



# INNOVATIVE APPROACHES TO MUNICIPAL STORMWATER MANAGEMENT

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## **Innovative Approaches to Municipal Stormwater Management**

*Utilizing Green Infrastructure as a Cost-Effective Means to Reduce Stormwater Runoff and Improve Water Quality*

### **INTRODUCTION**

Precipitation events produce massive amounts of water, which flow into the nearest body of water following the path of least resistance. In natural settings, pervious surfaces are abundant, allowing water to infiltrate into the ground. However, in built environments, impervious surfaces, such as roads, sidewalks, buildings and parking lots that inhibit the natural infiltration of water, abound. Since water cannot penetrate impervious surfaces it must instead flow over them as runoff. In urban areas excess water is collected in an engineered system of stormwater drains to control flow. Along its path, stormwater runoff may collect debris, sediment, and contaminants, resulting in negative environmental impacts to the water bodies into which it ultimately flows. Additionally, many large U.S. cities have combined sewer and stormwater systems in which large rainfall events may produce high stormwater flows that result in untreated sewage flowing directly into natural water bodies, further contributing to water quality degradation.

Green infrastructure may be implemented in urban and rural areas as a means to manage runoff entering stormwater drainage systems. In contrast to traditional grey infrastructure, such as stormwater drains, green infrastructure mimics natural, pre-development landscapes and their ability to capture, retain, and reuse water on-site. Green systems reduce stormwater flows, help to restore natural hydrology patterns, and improve water quality. Cities across the United States are recognizing the ecological and economic benefits green infrastructure presents and have begun implementing it into their water management plans in a variety of ways. This report highlights various green infrastructure techniques and some of the unique approaches of large municipalities.

### **TRADITIONAL STORMWATER MANAGEMENT**

Traditional stormwater management in the United States was developed with the intent of transporting stormwater away from urban centers as quickly as possible through the use of engineered storm drains, typically referred to as grey infrastructure. This method effectively reduces flooding in cities, but unfortunately, can lead to a host of negative environmental outcomes. Grey infrastructure creates an increased flux of discharge, may cause flooding of downstream areas, and contributes to urban and rural water quality degradation. Furthermore,

#### **Green Infrastructure and Low Impact Development (LID)**

On a broad scale, green infrastructure is defined as “strategically planned and managed networks of natural lands, working landscapes and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations.”[1]

Green infrastructure ranges widely in scale from ecosystem-wide to site-specific systems. For the purpose of this report, the scale of green infrastructure focuses on site-specific solutions for municipal stormwater management.

LID is an approach to land development and redevelopment that focuses on utilizing natural features to manage stormwater on-site. Often times, especially on a smaller scale, the terms LID and green infrastructure are used interchangeably. However, on a broader scale, LID serves as a tool utilized within the green infrastructure framework.

[1] Green Infrastructure: The Conservation Fund. “What is Green Infrastructure?”  
<http://www.greeninfrastructure.net/content/definition-green-infrastructure> Accessed June 28, 2012.

where cities employ combined sewer overflow systems, excess stormwater is mixed with untreated sewage and deposited directly into local waterways raising additional concerns about water quality and public health.<sup>1</sup> In order to manage stormwater in a more environmentally friendly way municipalities have begun employing green infrastructure techniques. In areas dominated by impervious surfaces, green infrastructure strives to maintain natural hydrologic functions by absorbing and filtering rainwater to levels similar to the landscape prior to development.<sup>2</sup>

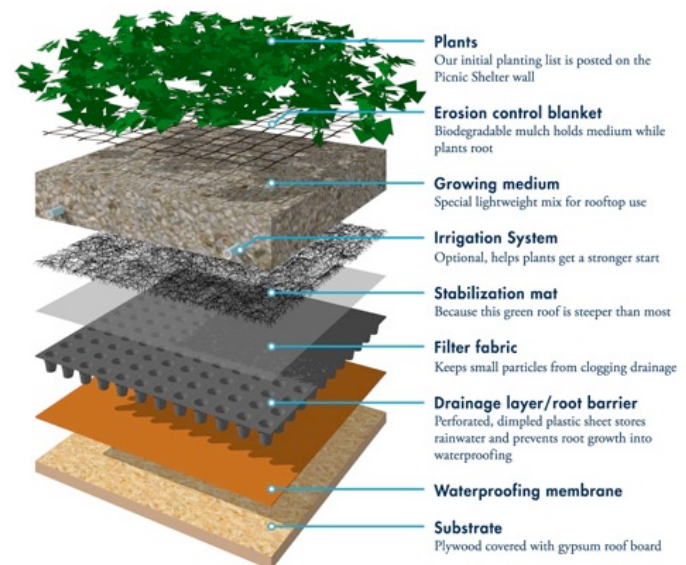
## GREEN INFRASTRUCTURE: TECHNIQUES FOR STORMWATER MANAGEMENT

Green infrastructure captures rainwater on-site and reduces stormwater runoff through a variety of techniques that include diverse approaches to design and construction as well as use of alternative materials.

