1 Streets as Ecosystems

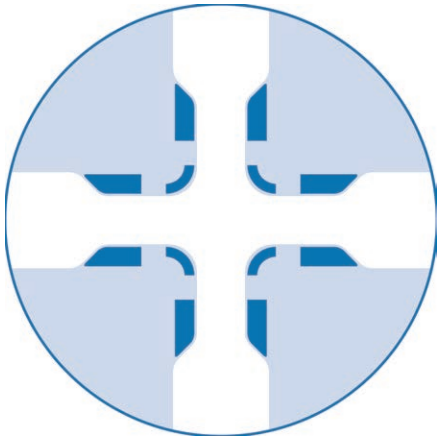
Green Street Principles

PROTECT AND RESTORE NATURAL RESOURCES

Capturing, filtering, and infiltrating stormwater is critical in urban environments where impervious surface covers 60% or more of all land area. Sustainable stormwater infrastructure filters pollutants from water and restores the natural hydrological cycle, protecting water resources.[1] Green infrastructure also improves air quality, mitigates the urban heat island effect, and increases species habitat, from small oases for birds and insects to the large water bodies that eventually receive stormwater runoff.

PROMOTE HEALTH, EQUITY, & HUMAN HABITAT

Green streets are part of healthy, equitable urban design that views streets as vital public spaces. Incorporating green elements into streets improves mental and physical health through better air quality, valuable shade, beautification, and contact with nature in areas where access to parks is limited. Ensure that the benefits of green stormwater infrastructure are provided equitably, especially in neighborhoods that have historically borne disproportionate air and water pollution or that lack green space.



DESIGN FOR SAFETY & MOBILITY

Street reconstruction projects that incorporate green infrastructure should be aligned with citywide traffic safety and mobility efforts, especially where opportunities arise to move curbs and reallocate street space for people walking and biking. Green infrastructure can be leveraged in conjunction with other street design projects to realize complementary goals, including transit access and safe mobility, providing greater value from city projects.

DESIGN FOR LIFE CYCLE

Green stormwater infrastructure is an asset for cities, providing quantifiable financial benefits. Stormwater management strategies should be planned and implemented with consideration for life-cycle costs and benefits, including the potential impacts of climate change and storm events. Green street elements that are properly designed, operated, and maintained extend the useful life of other infrastructure, especially graywater systems and pavement surfaces.

DESIGN FOR RESILIENCE

As the intensity and frequency of storms increases in many cities, and as drought conditions intensify in other cities, sustainable stormwater management is critical for climate change mitigation and adaptation. Incorporating natural systems into the built environment promotes ecosystem health and urban resilience.

OPTIMIZE FOR PERFORMANCE

Green stormwater infrastructure should be implemented at a network scale, but must be tailored to the specifics of its site. Use an understanding of topography and microclimates, available space, accessibility needs and the many human functions of a street, and desirable infiltration capacity to design appropriate green stormwater systems. Use the street to restore connections to the natural water cycle, and make comprehensive, citywide investments to see watershed-level benefits.

Vine Street, **SEATTLE, WA**

Streets are Ecosystems

The opportunity is ripe to reimagine how streets function in cities, not just as mobility corridors and public spaces, but as part of the natural ecosystem. With re-urbanization, aging infrastructure, and a changing climate, sustainable stormwater management is a core challenge for resilient cities.

Historically, streets have formed an impermeable paved layer on top of green space, disrupting hydrological cycles and requiring expensive stormwater infrastructure to manage stormwater runoff and protect ground and surface water quality. As cities face storm events of increasing frequency, duration, and intensity, as well as more persistent drought conditions, it is time to ask more of our streets.

Urban streets can reconnect rainfall to the environmental life of the city. Forward-thinking planners, engineers, and designers are treating streets as part of the ecological fabric of cities, integrating green infrastructure into the street alongside transit infrastructure and safe places for people walking and biking. By thinking of streets as ecosystems, we can build cities that are more resilient, sustainable, and enjoyable places to live.

Why Sustainable Stormwater Management Matters

Cities are defined by water. Waterways define city edges and boundaries, shape growth and development, and provide essential resources for human populations and the built environment. However, development patterns have too often removed water from urban places, channeling stormwater out of the human environment and therefore restricting natural functions and ecosystem services at great economic expense.

