STAYING GREEN:

Strategies to Improve Operations and Maintenance of Green Infrastructure in the Chesapeake Bay Watershed

American Rivers
Rivers Connect Us®

in partnership with

GREEN FOR ALL

Acknowledgements

Written by Stacey Detwiler.

This report was made possible by funding from the Campbell Foundation.

For their assistance, input, and review, American Rivers and Green for All would like to thank Amy Stevens, Richard Klein, Mike Rist, Paul Howard, Christin Jolicouer, Fran Geissler, Tracy Tackett, Matt Burlin, Michelle Virts, Ted Scott, Jennifer Guillaume, Becky Rice, Ed Murtagh, Lynn Vismara, Bryan Seipp, Milada Weaver, Lou Etgen, Donald Tsusaki, Cecilia Lane, Nissa Dean, and Ann English for their assistance. We would also like to thank American Rivers' staff members Jeff Odefey, Katherine Baer, Amy Trice, and Fay Augustyn for their contributions to this report.

The author is responsible for any factual errors. The recommendations are those of American Rivers and Green for All. The views expressed in this report are those of the author and do not necessarily reflect the views of our funders or those who provided review.

About American Rivers: American Rivers is the leading organization working to protect and restore the nation's rivers and streams. Rivers connect us to each other, nature, and future generations. Since 1973, American Rivers has fought to preserve these connections, helping protect and restore more than 150,000 miles of rivers through advocacy efforts, on-the-ground projects, and the annual release of America's Most Endangered Rivers™.

Headquartered in Washington, DC, American Rivers has offices across the country and more than 100,000 supporters, members, and volunteers nationwide.

For more information about American Rivers, visit our website at www.americanrivers.org

About Green for All: Green For All is a national organization working to build an inclusive green economy strong enough to lift people out of poverty. Green For All is dedicated to improving the lives of all Americans through a clean energy economy. We work in collaboration with business, government labor, and grassroots communities to create and implement programs that increase quality jobs and opportunities in green industry - all while holding the most vulnerable people at the center of our agenda.

Cover photo: © Environmental Services, City of Portland Oregon

TABLE OF CONTENTS

EXECUTIVE SUMMARY **1**

INTRODUCTION **3**
- Regulating Stormwater Runoff 4
- Green Infrastructure 6
- Maintaining Stormwater Infrastructure 7
- Maintenance Costs for Green Infrastructure and Gray Infrastructure 9

BARRIERS TO OPERATIONS AND MAINTENANCE OF GREEN INFRASTRUCTURE AND RECOMMENDATIONS **13**
- Paying for Operations and Maintenance 14
- Recommendations to Pay for Operations and Maintenance 15
  - *Implement a Stormwater Utility* *15*
- Evaluate Alternative Financing Mechanisms 18
  - *Beneficiary Opportunity Fund* *18*
  - *Public-Private Partnerships* *18*
  - *Infrastructure Improvement Districts* *20*
  - *Clean Water Fund* *21*
- Lack of Awareness or Poor Public Perception of Green Infrastructure 21
- Recommendations 23
  - *Homeowner Incentive Program* *23*
  - *Improve Awarenessof Practices Locations* *24*
  - *Offer Opportunities for Public Education* *24*
  - *Establish Volunteer Maintenance Programs* *25*
- Limited Training and Certification Available for Practitioners 27
- Recommendations 28
  - *Develop Maintenance Standards for Green Infrastructure* *28*
  - *Establish Maintenance Training and Certification Programs* *30*
  - *Leverage Existing Municipal Resources* *30*
  - *Improve Collaborations with Community Groups* *31*
- Minimal or Ineffective Enforcement and Inspection Procedures 33
- Recommendations 34
  - *Establish Inspection Procedures and Schedules for Green Infrastructure* *34*
  - *Establish Inspection Training and Certification for Green Infrastructure* *35*
  - *Evaluate Opportunities for Volunteer Inspection Programs* *36*
  - *Adapt Enforcement Procedures for Green Infrastructure* *36*

CONCLUSION **37**

ENDNOTES **38**

APPENDICES **46**
- Appendix A. Inspection and Maintenance Activities for Select Green Infrastructure Practices 46
- Appendix B. Sample Operations and Maintenance Manuals Including Green Infrastructure Practices 55
- Appendix C. Resources for Sample Operations and Maintenance Checklists by Green Infrastructure Practice 56
- Appendix D. Samples of Education and Outreach Materials for Private Property Owners and the Public 57
- Appendix E. Agendas from Training Programs 59

EXECUTIVE SUMMARY

Without proper maintenance, any type of infrastructure can lose functionality and ultimately fail. As more communities move towards adopting green infrastructure as a cost-effective approach to manage polluted runoff, it is critical that local governments address barriers to operations and maintenance.

The Chesapeake Bay watershed stretches across 64,000 miles and includes six different states as well as the District of Columbia. Encompassing 140 major rivers and streams as well as 11,684 miles of shoreline, precipitation that falls within this watershed makes its way ultimately towards the Chesapeake Bay. Within the watershed, a variety of land uses from forested areas to agricultural lands to urbanized areas impact the health of its rivers, lakes, streams, and coastlines. Precipitation falling on agricultural lands can pick up pollutants such as pesticides or nutrients and sweep them untreated into rivers and streams.[1] In urban or suburban areas, rainwater is unable to infiltrate into hard surfaces such as parking lots or rooftops. As a result, urban runoff flows over these hard surfaces where it picks up pollutants such as heavy metals, sediment, oil, and grease. Large volumes of polluted runoff can either flow untreated directly into local waters or overwhelm the capacity of storm sewers, resulting in sewage overflows in places with combined systems.[2] Polluted runoff is one of the only growing sources of water pollution in the Chesapeake Bay.[3]

Credit: U.S. Department of Agriculture

The Chesapeake Bay watershed.

Green infrastructure practices manage urban runoff to protect clean water by capturing and infiltrating rainwater where it falls. From green roofs to rain gardens, green infrastructure can be defined as an approach to wet weather management that uses natural systems, or engineered systems that mimic natural processes, to infiltrate, evapotranspire, and/or recycle stormwater runoff. These practices not only reduce polluted runoff, but can also provide multiple benefits to communities such as improved air quality and increased green space.[4] Already home to 17 million people, the Chesapeake Bay watershed encompasses major urban areas in the mid-Atlantic region such as Baltimore, MD, Richmond, VA, and Washington, DC. Projections estimate that development in the region could increase by 60 percent over the next thirty years.[5,6] By restoring and replicating natural processes, green infrastructure practices can mitigate the impact of increased hard and impervious surfaces from development that increase polluted runoff, threatening the health of the Bay and the communities that depend upon clean water.

Despite the benefits of green infrastructure, one of the major challenges to adoption of these practices is uncertainty surrounding how they will be maintained. Operations and maintenance has been repeatedly raised as a technical barrier to adoption of green infrastructure and remains a concern for many local governments in the Chesapeake Bay region and across the country less familiar with these approaches.[7] Similar to any type of infrastructure, without appropriate and consistent maintenance, green infrastructure will fail; rain gardens can lose functionality and fail just like a neglected detention pond or a roadway. This report examines some of the major barriers to effective operations and maintenance of green infrastructure practices in the Chesapeake Bay region and identifies strategies and best practices that local governments, practitioners, and other groups are using to develop and improve maintenance practices:

- ***Financing Operations and Maintenance for Green Infrastructure*** – One of the primary challenges for effective operations and maintenance of green infrastructure practices is identifying appropriate funding mechanisms. In many communities, stormwater programs are financed through general funds which compete with schools and other priorities. Stormwater utilities offer a consistent and stable stream of funding to pay for maintenance that more equitably links a user fee to impact and can incentivize private investment. Alternative financing mechanisms include beneficiary opportunity funds, public-private partnerships, infrastructure improvement districts, and dedicated clean water funds.

- ***Lack of Awareness or Poor Public Perception of Green Infrastructure***– Some municipalities have struggled with a poor public perception or lack of awareness about green infrastructure practices which can create a barrier to effective maintenance and their overall success. Voluntary homeowner incentive programs offer an opportunity to engage residents and educate them about maintenance responsibilities. Workshops, tours, and other events offer opportunities to educate the general public about green infrastructure practices. Volunteer programs, such as 'Adopt-a-BMP' programs can create opportunities for collaboration with community groups to engage residents to take a proactive role in maintenance of green infrastructure practices.