### GREEN ROOFS

Green roofs are rooftop gardens planted with vegetation that aid in decreasing stormwater runoff volumes by capturing and retaining considerable amounts of rainfall on-site. According to a stormwater management study conducted by the EPA in 2008, green roofs have the potential to remove 50% of the annual rainfall volume from a given roof through water retention and evapotranspiration.<sup>3</sup> Green roofs range in scale from low-intensity plantings to food producing gardens or tree bearing landscapes. Green roofs can be effective in reducing stormwater runoff volumes and can also reduce building management costs (roof repair, heating and cooling costs), improve air quality by decreasing airborne particulates, and aid in reducing the urban heat island effect.<sup>4</sup> In order for green roofs to perform these intended functions they must be engineered and maintained properly. Green roofs that are improperly designed and maintained may result in drainage issues.

**Figure 1: Typical Green Roof Layers**



Source: MN Landscape Arboretum – “The Green Roof at the Minnesota Landscape Arboretum”

[http://www.arboretum.umn.edu/green\\_roof.aspx](http://www.arboretum.umn.edu/green_roof.aspx)

It is important to note that green roofs are not simply roofs covered in soil and plants – they are designed using layers of engineered materials such as waterproofing membranes, filter fabrics, drainage layers, and substrates. These layers allow for the growth of plants, storage of water and protection of the roof structure (Figure 1). The type of vegetated cover a roof can support is

<sup>1</sup> Combined Sewer Overflows. EPA. [http://cfpub.epa.gov/npdes/home.cfm?program\\_id=5](http://cfpub.epa.gov/npdes/home.cfm?program_id=5) Accessed June 25<sup>th</sup>, 2012.

<sup>2</sup> *Stormwater Management*, Center for Watershed Protection <http://www.cwp.org/your-watershed-101/stormwater-management.html> March 6 2012

<sup>3</sup> “Green Roofs for Stormwater Runoff Control.” EPA Office of Research and Development – Water Supply and Water Resources Division. Report Number EPA/600/R-09/026. February 2009.

<sup>4</sup> Green Roofs. EPA <http://www.epa.gov/heatisld/mitigation/greenroofs.htm> Accessed March 6 2012

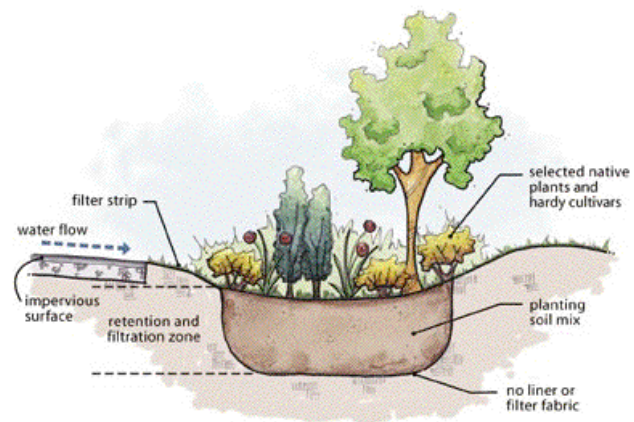
based on its respective structural integrity. The roof structure must accommodate the weight of the vegetation, substrate, and the planned volume of stored water, a factor that is important for consideration when designing new green roofs or retrofitting old buildings. An example of an innovative green roof retrofit can be seen atop Target Center in Minneapolis, MN. The aging sports arena's rooftop was replaced with a green roof in 2009 as a means to manage stormwater, conserve energy, and reduce the urban heat island.<sup>5</sup>

### *RAIN GARDENS*

Rain gardens are shallow vegetated depressions that collect rainwater from roofs and other impervious surfaces such as sidewalks and driveways. Similar to green roofs, rain gardens utilize vegetation in order to promote water infiltration and evapotranspiration, thus effectively removing a significant amount of water from stormwater drainage systems by retaining it on-site. A recent study conducted by the USGS discovered that rain gardens are effective at capturing close to 100 percent of stormwater runoff from the roof of an adjacent building regardless of soil type.<sup>6</sup>

Rain gardens can enhance landscape aesthetics and improve water retention, while also incorporating native plant species that provide diverse benefits and are tolerant of the climatic conditions of a given region.<sup>7</sup> Vegetation native to a given area's climate that has a deep root structure is especially effective at capturing, storing and infiltrating water. To ensure that rain gardens perform their desired function, it is important that they be well designed and maintained through periodic removal of accumulated sediments and dead vegetation. It is also important to perform seasonal rain garden maintenance to ensure an optimal lifespan of the system.

Rain Garden Schematic



Source: Hinman, Curtis. "Low Impact Development: Technical Guidance Manual for Puget Sound." Washington State University and Puget Sound Action Team. January, 2005.

When collecting water from rooftops, downspout redirection may be required in order to direct water into a rain garden. When a property's downspouts drain directly into the stormwater drainage network, downspout disconnection is required to redirect water flows. In order to retain water on-site, many municipalities promote downspout redirection and disconnection programs that encourage property owners to reroute their vertical drainage pipes so that their rooftop runoff drains into naturally porous mediums, such as rain gardens, or to on-site storage units, such as cisterns.