In the past, stormwater has been treated as waste, and stormwater management has meant dispensing of runoff as quickly as possible after a rainfall. This approach has required expensive "graywater" infrastructure: concrete and metal pipes, gutters, tanks, and treatment plants to convey, detain, and treat stormwater before discharging it into local water bodies. In many cities, intense storms overwhelm the gray infrastructure system, resulting in an outfall of polluted water into nearby streams and rivers, and potentially causing impassable streets and flooded homes and businesses. In cities across the country, gray infrastructure systems are under-maintained and reaching the end of their useful lives. Replacing this aging infrastructure can be a prohibitively expensive proposition.[2]

Such a singular approach to stormwater management is no longer possible or desirable. In an age of climate change, urbanization, and increasingly frequent, and intense storms and prolonged, devastating droughts, cities are now treating stormwater as a resource to be valued, not waste to be managed.

SEATTLE, WA

Green stormwater infrastructure (GSI) reintroduces ecological functions back into the built environment. Soil-water-plant systems—including biofiltration planters, bioretention swales, trees, and permeable pavements—intercept stormwater before it reaches gray infrastructure. Some water is infiltrated into the ground, some is evaporated into the air, and some is temporarily stored before being slowly released into the sewer system. Green stormwater infrastructure helps to reduce runoff volume to gray infrastructure and filter pollutants, protecting water quality and mitigating risks of flooding. Investments in green stormwater infrastructure complement gray infrastructure and may extend the useful life of major capital street and sewer projects. In addition to its hydrological role, green stormwater infrastructure can offer valuable co-benefits, like calming traffic and beautifying the urban landscape. An integrated approach to green stormwater management in the public right-of-way is central to the design of resilient urban landscapes.

The High Cost of Conventional Infrastructure

In 2010, New York City estimated that updating the city's stormwater system to control combined sewer overflows using only gray infrastructure would cost the city **$6.8 billion** of capital investment over twenty years. By blending gray and green strategies, the city reduced its estimated cost by $1.5 billion.[3]

Economic Losses from Storms

In 2016, four flooding events and eight severe storms have each incurred damages exceeding **$1 billion** across the United States.[4]

Public Health Risks

860 municipalities across the US with a total population of 40 million people, have combined sewer systems.[5] During heavy rainfall events that overburden the gray infrastructure system, untreated stormwater and sewage flows directly into local water bodies, causing serious public health risks and environmental pollution.

Prevalence of Urban Flooding

Storms of all magnitudes can cause flooding of homes and businesses, disrupting lives and damaging property. A study of Cook County, Illinois, found that urban flooding is chronic and systemic; property owners suffered an **average of $6,000 in damages per flooding event**, and 87% of homeowners surveyed had experienced multiple flooding events.[6] In addition to damaging buildings, flooding can disrupt street operations and prevent safe transportation.

Frequency of Storm Surges

Climate change is causing temperature increases and sea level rise, which combine to create increasingly frequent and dramatic storm surges that threaten low-lying parts of the city. In many coastal cities, "once-in-a-century" storm surges may occur once a decade in the future.[7]

The Role of Streets

Cities are uniquely positioned to take action on sustainable stormwater management.

Concrete and asphalt dominate urban landscapes. Typically in urbanized areas, 60% of land or more is impervious surface.[8] Water that falls on roofs, streets, and parking lots cannot soak into the ground, and instead becomes stormwater runoff, collecting pollutants like oil, grease, heavy metals, and bacteria before flowing through gutters and storm drains, and eventually discharging into local water bodies.

Streets comprise one-third or more of all land and half of the impervious surface in many cities.

Streets are the interstitial spaces that enable cities; they provide a network for all of the dynamic social, economic, and physical activities that make cities vital human habitat. By design, streets channel and convey stormwater, providing a network along which all the rain that falls on the city can be routed. While streets have traditionally functioned to collect and drain stormwater to water treatment facilities and designated outfalls, streets that capture and infiltrate stormwater back into the urban ecosystem can generate enormous ecological, economic, and public health benefits.

Streets present both a barrier to natural hydrology and an enormous opportunity for a better approach to stormwater management. Public rights-of-way are controlled by city agencies, from design to construction to operations to regular maintenance and permitting. Interdepartmental coordination enables more streamlined and holistic projects, ensuring that streets not only collect and infiltrate stormwater, but also realize the potential health, safety, and mobility benefits of urban stormwater street design. Integrated design strategies address water quality and regulatory compliance along with traffic calming, bike and pedestrian access, safety, urban greening and aesthetic improvements, air quality, urban temperature, public health, community development, and equity.