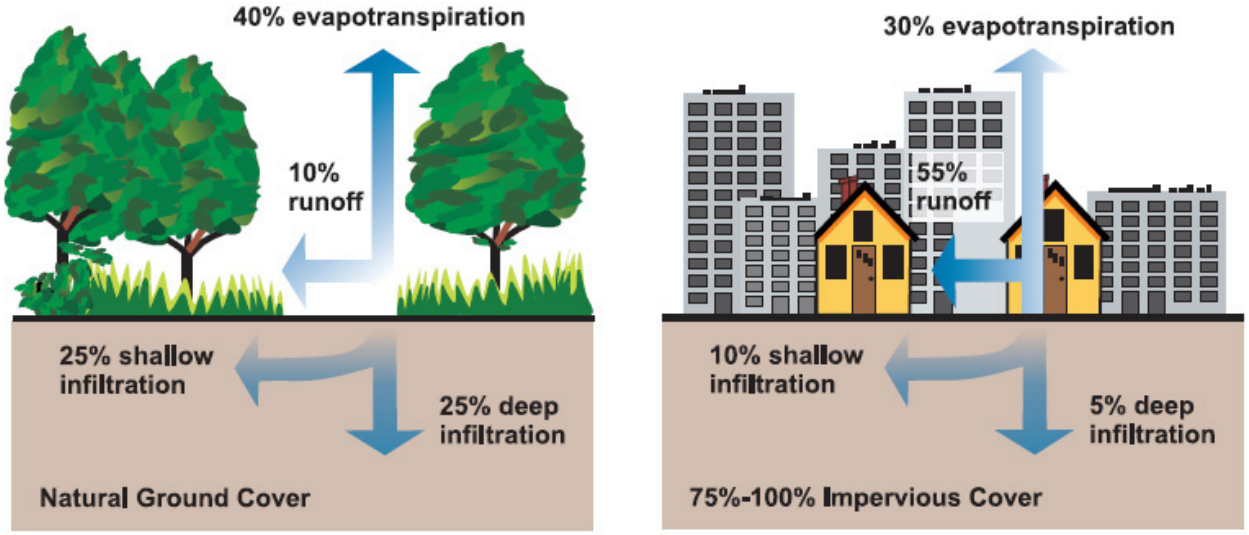
- ***Limited Training and Certification in Green Infrastructure Operations and Maintenance Available-*** Limited opportunities exist for practitioners such as landscape contractors, engineers, or landscape architects to become certified or receive training in operating and maintaining green infrastructure practices. Developing maintenance standards for green infrastructure will create a baseline from which to create tailored trainings and certifications following existing models such as the North Carolina State University's Best Management Practice Inspection and Maintenance Certification or training programs held by local governments. Leveraging existing municipal resources and collaborating with community groups can expand training and certification programs that can ultimately lead to employment and business opportunities for people with applicable skills to maintain green infrastructure.

- ***Minimal or Ineffective Enforcement and Inspection Procedures*** – Without appropriate inspections and enforcement procedures, both green and gray infrastructure practices can lose function and fail. Inspection and enforcement procedures and schedules should be modified to reflect the differences between green and gray infrastructure. Training and certifications should be developed specifically for inspections of green infrastructure and the applicability of volunteer inspection programs should be considered.

Operations and maintenance of green infrastructure practices in the Chesapeake Bay watershed and across the country is critical for the success of these approaches. While more research is needed to track and evaluate current projects and the ways that local governments, community groups, and homeowners are maintaining them, this report attempts to identify some of the primary barriers that local governments face regarding operations and maintenance and recommends different strategies that should be used to address those challenges.

INTRODUCTION

Polluted stormwater runoff is one of the only growing sources of pollution to the Chesapeake Bay.[8] When rainwater falls, some of the water is absorbed into the ground and the rest flows along the surface as runoff into local rivers and streams. In forested areas, around 50 percent of rainfall infiltrates into the ground where it recharges groundwater supplies. Over time, it is slowly discharged into springs and streams. Forty percent returns to the atmosphere through evapotranspiration and 10 percent flows along the surface as runoff.[9] The quality and quantity of runoff is affected by a number of factors, including land use and soil type.[10] Whether rain falls on farm fields or parking lots, the surface it lands on has a significant impact on the resulting runoff. Unlike forested areas, urbanized areas often have around 45 percent of land surface that is impervious to rainfall. [11] Roads and parking lots can have as much as 70 percent impervious cover.[12] The Environmental Protection Agency (EPA) estimates that with 75-100 percent impervious cover, 55 percent of rainfall runs along the surface as stormwater runoff.[13] When rain hits these hard surfaces, it is unable to absorb into the ground and instead flows quickly over them, into storm sewers and ditches, and directly into rivers and streams carrying pollutants and exacerbating floods.[14] Studies show that when impervious surfaces constitute over 10 percent of land use, streams become degraded and demonstrate increased levels of pollution, reduced groundwater recharge, impaired habitat, and increased erosion.[15]



Credit: U.S. Environmental Protection Agency

Land use in the Chesapeake Bay watershed directly impacts runoff and the resulting water quality of the Bay. Around 69 percent of land cover in the watershed is forest, 22 percent is used for agriculture, and 7 percent is developed urban or suburban land.[16] When rainwater falls in more urban areas, it is unable to infiltrate, instead flowing along hard surfaces where it picks up pollutants like heavy metals, polychlorinated biphenyls (PCBs), or insecticides.[17] This polluted runoff then flows directly into local rivers and streams or into storm sewers. In 64 communities across the Bay watershed, storm sewers flow into the same pipes as wastewater in a "combined sewer system," where it is then transported to a wastewater treatment plant.[18] However, if there is heavy precipitation and stormwater overwhelms the capacity of the system, the excess stormwater and wastewater are discharged untreated directly into local waters.[19] As of 2004, an estimated 850 billion gallons of untreated sewage and stormwater flows into rivers and streams annually from combined sewer systems.[20] Other communities within the Chesapeake Bay watershed have a "separate storm sewer system," where the pipes for stormwater and wastewater are separate.

Although agricultural runoff is a significant source of water pollution in the Chesapeake Bay, this report will address pollution from urban stormwater runoff and the green infrastructure practices that communities across the Chesapeake Bay region and throughout the country are using to protect clean water. Within the Chesapeake Bay watershed, polluted runoff from urban and suburban areas impairs 1,570 miles of streams and contributes an estimated 16 percent of sediment, 15 percent of phosphorous, and 8 percent of nitrogen loads to the Bay as of 2009.[21] Across the country, although urban areas make up only 3 percent of land cover, urban runoff was a significant source of impairment for 13 percent of rivers, 18 percent of lakes, 32 percent of estuaries, and 55 percent of ocean coastlines.[22,23] Urban runoff pollutes the rivers and streams where people fish, swim, and take their drinking water from; contributes to localized flooding; degrades habitat; and causes stream bank erosion. Increased development and urbanization combined with the pressures of chronic underfunding for water infrastructure, communities across the country are starting to incorporate innovative approaches to manage stormwater runoff, protecting clean water and public health.[24]

Photo Credit: Doug Wilson | USDA

Agricultural Runoff

In the Chesapeake Bay watershed, when rainwater falls on agricultural lands, it picks up fertilizers and manure that significantly contribute to water pollution.[1] In fact, agricultural runoff is the largest contributor of nitrogen, phosphorous, and sediment to the Bay.[2] While these nutrients are important for the health of aquatic ecosystems, large amounts can significantly degrade water quality.[3]

1 Chesapeake Bay, U.S. Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://www.epa.gov/oaqps001/gr8water/xbrochure/chesapea.html >, 2011.

2 Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorous, and Sediment, U.S. Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLExecSumSection1through3_final.pdf >, 2010.

3 Nutrient Pollution: The Problem, U.S. Environmental Protection Agency, Accessed 18 January 2013, Available online at < http://www.epa.gov/nutrientpollution/problem/index.html >.

Regulating Stormwater Runoff

The Clean Water Act regulates stormwater runoff through the National Pollutant Discharge Elimination System (NPDES), the permit program that controls discharges into rivers, lakes, streams, and other waters. The Act distinguishes between "point source" discharges of stormwater, or runoff that is conveyed through pipes or ditches and discharged into local waters, and "non-point source" discharges, or runoff that flows over farm fields or suburban lawns.[25] After the Clean Water Act passed in 1972, there was considerable disagreement about whether it required stormwater discharges to be covered under the NPDES permit program. In 1987, the Act was amended to require NPDES permits specifically for stormwater discharges including: discharges from some industrial activities, discharges from large and medium Municipal Separate Storm Sewer Systems (MS4s), and discharges from other sources deemed to be a significant source of pollution or a contributor to a violation of a water quality standard.[26]

Definitions

Municipal Separate Storm Sewer Systems (MS4s): A conveyance or system of conveyances owned by a state, city, town, village or other public entity that discharges pollutants into waters of the United States; used or designed to collect or convey stormwater; not a combined sewer; and not part of a sewage treatment plant.[1]

National Pollutant Discharge Elimination System (NPDES): Authorized under the Clean Water Act, the NPDES permit program regulates point source discharges into waters of the United States.[2]

Non-point Source: Any type of water pollution other than a point source, generally coming from diffuse sources caused by rainfall or snow melt moving over land or through the ground.[3]

Point Source: A discrete conveyance of water pollution including but not limited to a pipe, ditch, channel, conduit, well, concentrated animal feeding operation, or ditch that discharges or that may discharge pollutants.[4]

Total Maximum Daily Load (TMDL): A determination of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop TMDLs for prioritized waters that fail to meet water quality standards.[5]

[1] National Pollutant Discharge Elimination System, U.S. EPA, Available online at < http://cfpub.epa.gov/npdes/index.cfm >.

[2] What is Nonpoint Source Pollution?, U.S. EPA, Available online at < http://water.epa.gov/polwaste/nps/whatis.cfm>.

[3] What is Nonpoint Source Pollution?, U.S. EPA, Available online at < http://water.epa.gov/polwaste/nps/whatis.cfm>.

