids pollutant discharge into U.S. water systems by regulating point sources.

Natural drainage system

A quality of many green infrastructure mechanisms; systems that mimic the natural flow of water to create attractive open spaces while channeling stormwater.

Nonpoint-source pollution

Pollution that occurs when water runs over land, development, or through the ground and picks up pollutants that are ultimately carried into lakes, rivers, coastal waters, or groundwater.

Nonpotable water

Water that is not of drinking quality but that still may be used for other purposes, such as toilet flushing and clothes washing.

On-site mitigation requirements

Policies that require a development to capture a specific minimum volume of water, usually measured by inches of rain or a percentage of type of rain event, to deter stormwater from entering drainage or sewer systems.

Peak runoff rate

Maximum speed or flow rate of water during a storm event.

Percolation

Process by which water passes through a filter.

Permeable

Allowing liquid or gas to filter through.

Permeable pavement or pavers

Engineered porous paver, concrete, or asphalt that allows runoff to filter through strata and into a drainage system or directly into the aquifer.

Potable water

Water that is of drinking quality.

Rain barrel

A container or storage device that collects water, often from a roof.

Rain garden

A small vegetated area designed to be located where stormwater naturally flows, which captures and infiltrates runoff into the ground. It is a commonly used green infrastructure technique in landscape and streetscape designs.¹⁴

Rainwater harvesting

A green infrastructure technique that collects and stores rainwater for future use.

Retention pond/basin

A low-lying, sometimes concrete, area that is designed to hold water from a weather event for an indefinite amount of time. Retention basins hold harvested water or are connected to the sewer system for slow release.

Retrofit

A best management practice installed into a previously developed area to improve stormwater quality or reduce stormwater quantity when compared to current conditions.

Riparian

Related to a stream, river, or bank of a waterway.

SITES

A rating system administered by Green Business Certification Inc. that measures performance and value of sustainable landscaping. SITES certification projects include developments with or without buildings and range from parks to corporate campuses, streetscape, and residential homes.¹⁵

Stormwater management

Structural and nonstructural mechanisms used to control and prevent stormwater runoff over impervious surfaces into sewer systems.

Stormwater runoff

Portion of precipitation that flows over impervious surfaces and carries pollutants in quantities unmanageable by sewer and natural water systems.

Stormwater vault

A type of detention basin, this subsurface facility commonly made of concrete, steel, or fiberglass, manages stormwater in an urban setting because of its ability to capture large quantities of water.

Total maximum daily load (TMDL)

A regulatory term used within the U.S. Clean Water Act that describes the calculated maximum amount of a pollutant that a body of water can assume while maintaining designated water quality standards.

Tree pit

A commonly used green infrastructure technique that collects stormwater runoff, particularly in urbanized areas where space is limited, and diverts stormwater into the sewer system or subsoil.

Urbanization

An increase in human concentrations within dense urban areas and outer suburban periphery, which leads to the replacement of natural landscape with impervious surfaces.¹⁶

Watershed

An area of land, which is often regional, that drains to a single place, such as a river, stream, bay, or ocean.

Wetland

An area of land saturated by ground or surface water for all or part of the year. Wetland habitats typically support both aquatic and terrestrial species.

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APPENDIX

STORMWATER POLICY STRATEGIES: EXAMPLES FROM SIX CITIES (ANNOTATED)

	New York Capture rainfall on 10% of impervious surfaces by 2030	Chicago Capture up to 250 million gallons/year by 2020	Philadelphia Capture rainfall on 34% of impervious surfaces by 2035	Seattle Capture up to 700 million gallons/year by 2025	Baltimore Capture rainfall on 20% of impervious surfaces by 2018	Washington, D.C. Capture rainfall on 75% of all surfaces by 2035
STRATEGIES						
On-site water retention requirements	1	2	3	4	5	6
Credit-trading schemes						7
Green area ratios				8		9
Fee structures	10	11	12	13	14	15
Development incentives	16	17	18	19		20
Community grant programs	21		22	23	24	25
Open data and monitoring programs	26	27	28		29	30
Design and idea competitions	31		32		33	34
Household toolkits	35	36	37	38	39	40
Demonstration projects	41		42	43	44	
Greening vacant land	45		46		47	
CONTEXT						
EPA consent decree	48	49				50
EPA settlement agreement	51			52	53	
EPA partnership agreement			54		55	56
Average rainfall	50" average rainfall/year ⁵⁷	37" average rainfall/year ⁵⁸	43" average rainfall/year ⁵⁹	39" average rainfall/year ⁶⁰	42" average rainfall/year ⁶¹	40" average rainfall/year ⁶²
Public commitment	\$2.4 billion ⁶³	\$50 million ⁶⁴	\$1.6 billion ⁶⁵	\$57.7 million ⁶⁶	\$77.5 million ⁶⁷	\$2.6 billion ⁶⁸
Municipal plan	<i>2010 New York City Green Infrastructure Plan</i>	<i>2014 Chicago Green Stormwater Infrastructure Strategy</i>	<i>2009 Green City, Clean Waters: A Long Term Control Plan Update</i>	<i>2015 Seattle Green Stormwater Infrastructure, Implementation Strategy</i>	<i>2013 Baltimore City Watershed Implementation Plan</i>	<i>2012 Sustainable DC Plan</i>

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On the back cover: Green infrastructure can be used to manage water in arid climates, as pictured here at San Jacinto Plaza in El Paso, Texas. (ULI)

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