<sup>5</sup> Maynard, Meleah. "Target Center's Green Roof: A prairie in the sky". MinnPost. August 13, 2011. <http://www.minnpost.com/politics-policy/2011/08/target-centers-green-roof-prairie-sky>

<sup>6</sup> Selbig, William R. and Blaster, Nicholas. "Evaluation of Turf-Grass and Prairie-Vegetated Rain Gardens in a Clay and Sand Soil, Madison, Wisconsin, Water Years 2004-08". USGS, 2010. <http://pubs.usgs.gov/sir/2010/5077/>

<sup>7</sup> "Stormwater Technology Fact Sheet: Bioretention" EPA. EPA 832-F-99-012. September 1999

One common misperception of rain gardens is that they harbor mosquito breeding, however this may only occur if they are poorly constructed and poorly maintained. Rain gardens that are properly engineered and constructed allow water to infiltrate within 24 to 48 hours. Mosquito larvae require 24-48 hours to hatch and must live in standing water for 7-12 days before adult maturation.<sup>8</sup> According to a study conducted by Cooperative Extension at Rutgers University, rain gardens should be designed and constructed to drain water completely within 72 hours in order to prevent mosquito habitat.<sup>9</sup> The study goes one step further and suggests that rain gardens should be designed to allow water infiltration within 48 hours as a means of additional safety. In highly urban environments containing a large amount of impervious surfaces, rain gardens are typically built with emergency overflows so that excess water can be carried into existing stormwater sewers in order to avoid long periods of standing water.

#### *VEGETATED SWALES*

Vegetated swales (also referred to as bioswales) are broad, shallow channels planted with dense vegetation.<sup>10</sup> Because of their linear shape they are commonly installed along streets and parking lots and may replace gutters and sewers typically found in traditional stormwater designs. Bioswales can reduce peak water flows, encourage runoff infiltration, and promote pollutant capture. Similar to rain gardens, bioswales need to be properly designed for expected water flows and maintained through removal of sediments and accumulated vegetation.

#### *RAINWATER HARVESTING*

Rainwater harvesting utilizes systems that collect and store rainfall for future use. Rainwater capture systems reduce runoff volumes and provide a stored source of water, making it an especially attractive practice in arid regions where surface and groundwater resources are less abundant.<sup>11</sup> Two methods of capturing rainwater are common: rain barrels – barrels placed at the end of downspouts, and rain cisterns – larger, more durable storage tanks connected to rooftop drainage systems with pumps to redirect water for irrigation, plumbing, and gardening use. Rainwater harvesting systems need to be well designed to fit with expected rainfall quantities of a given location and maintained to ensure that stagnant water does not create public health or aesthetic concerns.

#### *PERMEABLE PAVEMENTS*

Permeable pavements allow water to infiltrate into underlying subsoil and shallow groundwater systems and provide an alternative to impermeable surfaces. There are several types of commercially available pervious surface materials including porous concrete, porous asphalt, and permeable interlocking pavers. Since the permeable nature of the material allows precipitation to

Bioswale along Street Boulevard



Source: Gardens by Gabriel, Inc.  
<http://www.gardensbygabriel.com/blog/>

<sup>8</sup> *A Word About Mosquitos*. Rain Garden Network. <http://www.raingardennetwork.com/mosquito.htm> Accessed June 25, 2012.

<sup>9</sup> Rector, P., Duckworth, T., and Obropta, C. "Rain Gardens and Mosquitos Fact Sheet." Rutgers Cooperative Extension. January 2012.

<sup>10</sup> *Storm Water Technology Fact Sheet: Vegetated Swales*. EPA September 1999  
[http://water.epa.gov/scitech/wastetech/upload/2002\\_06\\_28\\_mtb\\_vegswale.pdf](http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_vegswale.pdf)

<sup>11</sup> *Rainwater Basics*. Texas A&M AgriLife Extensions <http://rainwaterharvesting.tamu.edu/rainwater-basics/> Accessed March 6, 2012

infiltrate, the materials are less vulnerable to cracks and potholes caused by freeze-thaw cycles.<sup>12</sup> Permeable surfaces are generally lighter in color and can also decrease the urban heat island effect.

#### *STORMWATER BUMP-OUTS*

A stormwater bump-out is a curb extension filled with vegetation that protrudes into the street either midblock or at an intersection.<sup>13</sup> They feature curb cutouts, or inlets, that direct runoff from the street into a vegetated patch where it then can be temporarily stored, promoting infiltration and evapotranspiration. As with other types of green infrastructure, stormwater bump-outs must be well designed to manage expected stormwater volumes based on a given area's average annual rainfall and respective site conditions. Since stormwater bump-outs are engineered for average storm events they must contain emergency overflow devices that direct stormwater towards grey infrastructure in order to reduce flooding during large storm events. In addition to stormwater management, they also contribute to improved public safety by calming traffic and, when located at cross walks, reduce the distance pedestrians must cross.

Stormwater Bump-out in Portland, OR



Source: Streetsblog.org – "Portland's Greenstreets Model a Sterling Best Practice Model"

<http://sf.streetsblog.org/2009/11/13/portlands-greenstreets-program-a-sterling-best-practice-model/>

#### *TREE PLANTING*

Planting trees in urban and rural areas increases the amount of naturally pervious surfaces, which allows water to remain where it falls. Trees are highly effective at capturing incoming precipitation and storing it within their leaves and branches, a process known as interception storage. Depending on the given size and species of a tree, it can effectively store 100 gallons of water or more before it reaches saturation.<sup>14</sup> Trees also promote water infiltration at ground level through porous surface soils and extensive root systems. Within cities, increased tree canopies contribute to higher albedo levels (solar reflectance), resulting in a decrease in the urban heat island effect. Aside from stormwater benefits, tree plantings provide psychological, environmental, aesthetic, and spiritual benefits.<sup>15</sup> The establishment of trees in urban areas needs to be well planned to ensure that conflicts with other land uses are minimized. Trees must also be maintained and periodically replaced.

