GEORGETOWN CLIMATE CENTER
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Green Infrastructure Toolkit

Broadly called “green infrastructure,” this new set of strategies seeks to manage stormwater, reduce urban heat island effects, improve air quality, and promote economic development and other sustainability goals. Green infrastructure provides an attractive alternative to traditional concrete (or “gray”) infrastructure by making paved and hard surfaces vegetated or permeable. Permeable pavements and green roofs both capture rainfall and retain it on site, keeping it out of the stormwater system. Green infrastructure also provides wildlife habitat and greenhouse gas reduction benefits. While vanguard communities are innovating, most others are struggling to know where to begin. And while the professional design community has explored a new generation of best design practices, municipal policy frameworks have not incorporated these practices appropriately. In addition, limited resources are available to help jurisdictions develop technical expertise and share best practices. This Green Infrastructure Toolkit was developed in collaboration with leading cities to help them identify and deploy green infrastructure approaches in their communities.

This toolkit is powered by the Georgetown Climate Center's Adaptation Clearinghouse. For a full list of resources on green infrastructructure in the Adaptation Clearinghouse click here.

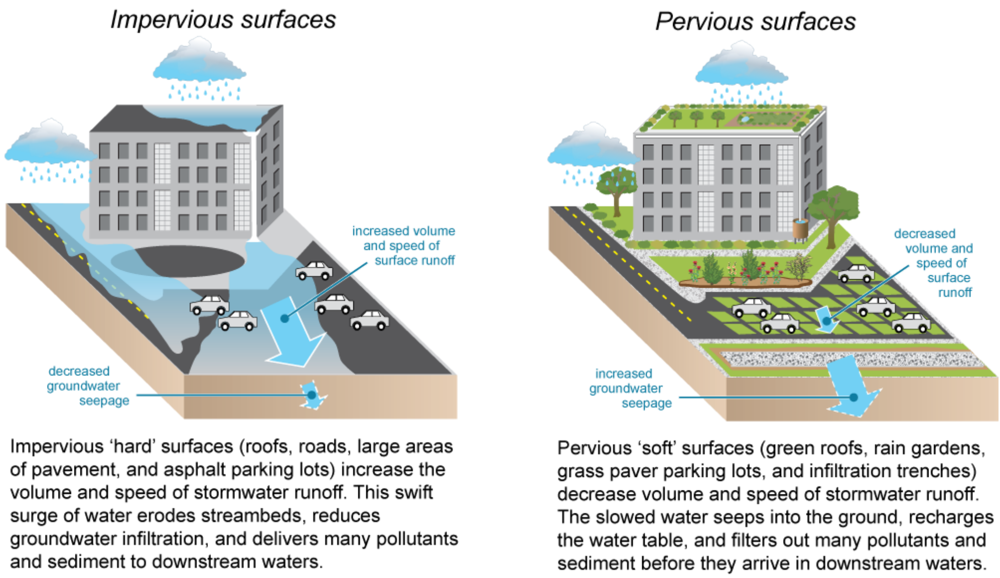
Introduction

Local governments across the country face serious challenges in managing urban stormwater (surface water runoff resulting from rainfall or snowmelt). Aging infrastructure, changes in precipitation patterns, watershed deforestation, and impervious surfaces such as roadways and parking lots cause urban flooding that pollutes waterways. Climate change will exacerbate these flood risks in many places due to more intense storms that could overwhelm existing infrastructure systems. If we fail to adapt these systems, severe repetitive flooding will increasingly affect community health, safety, and welfare, and the consequences of flooding often impose a disproportionate toll on the most vulnerable and disadvantaged populations and communities.

Innovative local communities and regions are beginning to implement a wide array of new “green infrastructure” measures, which retain and treat stormwater where it falls instead of relying on traditional, concrete-based systems largely underground. In order to ensure effective implementation, this toolkit identifies the best green infrastructure practices from cities across the country to guide those still designing their programs.

Conventional development and drainage techniques, also known as gray infrastructure, include man-made, constructed assets like roads and sewers.[1] “Gray surface infrastructure” covers natural landscapes with impervious surfaces such as concrete, asphalt, tile, or compacted gravel that increase the rate and volume of stormwater runoff. Stormwater runoff carries trash, bacteria, heavy metals, and other pollutants from the urban landscape to nearby waterways. Gray stormwater infrastructure generally uses large tunnels or other underground conveyances to move or store stormwater to treatment facilities.[2]

Green infrastructure, in contrast, includes techniques such as using permeable pavements and green roofs to both capture rainfall and retain it on site, keeping it out of the stormwater system.