Existing Condition

Auto-oriented streets have large linear swaths of underutilized and impermeable space. **NEW YORK, NY**

Interim Redesign

Interim projects to test or rapidly implement geometric redesigns can introduce temporary or movable green features, like planters, that improve the human environment. Interim projects may be implemented with a local maintenance partner. **NEW YORK, NY**

Capital Reconstruction

Interim designs can be formalized during full capital reconstruction, with improvements extended to drainage, public space, street furniture, and permanent vegetation and tree plantings. Transportation, Water & Sewer, and Parks departments may all have formal roles throughout design and implementation. **NEW YORK, NY**

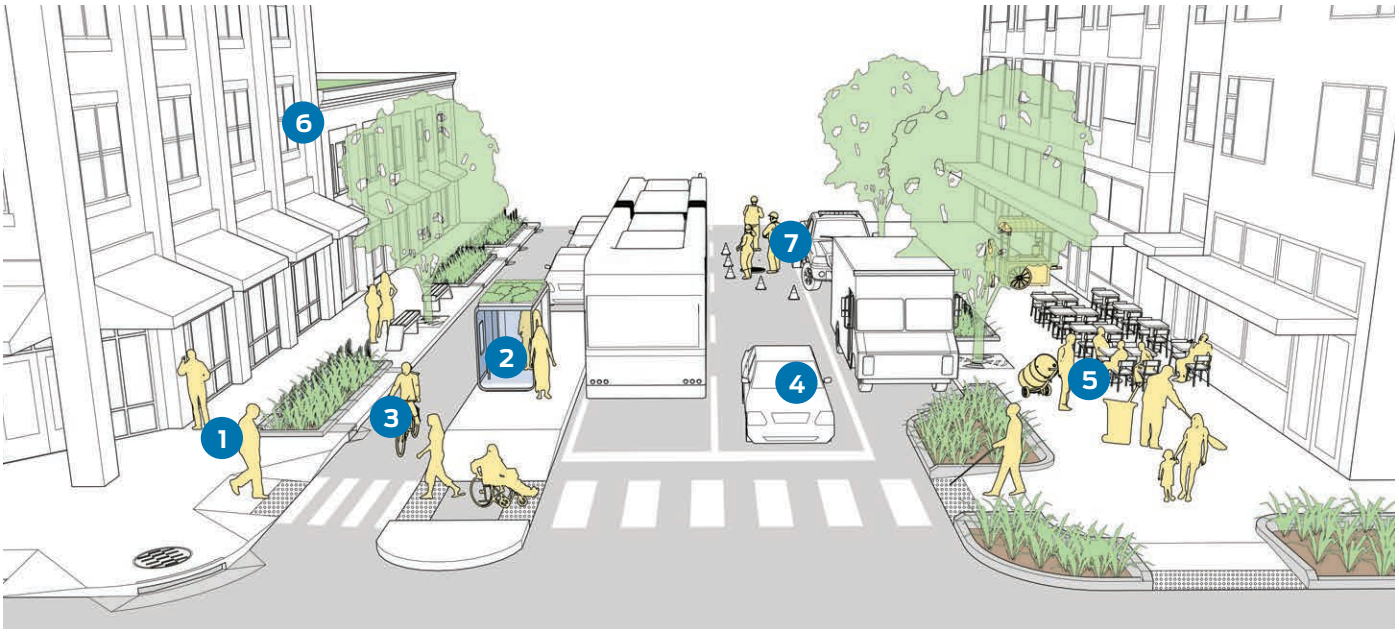
Streets can be changed; the time to act is now.

Complete Streets are Green Streets

A flooded street is not a complete street. During storm events, people walking, bicycling, and using transit are the first users to encounter barriers and lose access to the street, and are the last to regain it. Green street design tools, which integrate stormwater control and management within the right-of-way, are a critical component of complete street design, ensuring the street remains usable and safe for all people during storm events, regardless of mode.

Take into consideration both the impacts of stormwater on multi-modal travel and the potential for green street investments to transform the public realm and create economic, social, and environmental benefits for all street users.