<sup>12</sup>Brattebo, B & Booth, D. "Long-term Stormwater Quantity and Quality Performance of Permeable Pavement Systems." *Water Research*. 37.18 (2003): 4369-4376.

<sup>13</sup>*Stormwater Bumpout*. PWD [http://phillywatersheds.org/what\\_were\\_doing/green\\_infrastructure/tools/stormwater\\_bumpout](http://phillywatersheds.org/what_were_doing/green_infrastructure/tools/stormwater_bumpout) Accessed 29 May 2012

<sup>14</sup> MacPherson, Dr. Greg and Karpis, Jennifer. "How Trees Can Retain Stormwater Runoff". Arbor Day Foundation – Tree City USA Bulletin. No. 55, 2010. [http://www.fs.fed.us/psw/programs/uesd/uep/products/11/800TreeCityUSABulletin\\_55.pdf](http://www.fs.fed.us/psw/programs/uesd/uep/products/11/800TreeCityUSABulletin_55.pdf).

<sup>15</sup>*Chicago Trees Initiative*. City of Chicago. <http://www.chicagotrees.net/chicago-trees-initiative/> Accessed 23 May 2012

*GREEN STREETS*

Green streets include block-scale planning and design concepts that mimic natural conditions to manage stormwater while still facilitating traffic flow.<sup>16</sup> They incorporate a number of the green infrastructure techniques previously mentioned in a variety of ways depending on site-specific conditions, budget concerns and community involvement. Municipalities are applying green street designs to new streets as well as existing streets in need of retrofitting. The benefits of green streets include traffic calming, increased pedestrian usage and safety, increased on-site water retention, and enhanced landscape aesthetics. It is important to select locally appropriate green street techniques and create plans necessary for long-term maintenance.

**COST COMPARISONS: GREY VS. GREEN**

As grey infrastructure systems age and impervious surface expands in urban areas, municipalities, and ultimately taxpayers, are faced with significant stormwater management costs. Instead of spending millions of dollars repairing and upgrading current grey infrastructure systems, municipalities are increasingly turning to green infrastructure as a cost-effective strategy since it tends to cost less to install and maintain than its grey counterpart. Green infrastructure reduces costs of improvements to aging grey infrastructure, can reduce costs associated with stormwater management within new developments and redevelopments, may be integrated cost-effectively into other infrastructure projects such as roofs and driveways, and can reduce stormwater-related energy and flood costs.<sup>17</sup> Furthermore, money spent on grey infrastructure addresses urban stormwater quantity issues but does little to address water quality, whereas green infrastructure addresses both while simultaneously addressing future cost savings.

**ROADBLOCKS TO CONSIDER**

Although green infrastructure can save cities and taxpayers water service and related infrastructure costs, it is not always perceived positively by community interests. Without proper planning, site analysis, public outreach and education, green infrastructure may induce negative externalities that do not suit the best interests of local residents. For example, poorly planned rain gardens in Seattle's Ballard neighborhood initially resulted in standing water pools, inciting local residents' resentment and fears associated with aesthetics and safety.<sup>18</sup>

Additionally, as municipally funded green infrastructure projects are developed throughout the country, questions have been raised regarding who's responsible for ongoing maintenance and associated costs. Portland's Green Street Stewards program addresses these issues by setting up volunteer community agreements to maintain their Green Street infrastructure.<sup>19</sup>

Another area of contention presents itself amongst individual's preexisting embedded values. For example, some green infrastructure projects promote the use of native plant species, yet many people are not pleased with their aesthetics and prefer "traditional" lawns and landscaping.

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<sup>16</sup> Das, Nibedita. "Green Streets – An Innovative Street Design Approach". Sustainability and Built Environment, UC Davis. 31 October 2006. [http://extension.ucdavis.edu/unit/green\\_building\\_and\\_sustainability/pdf/resources/green\\_streets.pdf](http://extension.ucdavis.edu/unit/green_building_and_sustainability/pdf/resources/green_streets.pdf)

<sup>17</sup> N Garrison & K. Hobbs. *Rooftops to Rivers II: Green strategies for controlling stormwater and combined overflows*. NRDC 2011

<sup>18</sup> Seattle Public Utilities, Ballard Roadside Raingardens

[http://www.seattle.gov/util/Services/Drainage\\_&\\_Sewer/Keep\\_Water\\_Safe\\_&\\_Clean/CSO/CSOReductionProjects/BallardBasin/BallardRoadsideRaingardens/index.htm](http://www.seattle.gov/util/Services/Drainage_&_Sewer/Keep_Water_Safe_&_Clean/CSO/CSOReductionProjects/BallardBasin/BallardRoadsideRaingardens/index.htm)

<sup>19</sup> <http://www.portlandonline.com/bes/index.cfm?c=52501>

Another example - many green street designs include vegetated bump-outs that absorb street runoff, yet negative reactions occur since they tend to occupy areas previously available for parking. Thus, additional public outreach and education may be needed regarding certain aspects of green infrastructure in order for them to appeal to local residents. Effective use of cost-benefit analysis is also important to demonstrate to decision makers and homeowners that green infrastructure investments are financially responsible.