Conceptual diagram illustrating impervious and pervious surfaces. Impervious surfaces are hard and increase stormwater runoff, causing pollutant and sediment delivery in downstream waters. Pervious surfaces are soft and decrease stromwater runoff, which filters out pollutants and sediments before they arrive in downstream waters.
Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Chesapeake and Atlantic Coastal Bays Trust Fund, 2013. Stormwater Management: Reducing Water Quantity and Improving Water Quality. IAN press, newsletter publication.

These techniques also provide a multitude of benefits. Green infrastructure can:

- reduce urban heat island effects through evaporation of infiltrated water and through shade provided by urban forests;[3]
- improve air quality through increases in vegetation to filter pollutants, as well as indirectly from lowering temperatures (smog forms more easily at higher temperatures);[4]
- absorb carbon, because vegetation uses carbon dioxide as part of photosynthesis;[5]
- improve water quality by reducing runoff and filtering pollutants from the runoff that infiltrates or gets stored;[6] and
- provide urban recreational and open space.[7]

Building green infrastructure is not without challenges, however. In past years stormwater managers have struggled to quantify the effectiveness of green infrastructure, especially as compared to gray infrastructure. Ongoing monitoring programs are detailed in the Getting Started chapter of this toolkit. Green infrastructure can require collaboration by multiple local agencies that do not always work closely, such as transportation, stormwater, and public health. Successful collaboration efforts are also detailed in the Getting Started chapter. Last but not least, green infrastructure requires different, ongoing maintenance than traditional stormwater infrastructure. Coordinating and paying for that ongoing maintenance can be difficult to plan and implement. The Scaling Up chapter and Funding chapter describes how local governments are beginning to solve the maintenance challenge.

While vanguard communities are innovating, many others are struggling to know where to begin. And while the professional design community has developed a new generation of best design practices, municipal policy frameworks (land-use regulations, street design, etc.) have not institutionalized these practices appropriately. In addition, limited resources are available to help jurisdictions develop technical expertise and share best practices. This toolkit therefore has a chapter dedicated to incorporating green infrastructure practices into jurisdiction-wide plans and processes, from comprehensive plans to zoning and building codes.

Green infrastructure also has to operate within legal and regulatory frameworks at the federal, state, and local level. The Clean Water Act, for example, requires the US Environmental Protection Agency (EPA) to address stormwater runoff[8] in its effort to "restore the chemical, physical and biological integrity" of the waters of the nation.[9] In doing so, EPA has created consent agreements with many municipal governments. These agreements legally require cities to come into compliance with the Clean Water Act's requirements including controlling overflows from combined sewer systems. Local governments can incorporate green infrastructure practices in addition to gray infrastructure; cities from Louisville, KY to Chicago, IL, have incorporated green infrastructure into those formal agreements.[10]

State and local legal authority questions also affect implementation of green infrastructure at the local level. For example, some local governments have funded green infrastructure by setting up a stormwater utility or charging stormwater fees. However, to do so, local governments need specific authority delegated from their state legislatures authorizing the creation of a stormwater utility and the collection of those fees. The absence of the legal authority to establish a stormwater utility or to establish a stormwater fee can hinder a local government's ability to implement and pay for green infrastructure. Finally, constraints in some states on local authority over zoning or building codes can diminish a city's ability to change policy to require or encourage green infrastructure. This toolkit addresses these legal constraints and requirements where appropriate throughout.

The next tab in this introductory chapter introduces different green infrastructure techniques and their various applications.

Tools

Green Infrastructure Strategies and Techniques

Green infrastructure techniques for managing stormwater come in a variety of types, and several techniques can often be combined in one project. All provide stormwater management and water quality benefits, but each provides a different variety of co-benefits (social or public health, for example) and different approaches are more appropriate based upon site-specific conditions. The following describes the range of green infrastructure interventions, how each works, the benefits each brings, and the type of sites where the technique can be deployed.

Learn more at http://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/green-infrastructure-strategies-and-techniques.html

About This Toolkit

The purpose of this toolkit is to analyze common trends in the approaches various cities are taking to planning, implementing, and funding green infrastructure to manage stormwater. The toolkit is intended to aid local governments nationwide in comparing best practices across cities, drawing lessons from different approaches, and crafting similar policies for their own jurisdictions.

Learn more at http://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/about-this-toolkit.html

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Figure 1: *Green Infrastructure Approaches*

Street Features
Green infrastructure approaches can be incorporated into street design with permeable pavements, bioswales, tree pits, green streets, green alleys, and green parking.

Building Features
Buildings can be "greened" with green roofs, downspout disconnections, and rain barrels.

Landscape Features
Landscapes can be used to manage stormwater with rain gardens, urban tree canopy, land conservation, stream buffers, and stormwater parks.