[4] Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s), U.S. EPA, Available online at < http://cfpub.epa.gov/npdes/stormwater/munic.cfm >.

[5] Impaired Waters and Total Maximum Daily Loads, U.S. Environmental Protection Agency, Accessed 5 March 2013, Available online at < http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm >.

Lynette Batt | American Rivers

Urban runoff in Washington, DC.

Under section 402(p) of the Clean Water Act, dischargers are required to "reduce the discharge of pollutants to the maximum extent practicable," which has been applied by EPA regulations to mean that permittees must develop and implement stormwater best management practices that meet the six minimum control measures: public education and outreach, illicit discharge detection and elimination, public participation/involvement, construction site runoff control, post-construction runoff control, and pollution prevention/good housekeeping.[27,28,29] The Environmental Protection Agency (EPA) phased in this change by finalizing regulations for larger municipal dischargers, or Phase I communities, by 1990 and for Phase II communities, smaller municipalities and construction sites, by 1999.[30] The EPA is currently developing a national regulation to modernize its stormwater program, possibly by requiring an objective performance standard for development and redevelopment projects that will encourage the use of green infrastructure practices, increasing fairness by bringing in currently unregulated sources of stormwater that contribute to downstream pollution, and requiring existing sources of stormwater to reduce their impact by decreasing impervious surface.

Additionally, communities within the Chesapeake Bay watershed are subject to the Chesapeake Bay Total Maximum Daily Load (TMDL), which drives efforts to restore the Bay, including managing polluted urban runoff. Under section 303(d) of the Clean Water Act, every two years states must list waters that fail to meet state water quality standards. From their 303(d) lists, states must develop total maximum daily loads

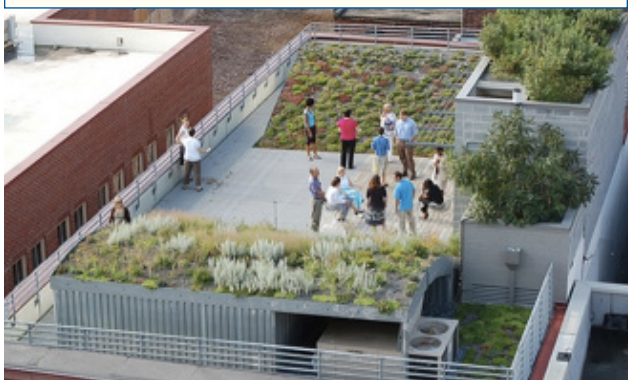
(TMDLs), essentially pollution caps with restoration plans, for prioritized waters.[31] Stormwater runoff is a significant contributor of pollutants that impair waters. In fact, the EPA found that stormwater is the primary source for five of the most common pollutants that impair waters on 303(d) lists.[32] The development of the Chesapeake Bay TMDL among the seven districts in the watershed (Delaware, the District of Columbia, Pennsylvania, Maryland, West Virginia, Virginia, and New York) began in 2000, spurred by the lack of progress in previous restoration efforts. The Chesapeake Bay TMDL sets pollution limits for nitrogen, phosphorous, and sediment loads from both point sources and non-point sources that are significant sources of impairment to the Bay. The Clean Water Act requires "reasonable assurance" that point source and non-point source load allocations can be achieved, which the Chesapeake Bay TMDL addresses through existing regulatory and non-regulatory programs at the federal and state levels. As part of this process, in 2010 each jurisdiction submitted a Phase I Watershed Implementation Plan (WIP) which outlined how it will meet statewide reductions in nutrient and sediment loads, providing reasonable assurance to EPA that those reductions can be achieved. Based on the Phase I WIPs, the EPA established the Chesapeake Bay TMDL in December 2010 including federal backstops to ensure reductions. Additionally, jurisdictions are also required to submit Two Year Milestones which outline the activities and strategies the jurisdiction will undertake over the next two years and the reductions they are expected to achieve. Currently, each jurisdiction is preparing its Phase II WIPs to include key stakeholders and strengthen strategies for achieving point source and non-point source load reductions. The ultimate goal is to achieve 60 percent of the reductions needed to restore the Bay by 2017 and all of the reductions by 2025.[33] The TMDL process is a critical driver in the Chesapeake Bay watershed for addressing urban stormwater runoff and the implementation of cost-effective solutions that protect clean water and provide multiple benefits to communities, like green infrastructure.

Green Infrastructure

Green infrastructure practices , also known as Low Impact Development (LID) or Environmental Site Design (ESD), work by capturing and treating rainwater where it falls. Green infrastructure can be defined as an approach to wet weather management that uses natural systems, or engineered systems that mimic natural processes, to infiltrate, evapotranspire, and/or recycle stormwater runoff. Practices range in scope and scale and include technologies such as rain gardens, green roofs, permeable pavement, and bioretention. Not only can green infrastructure provide a cost-effective tool to protect and restore clean water, but these practices can provide multiple benefits to communities from reduced flooding and sewage overflows to improved air quality and access to recreational green space.[34]

Green Infrastructure

Green infrastructure can be defined as an approach to wet weather management that uses natural systems, or engineered systems that mimic natural processes, to infiltrate, evapotranspire, and/or recycle stormwater runoff. It includes practices such as rain gardens and green roofs and provides multiple benefits to communities from improved air quality to flood mitigation.



American Society of Landscape Architects

For example, green roofs protect water quality by capturing and treating rainwater where it falls, and also stabilize rooftop temperatures to reduce heating and cooling costs as well as mitigate the urban heat island effect. By absorbing solar radiation, green roofs reduce rooftop temperatures by 60 degrees Fahrenheit in summer, compared to traditional black roofs.[35] One study demonstrated that a green roof could reduce energy use for cooling by 6 percent and by 10 percent for

heating.[36] This is demonstrated by the 175,000 square foot green roof on the FedEx Main Sorting Facility at Chicago O'Hare Airport that captures approximately two million gallons of rainfall every year and saves an estimated $35,000 in heating and cooling costs annually.[37] At a broader scale, green roofs and other green infrastructure practices help to counteract higher temperatures in urban areas caused primarily by large amounts of impervious surface. In Philadelphia, one study found that 196 heat-related fatalities over a forty-year period could be avoided through the use of green infrastructure practices.[38] Green roofs also offer an opportunity for more green space in urban areas. Bread for the City, an organization in Washington, DC that provides comprehensive services to vulnerable residents, built 30 raised beds on its existing green roof to grow herbs and vegetables. This rooftop garden not only reduces stormwater runoff, but is a source of fresh and nutritious food for local community members.[39] Green roofs are just one type of green infrastructure practice that offers multiple benefits to communities in addition to protecting clean water.

Across the country, many communities are beginning to integrate green infrastructure into their stormwater management plans. Particularly in the face of harsh budget realities, green infrastructure practices offer a cost-effective approach to managing stormwater and helping communities meet regulatory requirements. For example, New York City developed a plan to meet regulatory requirements to reduce its combined sewer overflows using green infrastructure to manage the first inch of rainfall from 10 percent of the impervious area in the City. This combination of green and gray infrastructure is expected to save $1.5 billion over the next 20 years compared to using gray infrastructure alone to achieve the same reductions.[40] Lenexa, Kansas established its Rain to Recreation program to address stormwater management with a cost-share program for residents to install rain barrels and rain gardens.[41] The City of Portland, Oregon spent $8 million to subsidize downspout disconnections for homeowners, keeping 1 billion gallons of runoff out of the combined sewer system every year and saving the city $250 million in hard infrastructure fixes.[42] Sixty-seven privately financed green infrastructure projects in Providence, Rhode Island keep an estimated nine million gallons of stormwater runoff out of the city's combined sewer system. Reducing pressure on the infrastructure system helps to reduce sewer overflows and saves the utility $9,000 annually in operating costs.[43]

Maintaining Stormwater Infrastructure

Like all infrastructure, green infrastructure practices require maintenance to ensure that they continue to function properly. As implementation of these practices continues to grow, it will become more important than ever to effectively address the resulting challenges of operating and maintaining these practices so that they continue to function properly.

Maintenance can be defined as "the purposeful management of a practice so as to preserve a desired level of performance and efficiency and extend useable life."[44] All stormwater management practices, whether traditional "gray" or green infrastructure, will require some type of maintenance to retain their functionality. Maintenance activities are typically divided into routine activities which should occur on a regular basis and emergency or infrequent activities. At the minimum, best practices for maintenance of all types of stormwater infrastructure include establishing a stormwater ordinance that requires development of a maintenance design manual or guidelines to provide a legal foundation and establish maintenance responsibilities, implementing a financing mechanism, and creating a tracking and evaluation system with consistent inspections.[45] Further, both green and gray infrastructure practices require some form of trash, sediment, and debris removal; structural repairs and replacements; and vegetation maintenance, such as mowing or invasive species control. Together, these components create the foundations of an effective maintenance program for both green and gray infrastructure.

However, maintenance of some green infrastructure can differ from more traditional gray infrastructure in important ways. Green infrastructure practices are often designed as infiltration, runoff reducing, and/or vegetation-based practices. This is a different approach than many more traditional gray infrastructure practices such as curb and gutter systems or culverts that are designed to move stormwater away from roads, parking lots, and buildings as quickly as possible with little pollutant removal and volume or velocity reduction. As a result, while some maintenance activities for gray infrastructure such as detention ponds and catch basins will be similar for green infrastructure practices, others will significantly differ and require other resources and expertise.