It has also been shown that green infrastructure tends to occur most frequently in neighborhoods with higher property values and not necessarily in urban centers or lower-income areas.<sup>20</sup> It is important that cities and green infrastructure supporters recognize this imbalance and implement initiatives, pilot projects, and incentives that provide greater distribution of benefits.

## **GREEN STORMWATER MANAGEMENT: MUNICIPAL CASE STUDIES**

### **PORTLAND, OREGON**

Portland, Oregon has combined community efforts and municipal requirements to create more sustainable ways to manage the average 37 inches of annual precipitation that the city receives.<sup>21</sup> The city's watershed history includes significant problems stemming from a combined sewer overflow system, impervious surfaces, small frequent storm events, and industrial pollution of the Willamette River. In 1991, the city began a 20-year Downspout Disconnection Program that disconnected more than 56,000 downspouts in the combined sewer overflow area, allowing more stormwater to infiltrate directly into the ground as opposed to flowing into the stormwater drains. Completed in 2011, the effort was a precursor to additional green infrastructure programs concerned with further decreases in stormwater runoff volumes.

#### *Grey to Green Initiative*

In 2008, Portland Environmental Services began the Grey to Green Initiative, which seeks to expand the city's green infrastructure in order to mimic natural systems, restore natural areas, and improve overall watershed health. Through a \$55 million five-year investment plan, the program plans to acquire 419 acres of natural lands to protect them from development, install 43 acres of green roofs, re-vegetate 350 acres with native species, replace eight under road culverts that currently block fish passages, add 920 green street projects, and plant 80,000 trees. As of October 2011, the completed projects included one replaced culvert, six and a half acres of green roofs, and 13,000 newly planted trees. These efforts have provided benefits to local wildlife habitat, reduced stormwater runoff volumes, and enhanced green job opportunities.<sup>22</sup>

#### *Green Street Program*

Portland's Green Street Program promotes the use of integrated green infrastructure including bioswales, bump-outs, and permeable pavements that reduce stormwater runoff and impervious surfaces.<sup>23</sup> The program also promotes Green Street Stewards, a volunteer program in which local residents participate in the care and maintenance of the green street projects once

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<sup>20</sup> \*In the case of Urban Tree Plantings\* Heynan, Nikolas C. *The Scalar Production of Injustice within the Urban Forest*. *Antipode*. 35.5 (2003): 980-998.

<sup>21</sup> Dr. James R. Fazio. *The Portland Example How Trees Can Retain Stormwater Runoff*. Arbor Day Foundation. Tree City USA Bulletin no. 55

<sup>22</sup> "Grey to Green Update." Bureau of Environmental Services, City of Portland October 2011 WS 11145

<sup>23</sup> *Portland Green Street Program*. City of Portland. <http://www.portlandonline.com/bes/index.cfm?c=44407> Accessed 29 May 2012

constructed. The program has led to the adoption of Portland's 2007 Green Street Policy, which requires all city-funded developments to manage stormwater runoff on site. If developers choose not to follow the policy, they are subject to a 1% tax on total construction costs, which contributes to funding future green street projects. This policy encourages the use of vegetation to improve water quality and promote water infiltration and capture. As of 2012, 950 green street projects have been completed.

Additionally, the city began a stormwater management project named the Tabor to the River program, which is active in a 2.3 square mile area stretching from Mt. Tabor to the Willamette River. This program plans to add 500 green street projects to reflect the natural conditions of a creek, now diverted, which once ran throughout the area.<sup>24</sup> The program combines city directed support and community involvement to solve the area's stormwater runoff problems. The project is projected to reduce flood resolution costs from \$144 million to \$86 million by employing runoff mitigation techniques as opposed to conventional stormwater infrastructure.<sup>25</sup>

#### *Portland's Green Roofs*

Portland was one of the first municipalities in the nation to adopt a green building policy in 2001. Portland's Green Building Policy, which requires new city developments to incorporate green building principles, was updated in 2005. The new policy requires higher LEED standards and mandatory green roofs for all city-owned buildings in need of roof replacement. Although the policy focuses primarily on city-owned buildings, privately owned buildings are also encouraged to build green roofs. In 2006, the city implemented the Ecoroof Grant Initiative, which offered grants of up to \$5/ft<sup>2</sup> for green roof projects as part of the city's Grey to Green initiative. The second cycle of the grant program began in April 2012. To promote green roof developments further, the city also provides educational and outreach materials to developers and residents interested in green roof construction, such as the Portland Ecoroof Guide (a do-it-yourself guide released in 2010), a green roof resource list with suggested architects, designers, and engineers, and ongoing green roof seminars.

## **CHICAGO, ILLINOIS**

Chicago, Illinois has been historically notorious for contributing to the pollution of Lake Michigan, the source of the city's drinking water, through conventional grey infrastructure systems such as stormwater drains and combined sewer systems. In 1998, under the administration of Mayor Richard M. Daley, the city began implementing green infrastructure practices emphasizing installations of rain gardens, green roofs, and vegetated swales in order to alleviate water quality issues related to grey stormwater infrastructure. Since then the city has enacted multiple green infrastructure programs that seek to further enhance sustainable watershed management practices.