Street User	User Considerations	GSI Benefits & Solutions
1 **People Walking**	» Ponding of stormwater, especially near intersection crossings and ramps, creates barriers, especially for people using mobility devices. Ponding may result from blocked drains and basins, wear over time to roadway slope and pavement quality, or improperly designed stormwater drainage systems. For people using mobility devices, stormwater on the street functionally and significantly prevents access. » Large or fast runoff streams also create barriers and degrade walking comfort. » Drainage grates, lips, high storm drains, and large seams sited in or near pedestrian crossings introduce hazards.	» Greenery and trees—especially those that introduce shade canopy—make the walking environment more inviting and pleasant by reducing temperature, attenuating noise, and improving air quality. » Green infrastructure can be used to calm traffic and improve safety conditions. » High-quality public gathering spaces with natural features improve mental health, and create opprtunities for community development and social cohesion.
2 **People Using Transit**	» People riding transit are also pedestrians and interact similarly with stormwater. Puddles or streams can impede walking and wheelchair access to transit stations and bus stops. » Rider comfort is enhanced by shelter, shade, and greenscape at the transit stop. Improving rider comfort and experience is critical to growing transit as a mode.	» GSI can be integrated into transit facilities, including boarding bulbs and islands, to improve passenger comfort and natural drainage near stops. » Transit shelter and facility roofs—usually owned or overseen by public agencies—can incorporate green features.
3 **People Bicycling**	» Puddling or ponding of stormwater impedes safe and enjoyable bicycling where drainage is insufficient or ineffective. » Wet pavement may discourage some potential riders who are concerned about mud and spray. An extended drying or drainage period may displace bicycle trips into other transportation modes. » The details of stormwater infrastructure design are safety-critical: poorly placed or antiquated drainage grates and storm drains can pose hazards to people biking, including slick surfaces, debris around grates, and the potential for wheels to become stuck in grates.	» Green stormwater infrastructure can be incorporated alongside bikeways to improve drainage and increase bicycling comfort and access during and after storms of any size. » Permeable pavements can be implemented on bikeways and raised cycle tracks to reduce the period of time required for pavement to dry. » Planters or vegetation may be incorporated into protected bikeway buffer elements to increase rider comfort and reduce stress.
4 **People Driving Motor Vehicles**	» Flooded streets can become impassable for motor vehicles. Puddles and pooled water can create poor or dangerous driving conditions, with splashing, poor visibility due to reflections, and unpredictable swerving to avoid water. » Poorly draining streets hinder curbside access for vehicle entry and loading.	» Green infrastructure facilities that capture runoff and reduce flooding and ponding promote safer driving conditions. » Design and site green infrastructure with sensitivity to context, and implement GSI with other geometric changes that reduce vehicle speed and improve visibility. People driving cars, especially in adverse weather, at night, or when driving at an unsafe speed, may drive their vehicle into a stormwater facility. Incursions that damage stormwater infrastructure are costly to repair.



Street User	User Considerations	GSI Benefits & Solutions
5 People Conducting Business	» Curbside access is universally critical, regardless of travel mode or trip purpose; people making freight deliveries or doing business by foot, bike, handtruck, transit, or motor vehicle all need to access the curb in order to reach their destinations. » Freight movement and deliveries are essential to businesses and cities' economies, requiring thoughtful integration into street design and urban life. Flooded streets that impede freight movement take an economic toll.	» The success and vitality of commercial districts and neighborhood storefronts depend upon the ability of workers, visitors, and essential services to be able to access and use streets comfortably. » Economic performance is tied to the comfort and attractiveness of streets—urban environments with green expressions, from planters to street trees to stormwater infrastructure, perform better than streets without green improvements.
6 People Residing	» Insufficient stormwater management on streets can cause flooding in homes and businesses. Property owners incur financial losses from flooded buildings, and insurance rates can rise after repeated claims. » Chronically wet houses and basements can reduce property values and deter potential buyers. Frequent flooding can cause mold, which can lead to an increase in respiratory problems » People may use downstream water bodies for recreational activities. Poor water quality in lakes, rivers, and streams poses a public health risk and limits opportunities to use waterfronts for recreation.	» The presence of green stormwater infrastructure can be an asset to property owners. Green stormwater networks work with gray infrastructure to mitigate flood risk, especially with careful siting guidelines and design strategies near basements and subsurface structures.[9] » Street trees and greenscape have been shown to increase property values.[10] » Green infrastructure can be implemented in collaboration with private properties to direct right-of-way runoff to bioretention areas beyond the right-of-way. » Runoff from buildings and structures can be captured and infiltrated into right-of-way green infrastructure.
7 People Working / Performing Maintenance	» City crews and utility companies require periodic access to elements within the street to perform routine or emergency maintenance, such as sewers, cleanouts, and subsurface utility lines. » Pavements cuts impact drainage and accessibility. » Snow clearance and storage during winter months impact street operations.	» Green infrastructure must be designed with maintenance in mind; crews must be able to access and navigate equipment around green elements. » Green infrastructure must be implemented with consideration for existing or planned subsurface lines (see page 24). » Vegetated strips provide linear space for snow storage.

Lawrence Street, **CHICAGO, IL**