Nancy Arazan | U.S. Environmental Protection Agency

Green street in Seattle, Washington's High Point Neighborhood.

Establishing and maintaining healthy vegetation is critical to the function of many green infrastructure practices. Maintenance for most green infrastructure practices will often require less structural maintenance than gray infrastructure. As an example, typical maintenance for a traditional dry detention pond includes inspecting for erosion and sediment accumulation, mowing the sides of the pond, and removing debris annually or semi-annually. Sediment will need to be removed from the forebay at a minimum every five years, but often more frequently. Every 25 to 50 years the pond may need to be completely dredged.[46] Maintenance for a catch basin, an underground structure designed to move stormwater through underground pipes, includes removing debris and sediment, repairing any structural cracks or fractures, removing vegetation, and replacing mechanical components.[47] In contrast, typical maintenance activities for a rain garden include replacing mulch annually, pruning trees and shrubs as needed, and removing invasive species and weeds by hand monthly or at the minimum three times a year.[48] Maintenance for a green roof includes removing weeds by hand, replacing dead plants, removing invasive species, clearing inlet pipes, removing trash and debris, and pruning.[49] In some cases, maintenance of native vegetation more typical of green infrastructure practices can be less intensive than turf grass often used with more traditional facilities such as stormwater retention ponds. See Appendix A. for typical maintenance activities and frequency of maintenance for different green infrastructure practices.

While maintaining green infrastructure practices requires knowledge of plants and plant health not traditionally needed for gray infrastructure, such expertise may already exist in other local government departments. Parks department staff may already have expertise in plant health and could perform some maintenance of green infrastructure installations on public property. For example, local parks department staff may have specialized knowledge about invasive species removal and plant identification that could be shared internally. The Arlington County Parks and Recreation Department offers multiple resources on its website about invasive species removal and works with local groups such as Arlingtonians for a Clean Environment and Arlington Regional Master Naturalists.[50] The Fairfax County Park Authority has a similar program for invasive species removal and works with the Department of Public Works as well as organizations like the Fairfax Master Naturalists and the Northern Virginia Soil and Water Conservation District to run their Invasive Management Area Volunteer Program.[51] In Olympia, Washington, the Department of Public Works constructed a porous pavement parking lot, rain gardens, and constructed wetlands with funding through the Green Project Reserve under the State Revolving Fund. While maintenance is paid for through the City

of Olympia's stormwater utility under the Department of Public Works, maintenance is conducted by the Olympia Parks Department.[52] Thus, while some maintenance activities for green infrastructure may differ from gray infrastructure, many local governments and community groups may already have existing expertise that could be applied to the stormwater management program.

Due to existing regulatory requirements and implementation of the Chesapeake Bay TMDL, it is inevitable that the number of green infrastructure practices within the watershed will continue to increase. For example, the Maryland Stormwater Management Act of 2007 requires the use of green infrastructure, termed environmental site design (ESD), to the "maximum extent practicable" for stormwater management.[53] In its Phase II WIP, Delaware gives priority to 'Green Technology Best Management Practices,' such as bioretention, in managing urban stormwater runoff to meet its nutrient and sediment reductions under the Chesapeake Bay TMDL.[54] In order to meet regulatory requirements and protect clean water, it will be critical to ensure that effective maintenance occurs so that these practices continue to function as designed.

Maintenance Costs for Green Infrastructure and Gray Infrastructure

Comprehensive data for the costs of maintaining stormwater infrastructure, and especially green infrastructure, is often limited and presented as an estimated percentage of capital costs or by specific maintenance activities. As identified by a 2003 survey of stormwater management facilities in western Washington and Oregon, maintenance costs are often reflective of available budgets, rather than actual costs to fully conduct the necessary maintenance.[55] However, whether or not a local government chooses to incorporate green infrastructure or only gray infrastructure, operations and maintenance will have costs regardless of the chosen technology.

Despite these challenges, communities across the country have used various gray infrastructure practices to manage stormwater runoff for decades and are more likely to have existing expertise and information about the typical activities, frequency, and costs of maintenance. In 2011, Brown and Caldwell put together a table comparing costs for repair and replacement of different sized stormwater pipes. Costs ranged from $50 to repair and $200 per foot to replace an 18-inch diameter pipe to $550 to repair and $2,200 per foot to replace a 120-inch diameter pipe.[56] Culverts are shorter sections of pipes used to move stormwater away from roadways and are more prone to clogging from vegetation, trash, and other debris. Maintenance for culverts and stormwater pipes typically involves sediment removal as needed with jet or vactor cleaning, rodding, or using a bucket machine.[57] Oil and grease trap devices are a structural stormwater practice used to remove petroleum, grease, and other suspended solids from runoff. Maintenance for these types of practices involves inspection every three months and sediment, oil, and grease removal using a vacuum pump or manual removal as needed and is estimated to cost $10 annually per cubic foot (in 1999 dollars).[58,59] Deep tunnels are another gray infrastructure practice that store large amounts of stormwater runoff during rain events to mitigate flooding and reduce combined sewer overflows and then send the stormwater to the wastewater treatment plant when it has capacity to treat the water. For instance, the Milwaukee Deep Tunnel system is 28.5 miles long and is 300 feet below ground with a diameter of up to 32 feet.[60] These require significant capital investment which has led some cities such as Philadelphia to favor the implementation of green infrastructure practices to reduce stormwater and provide other benefits to residents. Maintenance for deep tunnels, while infrequent, is significant and requires specially trained crews to remove debris and replace or repair structural components.

The Center for Watershed Protection compiled information about annual maintenance costs for more conventional best management stormwater infrastructure practices as a percentage of capital costs and for a typical application converted to 2009 dollars.[61]

Table 1. Typical Maintenance Activities and Costs for Conventional Stormwater Practices[62,63]

Infrastructure Practice	Annual Maintenance as a Percentage of Capital Cost	Maintenance Activity	Cost of Maintenance Activity for a "Typical" Application (2009 dollars)
Wet Ponds *Wet ponds have a permanent pool of water and treat stormwater by allowing pollutants to settle out.1*	3%-6%	*Annually or as needed*: • Cleaning or removing debris after major storm events (greater than 2" rainfall) • Repairing embankment and side slopes • Structural repairs *Every five years*: • After 60% of original volume lost, removing sediment from forebays or storage areas *Every 20 years:* Dredge pond to remove accumulated sediment once 50% of original volume is lost	$3,861-$7,722
Dry ponds *Dry ponds are designed to allow stormwater to infiltrate and don't have a permanent pool of water. 2*	Around 1%	Same as Ponds or Wetlands	$3,861-$7,722
Catch Basin *Catch basins are storm drain or curb inlets to a storm drain system and often contain a grate or sump to catch debris or pollutants.3*		*Annually or twice a year:* • Trash removal if a screen or grate is used • Sediment removal with a vactor truck	$10-$40 per catch basin[4] *Vactor trucks can cost between $125,000 and $150,000 and one truck can clean about 75-100 catch basins in one day. Disposal costs of contaminated sediment also need to be considered.*
Infiltration trench *An infiltration trench is a rock-filled trench without an outlet that receives stormwater runoff and infiltrates it into the soil.5*	5%-20%	*Annually or as needed:* • Mow and maintain upland vegetated areas • Clean and remove debris after major storm events (greater than 2" rainfall) • Remove sediment • Repair or replace stone aggregate • Maintain inlets and outlets *Every 4 years*: • Remove accumulated sediment from forebays or storage areas when 50% of original volume is lost	$2,960-$11,583
Sand filters *A sand filter is a two-chambered stormwater management practice where larger particles settle out in the first chamber and then finer particles are filtered out in the second chamber.6*	11%-13%	*Annually or as needed:* • Remove trash and debris from openings • Repair leaks or deteriorating components • Remove the top few inches of sand when filter bed is clogged *Every 3 to 5 years:* Clean sediment from filter bed chamber	$2,831

[1] http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=68

[2] http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=73&minmeasure=5

[3] http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=77&minmeasure=5

[4] http://www.rougeriver.com/pdfs/stormwater/sr25.pdf

[5] http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=70

[6] http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_sandfltr.pdf

As these numbers illustrate, costs of maintenance are often given as a percentage of capital costs or as a range of costs for different maintenance activities. Although the use of green infrastructure continues to increase across the country, there is still limited information about operations and maintenance for these practices and their associated costs compared to more traditional approaches. This creates a challenge for local governments that are considering incorporating green infrastructure into the suite of practices they use to manage polluted runoff and protect clean water. To address this problem, researchers across the country are beginning to evaluate maintenance activities for green infrastructure and their related costs and finding that, in many cases, life cycle costs are less than traditional practices.[64] Additionally, the costs of maintaining green infrastructure practices may often be comparable to maintenance of traditional landscape maintenance that may already be required on a property or for more conventional stormwater management practices such as a retention pond or sand filter.