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<sup>24</sup>*Tabor to the River*. Bureau of Environmental Services, City of Portland. <http://www.portlandonline.com/bes/index.cfm?c=47591>  
Accessed 23 May 2012

<sup>25</sup> "Portland, Oregon" *Rooftop to Rivers II* NRDC 2011

### *Green Roof Program*

In 2001 Chicago began its green roof program with the installation of a 20,000 square foot green roof on top of City Hall, which served as a showpiece for future installations throughout the city. In order to promote green roof installations, Chicago has implemented various economic incentives for developers. When green roofs are included in construction plans developers may receive height bonuses in the business district, a maximum \$25,000 waiver of building permit fees for exceptional green roof project applications, and be eligible for the Green Permit Program, which fast tracks the permitting process. This has led to significant green roof growth throughout Chicago. The frequency of green roof installations in Chicago has effectively decreased market fees. Since 2001 the average cost of installation has decreased from \$25/ft<sup>2</sup> to \$15/ft<sup>2</sup>.<sup>26</sup> As a result, Chicago now has almost 500 green roofs covering 5.5 million square feet.<sup>27</sup>

### *Green Alleys Program*

In 2006, the Chicago Department of Transportation (CDOT) enacted the Green Alleys Program with the goal of improving water infiltration rates, reducing stormwater runoff, and reducing the urban heat island effect in the Chicago alley system by using permeable pavements, proper grading, and open bottom catch basins. The city has approximately 1,900 miles of public alleys (a total of 3,500 acres of impervious surface) that provide a large opportunity to improve stormwater management practices.<sup>28</sup> Similar to the market results of increased green roof construction, market prices for green alley pavement and installation have dropped, making green alley construction equivalent in cost to conventional alley construction.<sup>29</sup> As of fall 2011, there have been a total of 150 green alleys installed. CDOT is also integrating Green Alley infrastructure techniques into other street improvement projects and has installed an additional 215,000 ft<sup>2</sup> of permeable pavement in parking lots, sidewalks, and bike lanes.

Typical Chicago Alley Vs. Retrofitted Green Alley



Source: Attarian, Janet. "The Chicago Green Alley Handbook" City of Chicago and CDOT. 2007.

<sup>26</sup> *Chicago's Green Roofs: Seven Million Acres and Growing* Green Infrastructure Digest. <http://hpigreen.com/2009/11/13/> Accessed 27 March 2012

<sup>27</sup> "Chicago, Illinois" *Rooftop to Rivers II* NRDC 2011

<sup>28</sup> "The Chicago Green Alley Handbook" CDOT 2007

<sup>29</sup> "Chicago, Illinois" *Rooftop to Rivers II* NRDC 2011

**PHILADELPHIA, PENNSYLVANIA**

Like many cities on the East Coast, Philadelphia produces more stormwater runoff than the long ago established sewer infrastructure can accommodate. Today, the city relies on a sewer system consisting of combined sewers (60%) and separate sanitary and stormwater sewers (40%); yet, combined sewer overflows are still a problem, overflowing up to 85 times annually in some highly impervious areas.<sup>30</sup> In 1997, the Philadelphia Water Department (PWD) completed a Combined Sewer Overflow Long Term Control Plan to address stormwater management issues, and invested \$150 million to improve the aging sewer infrastructure.

*Green City, Clean Water Plan*

In June of 2011, Pennsylvania state legislators approved the city's Green City, Clean Water Plan, a 25-year program committed to transforming one-third of existing impervious surfaces into green infrastructure that will accommodate the first inch of rainfall in any given storm event. The plan seeks to enhance overall watershed quality through innovative combinations of green infrastructure best suited to each location, including permeable pavements, increased sidewalk tree plantings, and stormwater bump-outs. The program is unique in that it does not dictate how developers must meet these goals, but rather allows for creative uses of green infrastructure elements. The goals are legally enforceable through the Clean Water Act. The plan calls for \$2.4 billion to be invested over the next 25 years, with \$1.67 billion invested in green stormwater infrastructure projects, \$345 million to update the city's existing sewer capacity, and \$420 million allocated to a "flexible spending category" to be used on green or gray infrastructure.<sup>31</sup> The investments are expected to fully payoff within the next 45 years. The Philadelphia Water Department (PWD) will also provide financial and technical assistance in reaching the program's objectives.

The PWD relies on highly visible green infrastructure demonstration projects in public spaces in order to raise public awareness of green stormwater management practices. An example of one such project is a bus stop terminal located at a busy intersection in the city center that was outfitted with a green roof. Outside of the city center the PWD has retrofitted 56 city blocks in 14 different neighborhoods. With assistance from several community groups under the Model Neighborhoods program the projects have included green infrastructure such as street bump-outs and tree trenches<sup>32</sup> that further capture stormwater runoff and raise public awareness. The PWD also focuses on schools since they contain many impervious surfaces. The PWD views schools as "neighborhood anchors" that offer excellent opportunities to educate community members about green stormwater infrastructure.<sup>33</sup>

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<sup>30</sup>Philadelphia, Pennsylvania" *Rooftop to Rivers II*. NRDC 2011

<sup>31</sup>"Green City, Clean Waters: The City of Philadelphia's Program for Combined Sewer Overflow Control." Summary Report. PWD. 1 June 2011

<sup>32</sup> A stormwater tree trench is a series of planted street trees connected by an underground infiltration structure that manages the incoming runoff. [http://www.phillywatersheds.org/what\\_were\\_doing/green\\_infrastructure/tools/stormwater\\_tree\\_trench](http://www.phillywatersheds.org/what_were_doing/green_infrastructure/tools/stormwater_tree_trench)

<sup>33</sup>Green Stormwater Infrastructure Programs [http://phillywatersheds.org/what\\_were\\_doing/green\\_infrastructure/programs](http://phillywatersheds.org/what_were_doing/green_infrastructure/programs) Accessed 17 April 2012

## SEATTLE, WASHINGTON

Seattle is a highly urbanized area located between the environmentally sensitive Puget Sound and Lake Washington with tributaries running throughout the watershed that contribute to salmon spawning areas. Seattle Public Utilities (SPU) is responsible for the city's network of sewer and drainage systems and has recently taken a green infrastructure approach to control stormwater runoff through their Green Stormwater Infrastructure (GSI) program.