Green roofs: Traditional roofs absorb sunlight and radiate heat into the surrounding air.[11] Vegetation on green roofs shades the roof and cools the air through evapotranspiration.[12] In this way, vegetation can cause a green roof to be 100 °F cooler than a traditional black roof,[13] and these cooler roofs transfer less heat to the ambient air. Green roofs do not have as great a cooling effect on air temperatures as ground-level vegetation does, but they have the advantage of not taking up additional land and of keeping building occupants cooler.[14] In addition to managing stormwater, green roofs help decrease energy use, improve air quality, and reduce heat.[15] Green roofs, however, are not without challenges: They require greater structural support than cool roofs and are expensive to install.

Permeable pavements: Permeable pavements have spaces for air and water to pass through; the spaces allow water to infiltrate into the ground, reducing runoff. Asphalt and concrete can both be made porous by omitting the smaller aggregates that are usual components.[16] More specialized forms of porous pavements include interlocking concrete pavers, in which water drains through the gaps between precast blocks, and grass or gravel pavers, in which fill materials are laid on top of a plastic grid.[17] Permeable pavements also have cooling properties due to evaporation and reduced heat storage.[18] Permeable pavements are appropriate for sidewalks, parking lots, alleys, and streets; some concerns about whether permeable pavements are appropriate for cold climates or high-traffic areas are being monitored and evaluated now in cities like Chicago and Washington, DC, with positive results to date.[19]

Bioretention and Bioswales: Bioswales are a type of stormwater retention that use an open-channel shape and vegetation to slow runoff and filter pollutants, reducing strain on stormwater infrastructure and improving water quality.[20] Often integrated into streetscapes or used to convey stormwater away from critical infrastructure, bioswales can also reduce the need for gray stormwater systems to be installed by capturing and storing some of the stormwater.[21] Bioswales can also reduce temperatures, increase habitat for urban wildlife, and improve air quality. As an added benefit, they are often aesthetically pleasing and potentially increase property values.

Green Streets, Alleys, and Parking Lots: Green streets, alleys, and parking lots can combine all of the above strategies (except perhaps green roofs) into a coherent package. By combining the strategies, green streets can provide multiple benefits, including runoff and pollutant reduction, air quality improvement, and urban heat island mitigation.[22] Local governments primarily install green streets in the public right-of-way, but green alleys and parking lots can be installed on both public and private land. For all three, a critical element can be to minimize pavement in the first place.

Rain Gardens: Rain gardens are small gardens that are designed to survive extremes in precipitation, and help retain or reduce stormwater runoff through infiltration or storage.[23] The gardens are often small and placed strategically in areas where stormwater currently overwhelms drainage capacity. They can be incorporated as part of general landscape design or as part of a larger streetscape (see Green Streets, Alleys, and Parking Lots, just below). In addition to managing stormwater and reducing nutrient pollution, rain gardens can also reduce temperatures, provide wildlife habitat, and improve aesthetics.[24] Rain gardens can be installed in many different areas and do not need to take up much space.

Urban Forestry: Urban forestry is suitable for both public and private properties, including rights-of-way and near existing buildings and homes for shade. Urban trees provide air quality and heat reduction benefits, along with mental health and other social benefits.[25] Urban forestry policies can include not only increasing existing canopy (many local governments are setting percentage targets) and planting new trees, but also ordinances to preserve existing mature trees, which provide greater benefits for stormwater and public health than young trees.[26] Ongoing maintenance and care can be a concern for urban forestry, as well as balancing canopy goals with power utility concerns, particularly during extreme weather events.

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The Georgetown Climate Center benefitted from the expertise of an extensive network of experts and leading communities pursuing adaptation across the country to develop this toolkit of best practices for using green infrastructure to manage stormwater in the face of changes in precipitation due to climate change. Our advisory group included expert representatives from Milwaukee, WI; Ann Arbor, MI; Detroit, MI; Cambridge, MA; Baltimore, MD; Delaware County, PA; Washington, DC, Santa Fe, NM; and Denver, CO; the Environmental Protection Agency (EPA) Innovation Division and Office of Water; the Urban Sustainability Directors Network (USDN); Smart Growth America (SGA); the National Association of City and County Health Officials (NACCHO); and the University of Maryland Environmental Finance Center. By aligning the development of this toolkit with these organizations, GCC was able to reach a broader national platform, provide desperately needed research capacity to these front-line networks of public officials, and connect this work to public health officials who provide an important constituency in advocating measures that improve water quality. We developed this toolkit in response to requests made by a number of communities through a Request for Proposals (RFP) GCC released in late 2013. Over a quarter of the applications we received from across the U.S. involved requests for assistance with stormwater, illustrating the needs jurisdictions face in trying to use green infrastructure to adapt. GCC would like to thank representatives from those organizations and local governments listed above for their assistance in developing the content.

Endnotes

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