In 2009 the Water Environment Research Foundation (WERF) collaborated with the EPA to develop spreadsheet tools to estimate whole life costs of specific green infrastructure practices, including maintenance costs. The tool enables users to enter basic information for a generalized cost analysis or more site-specific information for individual components. Models are available for permeable pavements, green roofs, cisterns, rain gardens, curb-contained bioretention, and in-curb planter vaults. These models represent a key tool that local governments can use to estimate costs for the maintenance of select green infrastructure practices. Table 2 shows maintenance costs for these practices based on the default data through the WERF and EPA tool compiled from interviews with stormwater management agencies and literature review.[65]

Table 2. Annual Average Maintenance Costs for Select Green Infrastructure Practices[66]

Green Infrastructure Practice	Annual Routine Maintenance Cost	Annual Infrequent or Corrective Maintenance Cost	Combined Annual Routine Maintenance and Infrequent or Corrective Maintenance Costs
Green roof	$4,120	$2,486	$6,606
Rain garden	$72	$157	$229
Bioretention	$313	$1,192	$1,505
Permeable pavement	$247	$623	$840
In-curb planter vault	$310	$145	$455
Cistern	$980	$328	$1,308

Converting the Center for Watershed Protection's cost estimates for routine and less frequent emergency maintenance of conventional gray infrastructure into 2009 dollars enables a rough comparison of cost estimates of routine and emergency maintenance for green infrastructure through WERF's tool. Of the six green infrastructure practices researched, green roofs have potentially the highest overall maintenance costs of approximately $6,606.00 for combined annual maintenance costs and infrequent or corrective maintenance costs. Costs of maintenance activities for infiltration trenches, including routine maintenance and less frequent corrective maintenance, are estimated by the Center for Watershed Protection to fall within a range of $2,960.00-$11,583.00. For wet ponds and dry ponds, the range is estimated to be between $3,861.00 and $7.722.00. The costs of maintaining a green roof falls within this range and below the highest estimate for the more conventional infrastructure practices. Other higher estimated maintenance costs for green infrastructure are for bioretention at $1,505.00 followed by cisterns at $1,308.00. However, in any discussion of costs, it is important to note that gray infrastructure practices are often designed to treat larger drainage areas. For instance, detention ponds can manage stormwater from drainage areas less than an acre to several hundred acres. Rain gardens are typically designed to manage one to two acres of runoff.[67] While this initial comparison demonstrates the potential for maintenance of green infrastructure practices to be comparable to, or potentially

less than, maintenance costs for conventional gray infrastructure practices; more information is needed to more accurately compare costs.

Additional data on the specific and relative costs of maintaining green infrastructure can be found in case studies from around the country. For instance, as part of New York City's 2010 Green Infrastructure Plan the city would spend far less on maintaining green infrastructure over time. This plan outlines strategies to integrate green infrastructure into stormwater management to reduce combined sewer overflows (CSO) by managing the runoff from 10 percent of the impervious surface across the city with green infrastructure over a 20-year time period. This combination of green and gray infrastructure (Green Strategy) is expected to reduce CSOs by 2 billion gallons more over twenty years than using only gray infrastructure (Grey Strategy) and to cost $1.5 billion less than an all gray infrastructure strategy. This plan also compares projected operations and maintenance costs of both the Green Strategy and the Grey Strategy over the next twenty years. Initially, operations and maintenance costs are higher under the Green Strategy as new practices are built that require more intensive maintenance until they become established. However, by 2024, the City would spend nearly $200,000 less annually on operations and maintenance under the Green Strategy because of the increased energy needs of gray infrastructure and the maintenance required for larger projects such as tunnels and tunnel expansions as required under the Grey Strategy. Importantly, green infrastructure practices also offer the potential to leverage further private investment in stormwater management. [68]

In Minnesota, the University of Minnesota documented the potential to establish a Green Infrastructure Regional Maintenance Alliance and compared maintenance practices and costs for rain gardens in several communities across the region. The Capitol Region Watershed District (CRWD) was established to protect Como Lake and includes five cities in Minnesota. The CRWD installed eight rain gardens in the city right-of-ways as part of a street reconstruction and stormwater improvement project. Along with these and other rain gardens, the Watershed District inspects 100 rain gardens across the City and assigns them different levels of maintenance needs. Maintenance is performed by the Watershed District, Saint Paul Parks and Recreation, and volunteers. Over a two year period, the CRWD spent $22,394 to maintain the rain gardens, averaging $1,399 annually per garden. Seventy percent of those costs were for the 1,046 volunteer and staff hours spent on maintenance. The City of Chanhassen has 21 rain gardens built on public property with most built in the right-of-way. Weeding, re-planting, mowing, and mulching occur once or twice a year. The City estimates that it costs $5,227 every year to maintain these rain gardens at an average cost per garden of $249. The City of Prior Lake has 50 rain gardens with many located on private lands. For the first three years following installation, the City partners with landowners to pay for maintenance and conducts inspections and replaces plants as needed. Following that period, paying for and conducting major maintenance and plant replacement are the responsibility of the property owner and should occur every five years. During this period, the City will only conduct maintenance on inlets and estimates that this costs $18 annually per rain garden. A 200 square foot rain garden with a 15 year lifetime would have an estimated $1,650 in total maintenance costs, averaging $110 per rain garden in annual maintenance costs.[69]

In North Carolina, Wossink and Hunt at North Carolina State University collected construction and maintenance costs for detention ponds, constructed wetlands, bioretention, and sand filters. Based on their analysis of more than 40 different facilities, they developed equations to calculate twenty-year maintenance costs. Using this analysis, the study uses annual maintenance costs along with other cost considerations, such as opportunity costs of building on the land and construction costs, to compare those four practices. For a ten-acre watershed with a curve number of 80, which indicates the ability of a watershed to store water and infiltrate it, the researchers found that a detention pond in a watershed fitting these parameters would have the highest annual maintenance costs followed by a constructed wetland and then bioretention. This example demonstrates how maintenance for a bioretention facility designed to manage the same amount of runoff as a detention pond could require less

costly maintenance. Importantly, the researchers also developed a maintenance cost curve for detention ponds, constructed wetlands, bioretention, and sand filters that could be used to roughly approximate twenty-year maintenance costs in North Carolina and potentially more broadly along the East Coast.

Table 3. Comparison of Annual Maintenance Costs for Four Stormwater Management Practices in a Ten Acre Watershed (CN = 80)[70]

	Detention Pond	Constructed Wetland	Bioretention (clay soil)	Bioretention (sandy soil)
Annual Maintenance Costs	$4,411	$752	$583	$583

A more targeted study examining both maintenance costs and pollutant removal was conducted by the University of New Hampshire Stormwater Center to analyze maintenance activities and costs over a six year period for seven different stormwater management technologies including both green infrastructure and more conventional practices. Stormwater was distributed to normalize pollutant loading, rainfall, and other watershed characteristics among the different practices. Researchers found that maintenance of vegetated practices was less costly and required fewer labor hours, even during the most expensive period following installation, compared to conventional infrastructure. In fact, wet and dry ponds had the heaviest overall maintenance burdens because of the high number of maintenance activities required and the increased likelihood of expensive emergency activities. The study found that the practices that required more frequent and proactive maintenance had lower overall maintenance burdens than those that required less frequent but more costly and reactive maintenance. In general, the green infrastructure practices had lower costs and labor hours and were able to reduce pollutant loads more than conventional infrastructure.[71] Overall, this study found that green infrastructure practices offer lower maintenance burdens in regards to cost and labor hours while at the same time providing greater capabilities to protect water quality through pollutant removal.

While these examples demonstrate that maintenance for properly designed and appropriately selected green infrastructure practices can be less costly than conventional stormwater infrastructure, more research is needed. Costs of maintenance for any type of stormwater management practice, green or gray, will continue to be a significant barrier to maintenance. Comprehensive data that show the comparative costs of green infrastructure maintenance to gray infrastructure maintenance will be critical in decisions to incorporate green infrastructure for local governments in the Chesapeake Bay region and across the country. As a result, better tracking of maintenance costs for green infrastructure combined with increased research will provide a strong foundation for local governments to make informed choices about their options for cost-effective stormwater management.

BARRIERS TO OPERATIONS AND MAINTENANCE OF GREEN INFRASTRUCTURE AND RECOMMENDATIONS

In the face of budget realities and regulatory drivers such as the Chesapeake Bay TMDL, green infrastructure practices offer an alternative tool to manage stormwater runoff, protect clean water, and provide multiple benefits to communities.[72] While there is increasing information available on the design and installation of these practices, questions remain about effective operations and maintenance strategies and costs. This report explores four significant barriers identified through literature review and interviews with local governments, watershed groups, and practitioners in the Chesapeake Bay region and recommends multiple strategies to

overcome these challenges. One of the most critical barriers is the need to develop appropriate financing mechanisms to fund operations and maintenance of green infrastructure practices. Another challenge to operations and maintenance of green infrastructure is the lack of appropriate training available, resulting in ineffective maintenance and potential failure of these practices. A lack of awareness among homeowners who may have green infrastructure on their property and from the general public also contributes to lack of support for maintenance of green infrastructure. Finally, communities have noted the need to improve and adapt inspection and enforcement mechanisms to fit green infrastructure practices, especially as they may be increasingly built on private property. This report identifies these barriers, highlights different tools that local governments and outside groups are using, and provides recommendations to address these challenges.