### *Natural Drainage System Strategy*

Nearly one-third of Seattle contains no storm drains.<sup>34</sup> In those areas, stormwater runoff flows overland, picking up pollutants and lawn chemicals, and washes into waterways leading to the Puget Sound. Instead of investing millions of dollars and an estimated 50 years of planning and construction towards traditional grey infrastructure, Seattle city planners are looking into alternatives that would imitate natural drainage systems. The Natural Drainage Systems (NDS) strategy mimics natural hydrologic functions through the utilization of plants, trees, and soils to manage stormwater flows. The strategy includes design components such as bioswales, narrow curvilinear streets, permeable pavements, cascading pools, and rain gardens.

The Street Edge Alternatives (SEA Street) NDS pilot project, completed in 2001, is a residential block retrofitted with such goals in mind. Monitoring over a period of two years has shown that the SEA Street has reduced the total volume of stormwater leaving the block by 99%, compared to traditional residential streetscapes.<sup>35</sup> The success of SEA Street has spurred subsequent projects such as the 110<sup>th</sup> Cascade Project, which features cascading natural pools to retain and slow stormwater runoff, and the Broadview Green Grid, which incorporates aspects similar to SEA Street on a larger, 15 block area. There have been some problems with the initial project installations and public concerns have been raised related to maintenance and road safety. Since identifying design problems, SPU has worked to address them and believes that the program provides an effective strategy for reducing stormwater runoff when applied appropriately.<sup>36</sup>

SEA Street Aerial View



Source: Montreal Urban Ecology Center –  
 “Seattle’s Bioswales”  
<http://www.urbanecology.net/exemples/seattle/seattle-s-bioswales>

### *Residential RainWise Program*

The Residential RainWise Program is a pilot project that focuses on community education to encourage homeowners to implement sustainable rainwater management designs on their own properties. Since January 2010, the program has emphasized tree planting, pavement reduction,

<sup>34</sup>Seattle’s Natural Drainage Systems: A low-impact development approach to stormwater management. Seattle Public Utilities

<sup>35</sup> “Natural Drainage Projects” Seattle Public Utilities

[http://www.seattle.gov/util/About\\_SPU/Drainage\\_&\\_Sewer\\_System/GreenStormwaterInfrastructure/NaturalDrainageProjects/index.htm](http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/GreenStormwaterInfrastructure/NaturalDrainageProjects/index.htm) Accessed 07 May 2012

<sup>36</sup>“Seattle, Washington” *Rooftop to Rivers II*. NRDC 2011

rain barrel use, downspout redirection, rain garden installation, and storm trench building.<sup>37</sup> The program also provides rebates to homeowners interested in installing rain barrels and rain gardens.

### *Green Factor Program*

In 2006, Seattle instituted the Green Factor Program that requires development projects (both business and multifamily residential) to achieve a minimum rating score based on inclusion of green infrastructure and the stormwater code. A landscaping requirement encourages elements of design such as green roofs, vegetated swales, permeable pavements, and large plant landscaping.<sup>38</sup> The Green Factor Scorecard ensures that a certain percentage of vegetation is included in the design, with bonus points for uses that include food cultivation, native plants, and rainwater harvesting. The program seeks to increase the amount of green roofs and other green infrastructure incorporated into new developments and is also expected to increase local food production and water storage.

### **NASHVILLE, TENNESSEE**

Until the 1950s, the combined sewer system of Nashville, Tennessee carried both stormwater and untreated sewage to the Cumberland River. Today, a wastewater facility treats the flow before it reaches the river, but 12.3 square miles of the core city still rely on the combined sewer system. In order to alleviate the sewer problems, the city has created a Green Infrastructure Master Plan with help from the Metro Water Service (MSA), which is responsible for the development and implementation of green stormwater infrastructure.

### *Green Infrastructure Master Plan*

Approved in 2009, the Green Infrastructure Master Plan identifies four areas of green infrastructure for the Nashville metropolitan area: stormwater harvesting, green roofs, increased urban tree plantings, and natural infiltration areas. Since the initial plan was created, pilot projects have been identified including adding green street components which are estimated to reduce yearly runoff volume by 3.8 million gallons, adding a green roof and rainwater harvesting system to a local school which is estimated to reduce yearly runoff volume by 347,000 gallons, adding rainwater harvesting and permeable surfaces to the Farmer's Market which is estimated to reduce yearly runoff volume by four million gallons, and renovating the Metro Parks Administrative Facility with a green roof, vegetated swales, permeable pavements, and rainwater harvesting which is estimated to reduce yearly runoff volume by 6.1 million gallons.<sup>39,40</sup> The city has also identified several additional green infrastructure development opportunities, including:

- Green roofs - Nashville contains 708 commercial buildings with flat roofs that the city has found suitable for green roof retrofitting. Retrofitting all of these roofs would result

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<sup>37</sup>Residential RainWise Program Seattle Public Utilities

[http://www.seattle.gov/util/About\\_SPU/Drainage\\_&\\_Sewer\\_System/GreenStormwaterInfrastructure/ResidentialRainwiseProgram/index.htm](http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/GreenStormwaterInfrastructure/ResidentialRainwiseProgram/index.htm) Accessed 17 April 2012

<sup>38</sup>Seattle Green Factor DPD <http://www.seattle.gov/dpd/Permits/GreenFactor/Overview/> Accessed 17 April 2012

<sup>39</sup> Andy Reese. *Nashville's Green Infrastructure Master Plan*. Metro Water Services. Presentation. 2010  
[http://seswa.timberlakepublishing.com/Files/Services/Conference/2010%20presentations/06%20-%20Nashville's%20Green%20Infrastructure%20Master%20Plan%20\[Reese\].pdf](http://seswa.timberlakepublishing.com/Files/Services/Conference/2010%20presentations/06%20-%20Nashville's%20Green%20Infrastructure%20Master%20Plan%20[Reese].pdf)

<sup>40</sup>*Green Infrastructure Master Plan* The Metropolitan Government of Nashville and Davidson County. Metro Water Services. 1 November 2009

in 6.8 million square feet of green roofs and would remove 112 million gallons of stormwater annually from the city's storm sewers.

- Urban tree planting - Nashville currently has an average tree canopy cover of 19.5%. According to the city, there are an estimated 51,800 acceptable sites for new tree plantings, which would add 811 acres of tree canopy and increase average cover to 30%.
- Permeable pavement - 1,175 acres of parking spaces exist in Nashville, which the city would like to retrofit with permeable pavers resulting in the removal of 80% of current annual parking lot runoff volumes.

## **TUCSON, ARIZONA**

An arid city, Tucson, Arizona does not come to mind as a city with active green stormwater infrastructure initiatives. However, because the city only receives about eleven inches of precipitation per year, its residents view rainwater as a valuable resource as opposed to wetter cities that view runoff as a menace to manage.<sup>41</sup> Tucson views stormwater practices through the lens of resource management as opposed to waste management. Tucson utilizes rainwater harvesting as a means to supplement water supplies and makes a large effort to educate residents on green infrastructure.

The City of Tucson takes a multi-scale approach to stormwater and rain harvesting practices.<sup>42</sup> The city is divided into smaller watersheds in order to make management assessments easier based on the immediate local topography. Although seemingly counterintuitive to regional climate, overflow devices such as spillways are used to divert excess stormwater to locations where it can be used beneficially. In an effort to maintain as much soil moisture for vegetation as possible, the city recommends mulching to encourage moisture retention and utilizes landscape techniques to slow stormwater flow and encourage infiltration.

### *Water Ordinances*

In June 2010, Tucson was the first city in the country to pass a municipal ordinance for rainwater harvesting. The Commercial Rainwater Harvesting Ordinance requires 50% of a property's landscape to utilize harvested rainwater within three years of ordinance passage. Also in June of 2010 Tucson passed the Residential Gray Water Ordinance that requires all new residential developments to be able to accommodate gray water plumbing systems. Gray water systems utilize and process wastewater that is generated from activities such as dishwashing, laundry and bathing and recycles it on-site for reuse.

## **THE BOTTOM LINE**

The examples of green infrastructure techniques and brief case studies illustrate opportunities for implementing green infrastructure into stormwater management practices in large and small cities as well as in rural areas. Whereas conventional grey infrastructure systems promote the

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<sup>41</sup>"Composite Case Studies" *Rooftop to Rivers II*. NRDC 2011

<sup>42</sup>*Water Harvesting Guidance Manual*. City of Tucson. October 2005

direct removal of water from impervious surfaces, green infrastructure promotes water capture, infiltration, and reuse on-site.

Diverse green infrastructure techniques have been implemented in cities throughout the U.S. including green roofs, rain gardens, bioswales, green streets, permeable pavements, and increased tree plantings. Cities are promoting green infrastructure programs through a number of financial mechanisms, ranging from tax programs, grant programs, stimulus funds, and construction and planning incentives. Furthermore, studies have shown that green infrastructure is a cost-effective alternative to traditional grey infrastructure in terms of initial cost and long-term maintenance. Municipalities have implemented green infrastructure techniques to address stormwater management issues because of their ability to provide ecological and economic benefits as well as an increased quality of life.

## RESOURCES

EPA - “Green Infrastructure”

<http://water.epa.gov/infrastructure/greeninfrastructure/>

EPA – “Low Impact Development”

<http://water.epa.gov/polwaste/green/index.cfm>

Minnesota Pollution Control Agency – “Stormwater Management: Low Impact Development and Green Infrastructure”

<http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/low-impact-development-stormwater-management.html>

NRDC - Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows

<http://www.nrdc.org/water/pollution/rooftopsii/>

American Society of Landscape Architects – Banking on Green: How Green Infrastructure Saves Municipalities Money and Provides Economic Benefits Community-wide

[http://www.asla.org/uploadedFiles/CMS/Government\\_Affairs/Federal\\_Government\\_Affairs/Banking%20on%20Green%20HighRes.pdf](http://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking%20on%20Green%20HighRes.pdf)

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