Paying for Operations and Maintenance

Identifying ways to pay for operations and maintenance of stormwater management is a challenge not unique to green infrastructure practices. In order to meet regulatory requirements and protect clean water, many local governments will need to ensure that stormwater infrastructure practices continue to function throughout their designed life. Integrating green infrastructure practices into the suite of approaches that local governments use can open up opportunities to incentivize private investment and create multiple benefits for communities. Many existing resources focus on the methods that communities can use to leverage capital funding for implementation of green infrastructure, which is not specifically covered in this report. However, securing financing for the operations and maintenance of green infrastructure is an additional barrier for many communities in the Chesapeake Bay region and across the country. Identifying financing mechanisms that can provide sufficient and stable funding specifically for maintenance is critical to mitigating and removing this barrier to adoption of green infrastructure practices.

Traditionally, stormwater management of publicly owned projects has been funded through a combination of sources including general funds, bonds, impact fees, special user fees, and federal or state grant or loan programs.[73] These sources of funding are often limited, can increase the overall debt burden of a community, and are an inequitable approach to deal with the problem of polluted stormwater runoff. Chronic underfunding of stormwater infrastructure is demonstrated at the broadest scale, with the American Society of Civil Engineers giving the nation's wastewater infrastructure a grade of D minus in 2009.[74] The EPA's 2008 Clean Watersheds Needs Survey demonstrated that total needs for stormwater and wastewater are estimated to be $298.1 billion.[75] At the local level, operations and maintenance of stormwater practices and stormwater management programs more broadly often compete with schools, public safety, and other municipal programs for limited general funds. Bonds can be used for operations and maintenance, but must be repaid often from these general funds and can add to the overall debt burden to the community. Additionally, general funds are often paid for through property taxes on residents. Tax-exempt property owners that may have large amounts of impervious surface and contribute to stormwater pollution or other differentially taxed properties may not pay into those funds. As a result, payment for stormwater management is not equitably linked to impact.

In the face of constraints on local budgets, funding for operations and maintenance for stormwater is often cut in favor of schools, libraries, or police departments. Even within stormwater program budgets, funding for operations and maintenance may not be prioritized. Maintenance of green infrastructure practices is no less important than for gray infrastructure; without appropriate maintenance neither type will continue to function properly. As regulatory requirements evolve, particularly in the Chesapeake Bay region with the Chesapeake Bay TMDL and the Maryland Stormwater Act, and development continues to exacerbate flooding and water quality problems, some communities are beginning to adopt specific financing mechanisms to better fund stormwater management. For example, some communities have developed stormwater utilities that provide dedicated funding specifically for stormwater management through a user or service fee designed to cover the costs of stormwater

management service, and there are now over 1000 such utilities nationwide. Fort Collins, Colorado developed its stormwater utility in 1980, primarily to address flooding, that would fund operations and maintenance as well as new capital projects for stormwater management. Residential and non-residential properties pay a fee based on the area of the property and the percentage of impervious surface of the property.[76] Other communities are experimenting with public-private partnerships and alternative financing mechanisms to pay for stormwater management and operations and maintenance of stormwater infrastructure.

Recommendations to Pay for Operations and Maintenance

Establishing a consistent and stable stream of funding is integral to developing successful, affordable programs to ensure optimal maintenance for green infrastructure practices. Stormwater utilities offer one of the most effective mechanisms to ensure that funding is available, not just for capital projects, but also for operations and maintenance. They provide a stable revenue source that can be tailored to meet community needs, a more equitable approach by basing fees on impact, and the ability to create credit structures that reduce fees by reducing impact and incentivizing private investment. Alternatively, leveraging public resources, beneficiary opportunity funds, public private partnerships, infrastructure improvement districts, and clean water funds represent other financing mechanisms that could be adapted to pay for operations and maintenance of green infrastructure.

Implement a Stormwater Utility

When stormwater program budgets are forced to compete with schools and libraries, it's unlikely that maintenance activities will receive priority funding. Instead, where allowed by state law, local governments should consider developing a stormwater utility to provide dedicated funding to ensure that maintenance needs can be met and practices continue to function as designed to meet regulatory requirements and protect clean water. Similar to designated fees for water or sewer, a stormwater utility is a user or service fee designed to cover the costs to the local government of managing stormwater runoff to reduce pollution, flooding, and other problems. One of the earliest adopters was Billings, Montana which developed a "storm water charge" in 1964 that was upheld in the state Supreme Court two years later.[77] Stormwater utilities began emerging in Washington and Oregon during the 1970s and gradually became more common in the 1980s and 1990s. According to the Western Kentucky University's 2012 survey, there are over 1,000 stormwater utilities across the country.[78]

A stormwater utility offers a flexible approach that local governments can use to provide consistent, long-term funding for operations and maintenance of green infrastructure practices. At the most basic level, a local government sets a fee to cover the costs of providing a stormwater service to reduce pollution, protect clean water

City of Rockville, MD Stormwater Utility Fee

The City of Rockville, Maryland implemented a stormwater utility fee in 2007 to reduce flooding, provide funding for deteriorating stormwater infrastructure, and to meet regulatory requirements. The fee is based on an Equivalent Residential Unit (ERU) of 2,330 square feet, or essentially the average amount of impervious area found on a typical single family home in Rockville. Single family homes pay a flat rate based on one ERU and all other property owners pay a fee based on the ERU rate multiplied by the amount of impervious area on their property measured in ERUs. The stormwater fee helps the City comply with NPDES requirements as well as implementation of the Chesapeake Bay TMDL. Property owners can apply for stormwater fee credits to reduce their bill by committing to operate and maintain privately owned and approved stormwater management facilities, including green infrastructure practices such as bioretention. Every three years, participating property owners must submit inspection reports to document maintenance.[1]

[1] Stormwater Management Utility Fee, City of Rockville, MD, Accessed 8 March 2013, Available online at < http://www.rockvillemd.gov/residents/swm/#used >.

for drinking and recreation, and mitigate flooding. There is an important legal distinction between a tax and a user or service fee that is critical to the development of a stormwater utility. Many states restrict the ability of local governments to impose taxes, but not fees or service charges which have different attributes than taxes. While the differences between taxes and fees may vary by state, in general a user or service fee must be charged for a specific service which benefits the user; the fee should be based on a contribution to the problem; and the amount of the fee must be designed to cover the actual costs of the service.[79]

From this common foundation, communities have the flexibility to refine and adapt this concept to meet their needs. The majority of stormwater utilities base stormwater user fees on the amount of impervious surface on a property, which impacts the volume of runoff flowing from that site. Percent impervious surface and gross parcel area are other measurements that local governments may use to determine a user fee. [80] Local governments also have the flexibility to use different rate structures using a combination of flat, tiered, and variable fees.[81] One of the most common rate structures is a flat fee for single-family residential property and then either a tiered or variable fee for non-residential properties. However, communities have implemented many variations of rate structures. For example, Valparaiso, Indiana, with a population of 25,500, established a stormwater utility in 1998 and raises $520,000 annually for stormwater management. Residential single-family properties are charged a flat fee of $3 per month. Non-residential properties use a tiered system based on impervious surface area. For instance, a non-residential property with between 10,000 and 40,000 square feet of impervious surface would pay $12 per month. Other utilities set fees by calculating a user fee proportional to the impervious area on the property, known as the "Equivalent Residential Unit," or ERU. ERUs are used by an estimated 80 percent of stormwater utilities.[82] One example of this can be found in the community of Griffin, Georgia which established its stormwater utility in 1997 and uses a tiered approach for residential properties and a variable rate for non-residential properties. Small single-family residential properties are charged $1.77 per month and large single-family residential properties are charged $2.95 per month. Non-residential properties are charged $2.95 per ERU every month (with an ERU value set at 2,200 square feet of impervious surface).[83] Some communities begin with a simplified rate structure, charging a flat fee, at first and then refine their model. Others develop a more detailed structureupfront.

An emerging trend among stormwater utilities is the use of a credit system for landowners who install green infrastructure to reduce the stormwater generated on their property. Incorporating a credit allowance serves as an incentive for property owners to use their own funds to build stormwater controls, shifting the burden of paying for this infrastructure service from the public budget to the private sector and allowing property owners to design, install, and maintain controls that are tailored to their individual sites. One additional advantage of this shift may be that far more stormwater controls are built than would be possible through public funding alone. For example, Washington, DC has two different stormwater fees, one through the District Department of the Environment (DDOE) to fund stormwater controls required for the District's MS4 and the Clean Rivers Impervious Area Charge through DC Water to fund stormwater controls required for the District's combined sewer system.[84] In 2010, the District enacted new legislation to base their

City of Griffin, GA

Workers install permeable pavement in Griffin, GA.

stormwater fee through DDOE on impervious surface to more equitably link the fee to impact. Through their RiverSmart Rewards Program, DDOE offers property owners the ability to reduce their stormwater fee up to 55 percent by installing eligible stormwater best management practices including green roofs, permeable pavement, and bioretention.[85] DC Water is coordinating with DDOE to develop a similar incentive program for the Clean Rivers Impervious Area Charge.[86]

The flexibility that local governments have to set stormwater fees and develop rate structures is one of the primary benefits of stormwater utilities. Starting with a simplified flat fee rate structure can help to improve public acceptance of the concept and requires less data than more refined structures. Conversely, some local governments may find that a more refined system that more accurately define the amount of stormwater running off of each site are both more equitable and legally defensible. Resources such as the New England Environmental Finance Center's "Stormwater Utility Fees: Considerations and Options for Interlocal Stormwater Working Group (ISWG)" and the National Association of Flood and Stormwater Management Agencies "Guidance for Municipal Stormwater Funding" highlight many examples of diverse stormwater utilities from across the country.[87] Stormwater utilities also provide a more equitable approach to fund stormwater management including operations and maintenance. Users are charged based on the impact of their property rather than property value. Tailoring fees to reflect land use characteristics and the needs of the community provides a stable and equitable revenue stream not just for capital projects, but also for operations and maintenance. As demonstrated by Washington, DC, stormwater utilities also offer the ability to create a credit structure that reduces fees in reward for reducing runoff, incentivizing cost-effective green infrastructure approaches as well as providing funding for maintenance.

Linking Stormwater and Transportation in San Mateo County

In 2005, Assembly Bill 1546 was signed into law requiring that a $4 annual fee be charged by the City/County Association of Governments of San Mateo County in California for motor vehicles registered with the County. The revenue from this fee was used to fund not only programs to improve traffic congestion but also to reduce stormwater pollution in the County. A grant program was developed to fund green infrastructure demonstration projects and a guidebook for the implementation of green streets and parking lots was produced. Although this fee is different than a more traditional stormwater utility, it is innovative in that it clearly links the impact of roadways and vehicles to polluted runoff and related water quality problems. In 2010, voters decided to continue the fee under a ballot measure and raised it to $10 annually. The fee is expected to yield over $6.7million annually in funds that can be used to mitigate congestion and polluted runoff.[1]

[1] San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook, Nevu Negan Associates and Sherwood Design Engineers for the San Mateo Countywide Water Pollution Prevention Program, Accessed 12 March 2013, Available online at < http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/03/San-Mateo-Green-Streets.pdf >, 2012.

In the Chesapeake Bay watershed, most state legislatures have granted local communities the authority to develop stormwater utilities and assess fees related to stormwater management, including both structural and natural systems. For instance, as a result of a law passed in 2012, many MS4s in Maryland are required to implement a stormwater utility program. Montgomery County, MD was an earlier adopter, establishing a Water Quality Protection Charge in 2002 based on the average amount of impervious surface to fund stormwater management.[88] At the same time, neither New York nor Pennsylvania expressly provides local governments with the authority to use this important financing tool. Particularly within the Chesapeake Bay watershed where jurisdictions are under the Chesapeake Bay TMDL, many communities will need to explore financing mechanisms that cover the costs of stormwater management to protect the Bay and meet regulatory requirements.

Stormwater utilities are not a panacea to address all of the financing concerns related to operations and maintenance of green infrastructure practices. While they offer a solution to the problem of underinvestment

in stormwater management, they may not be appropriate or even available in every place. Additionally, if the stormwater utility is not properly designed, lacks public support, and is poorly implemented it is unlikely to be successful. The New England Environmental Finance Center identifies several characteristics of successful stormwater utilities including starting with upfront planning and a defined strategy with cost projections and resource needs outlined. A public outreach campaign is critical to the success of the utility to build public support and improve understanding of both the problem of stormwater and how people are affected. Other characteristics of successful utilities include involvement and education of public officials, a clear plan for linkages and dependencies such as formal approvals, and clear champions for the development of a stormwater utility within the municipal staff.[89] When properly designed, stormwater utilities offer an important tool that local governments can use to pay for operations and maintenance of green infrastructure.

Evaluate Alternative Financing Mechanisms

Beneficiary Opportunity Fund

Communities where a stormwater utility may be inappropriate may consider exploring alternative financing mechanisms to fund operations and maintenance of green infrastructure practices. Another approach for municipalities interested in creating a sustainable and more predictable funding stream would be to establish a "beneficiary opportunity fund." This type of financial instrument is familiar to most universities and is commonly used by community organizations and land trusts to fund their activities. Beneficiary opportunity funds differ from endowments in that the original principal can be accessed.

These types of funds can be established by a local government acting in partnership with a capable community or watershed organization and rely on the interest earned on a principal endowment to fund stormwater infrastructure maintenance. The contributions to the principal could come from grants, private donations, or money that cities, watershed districts, or landowners would deposit as a percentage of construction costs for the green infrastructure practice. Annual returns on this initial investment would be withdrawn from the fund to pay for ongoing maintenance activities. Regular fundraising, or deposit of fees assessed to landowners, would increase the principal over time thus increasing the amount of interest income available to fund O&M activities. The effectiveness and sufficiency of this approach would depend on both the amount of principal held in escrow and the prevailing rates of return on the investment.

The organization Metro Blooms, located in Minneapolis, Minnesota is currently in the process of developing a Green Infrastructure Maintenance Alliance (GIRMA) to provide public education and outreach, develop a long-term financing mechanism for maintenance of green infrastructure in the region, explore and analyze maintenance best practices, and provide potential employment and job training to youth. Metro Blooms is pursuing the establishment of a beneficiary opportunity fund through private fundraising that would provide long-term financing for green infrastructure maintenance through GIRMA. With a $10,000 principal from Metro Blooms, a government entity, or agency partnership and held by a foundation, investment returns would be used to finance maintenance of specific projects.[90]

Public-Private Partnerships

Public-Private Partnerships, or PPPs, can be defined as interactions between public and private entities, such as technical assistance or cost-sharing, to provide a service to the public and offer another financing mechanism to communities.[91] Typical participants in PPPs are often government entities, non-profits, and private sector organizations. Combining the resources and strengths of each can benefit both the public and the participants. PPPs can be used

in stormwater management to promote innovation, meet regulatory requirements, and provide financial support. For example, the City of Lynchburg, Virginia as a combined sewer overflow (CSO) community is required to reduce its overflows through a Long Term Control Plan.[92] The City worked with a private engineering consulting firm to develop a plan to disconnect downspouts on the privately owned Randolph College campus. By disconnecting the downspouts, stormwater runoff from 20,000 square feet of rooftops would be kept out of the sewer system and re-directed into rain barrels and rain gardens. Approximately 90 percent of funding for the project came from the Green Project Reserve, dedicated federal funding for green infrastructure, water efficiency, and environmentally innovative projects under the State Revolving Funds (SRFs).[93] This example demonstrates how government, non-profit, and for-profit entities can work together to develop and implement forward-thinking approaches to stormwater management that protect clean water.

The Center for Neighborhood Technology's "Wetrofit" Program

The Center for Neighborhood Technology is piloting a "Wetrofit" program to provide free audits for neighborhoods in and around Chicago that experience flooding. The audit will help to identify potential flood risk and make recommendations to the property owner about the type of green infrastructure practices, if appropriate, that they could install to reduce basement flooding. Although property owners would be responsible for installation and maintenance costs, the audits are free and the overall Wetrofit program is partially funded through a private insurance agency and a private foundation.[1]

[1] Eidson, Carrie, "Wetrofit offers free audits and green ways to prevent repeat flooding," Medill Reports, Accessed 8 March 2013, Available online at < http://news.medill.northwestern.edu/chicago/news.aspx?id=215382 > and Reduce Flooding with the Wetrofit Service, Center for Neighborhood Technology, Accessed 8 March 2013, Available online at < http://www.cnt.org/news/media/Factsheet-Wetrofit.FINAL.pdf >.

In Pennsylvania, the Pennsylvania Environmental Council (PEC) received federal funding from PennVest also as part of the Green Project Reserve through the American Recovery and Reinvestment Act of 2009 (ARRA) to install 41 rain barrels, approximately 16,000 square feet of pervious pavement, over 3,700 square feet of bioswales, and native vegetation and trees along several streets in Ohiopyle, PA.[94] PEC administered the project and put it out for bid to private firms.[95] Design for the project was completed by URS and construction was completed by Fairchance Construction of Fairchance.[96] This project demonstrates an informal public-private partnership between PennVest, an independent financing authority; a non-profit, PEC; and private firms to develop multiple green streets to better manage stormwater runoff in Ohiopyle.

Additionally, the Rockefeller Foundation recently announced plans to provide funding for a public-private partnership to enable eight cities to better leverage private financing for sustainable stormwater management. The Foundation will provide up to $3 million as part of this RE.invest Initiative to develop Community Investment Vehicles (CIVics) to better leverage private investment in infrastructure. This example demonstrates the potential momentum behind the development of public-private partnerships for investments in sustainable water infrastructure.[97]

While many PPPs for stormwater management are used to fund capital projects, these partnerships could also be used to finance operations and maintenance of green infrastructure. For example, a local government could contract out its maintenance of green infrastructure practices to a private firm or even to a non-profit organization. The City of Seattle, Washington developed its Natural Drainage System to integrate green infrastructure practices into the City's stormwater management. The City contracts out its maintenance to the Seattle Conservation Corps, a job training program established in 1986 under the Parks and Recreation Department. The Seattle Conservation Corps provides a one year position for unemployed and underemployed adults and is funded largely by working for other City departments. While this demonstrates an inter-governmental partnership, there is the potential that a non-profit job training organization could partner with a local government to provide job training skills and conduct needed maintenance for green infrastructure practices.

Infrastructure Improvement Districts

In addition to beneficiary funds and public-private partnerships, communities should consider creating an infrastructure improvement district through which a group of property owners can share in the costs of infrastructure improvements and maintenance costs. There is great flexibility in the scale and implementation of improvement districts, which often begin voluntarily with stakeholders voting to approve or reject their creation. Once the district has been created, property owners within the district are assessed a fee paid to the organization that runs the improvement district's activities. Generally, improvement districts are managed by a Board of Directors either made up of the businesses and owners within the district or elected by them.[98,99] Business Improvement Districts, Neighborhood Improvement Districts, and Community Improvement Districts are three examples of improvement districts where property owners pay for services that improve their area such as public safety, landscaping, and capital improvements.

In Portland, Oregon, groups of property owners can join together to form a Local Improvement District which will fund transportation infrastructure improvements including building sidewalks and installing stormwater management. For example, the Northeast 97th Avenue Green Street Local Improvement District was formed in 2010. Property owners of the District funded improvements to 97th Avenue including installing vegetated swales and planting street trees to manage stormwater runoff. Additional funding for the project came from the Gateway Urban Renewal Area through the Portland Development Commission, a tax increment district, as well as the Bureau of Environmental Services' Watershed Investment Fund and the 1% for Green Fund.[100,101]

The City of Philadelphia also has multiple improvement districts. The Mount Airy Business Improvement District is focused on improving and beautifying the Germantown Avenue commercial corridor including adding rain barrels decorated by local artists.[102] Through the Philadelphia Water Department (PWD) and the Philadelphia Industrial Development Corporation (PIDC), the City offers the Stormwater Management Incentives Program Business Improvement District (BID) Grant created to fund feasibility studies for BIDs to collectively manage their stormwater runoff. Non-residential properties can also apply for grants under the Stormwater Management Incentives Program to fund design and construction of green infrastructure, although operations and maintenance are not eligible. Since both Portland and Philadelphia also have a stormwater utility to fund stormwater management, these examples illustrate how multiple financing mechanisms can leverage resources.

While many improvement districts are designed to fund capital projects, property owners could collaborate to develop an Infrastructure Improvement District specifically to fund maintenance for green infrastructure practices on private property. Conceptually, this would be similar to a Common Area Maintenance Fee (CAM) that is used with commercial or residential properties with landlords and tenants. For instance, a shopping mall managed by one owner rents retail space to various tenants who are responsible for paying a CAM fee to cover maintenance for shared areas inside and outside of the mall, such as parking lots and landscaping.[103] Property owners could establish an Infrastructure Improvement District to create a fund for maintenance of collectively managed green infrastructure practices, such as rain gardens in a parking lot or green streets in a commercial district.

On a smaller scale, homeowners could potentially reduce the costs of maintenance by establishing a maintenance pool for green infrastructure practices within their neighborhood. By bundling multiple practices, homeowners could submit a bid to contractors that would likely be lower in cost than if each homeowner used a separate contractor.

Clean Water Fund

Another alternative that communities should consider is the establishment of a Clean Water Fund to help finance operations and maintenance of green infrastructure projects. This could be funded through an increase on taxable sales with the revenue generated going towards clean water protections. Essentially, communities should evaluate opportunities to dedicate specific tax revenue for the operations and maintenance of green infrastructure.

One example of a Clean Water Fund can be found in Minnesota where in 2008 voters approved a 0.37% increase of the sales and use tax rate to fund an Outdoor Heritage Fund, a Clean Water Fund, a Parks and Trails Fund, and an Arts and Cultural Heritage Fund. Thirty-three percent of this increase goes to the Clean Water Fund, generating approximately $91 million in FY 2011, to "protect, enhance, and restore water quality in lakes, rivers, streams, and groundwater, with at least 5% of the fund spent to protect drinking water sources."[104] The Fund is administered by the Board of Water and Soil Resources (BWSR) and provides grants to eligible recipients including local governments, counties, and cities for both structural and non-structural practices. Projects must include an operations and maintenance plan along with an inspection schedule and procedure and assurances from property owners that the project will be maintained to perform its intended use over the designed life of the project.[105] Over the past year, policy guidelines were changed to support maintenance activities during the 1-3 years following installation.[106] This example could provide a model for policy changes at the state level to prioritize and fund green infrastructure practices including operations and maintenance.

A related example is Portland, Oregon's 1% for Green Fund. The City requires that one percent of the budget for construction projects built in the public right-of-way that are not subject to Portland's stormwater requirements for all development and redevelopment projects within the City on private and public property defined in Portland's Stormwater Management Manual be collected into the 1% for Green Fund. Revenue from this fund is used to pay for construction of green streets in Portland.[107] Similar to the Clean Water Fund in Minnesota, maintenance is eligible for funding for the first 1-2 years following installation during the establishment period.[108] Although this Fund isn't designed for long-term maintenance, it could provide a model for similar mechanisms that are specifically for operations and maintenance of green infrastructure practices.

In conclusion, one of the most effective ways to pay for operations and maintenance of green infrastructure is through the establishment of a stormwater utility. Cities across the country demonstrate the flexibility of this financing mechanism to equitably link fees to impact and leverage private investment. Where developing a stormwater utility is infeasible, communities should consider alternative financing mechanisms including strategies to leverage public resources, beneficiary opportunity funds, public-private partnerships, infrastructure improvement districts, and clean water funds.

Lack of Awareness or Poor Public Perception of Green Infrastructure

In addition to concerns over how to pay for operations and maintenance of green infrastructure, some municipalities interviewed noted that a lack of public awareness about these practices creates a significant barrier to their success. Private property owners may not be aware that green infrastructure practices are located on their property and that they are responsible for maintaining them. Poor or little public perception of green infrastructure can also contribute to problems in operations and maintenance. It is critical to ensure that the property owners understand what to expect from green infrastructure practices, how they function, and any maintenance activities for which they are responsible.

Montgomery County, MD

Rain garden constructed under the RainScapes Program in Montgomery County, MD

The RainScapes Program in Montgomery County, MD

The RainScapes Program in Montgomery County, Maryland provides rebates up to $2,500 per parcel for homeowners and up to $10,000 per parcel for commercial, institutional, and multi-family properties to install eligible practices including rain gardens, green roofs, permeable pavers, and cisterns. Participants are required to sign a maintenance agreement with the County. Funding for this program comes from the Water Quality Protection Charge based on the amount of impervious surface of a property.[1]

[1] English, Ann, RainScapes Program, Montgomery County DEP, Email Communications, 22 March 2013.

Municipalities and community groups are addressing this challenge in a variety of ways. For instance, homeowner incentive programs are one tool that local governments can use to encourage voluntary installation of green infrastructure practices. These types of programs can help to raise homeowner awareness about stormwater pollution and how they can protect clean water by installing practices on their property. In general, the local government will offer a rebate for installation of select green infrastructure practices on residential or commercial property. In Washington, DC under the RiverSmart Homes Program, homeowners are eligible for rebates up to $1,200 for installing green infrastructure practices that reduce stormwater runoff.[109] Maintenance agreements are also required for these projects that outline maintenance responsibilities, access for municipal staff, and ensure that homeowners consider participating in tours of participating homes or including signage on the project.[110] Arlington County, Virginia developed a similar incentive program called Stormwater Wise Landscapes.[111] Nationally, Seattle, Washington's RainWise Program represents another model of a homeowner incentive program. Under this program, rain gardens or cisterns installed within target Combined Sewer Overflow (CSO) basins are eligible for rebates.[112] In order to receive the rebate, the homeowner and contractor must jointly sign paperwork to get the rebate for the homeowner and there is a five year requirement to keep the practice functioning.[113] While landscape contractors do the installation and maintenance, the City of Seattle has found the most success and homeowner buy-in when the homeowners design the green infrastructure practices.[114] Voluntary homeowner incentive programs are one way that local governments can engage the public and raise the profile of green infrastructure projects in the community.

Tours and workshops offer another tool that municipalities and outside groups have used to raise public awareness about green infrastructure practices and the maintenance they require. The Turf Love/Garden Love Program in James City County, Virginia is a partnership between the County's Protecting Resources in Delicate Environments (PRIDE) program and Virginia Cooperative Extension Master Gardener volunteers.[115] The program combines a homeowner incentive program, offering $8 per square foot rebate for rain garden installations, along with workshops to help residents design and install their rain gardens.[116] In Washington, DC, participants in the RiverSmart Homes Program can volunteer to be a part of tours held by the District Department of the Environment.[117] Arlington County has hosted the Green It! Arlington series of workshops since 2007 which include sessions on green landscaping, rain gardens, and rain barrels. Posters advertising these workshops are posted in County libraries, community centers, and other public spaces. Arlington also holds a specialized Rain Garden Workshop to teach residents how to design, install, and maintain rain gardens on their property.[118] These programs are advertised in a bimonthly print newsletter sent to all County

residents, an online newsletter sent out every two weeks as well as through social media, Arlington environmental commissions, the local non-profit Arlingtonians for a Clean Environment, and other listservs.[119]

In addition, both local governments and their partnering community groups are using fact sheets, websites, and videos to provide further information to private property owners and the general public about green infrastructure and their maintenance responsibilities. Montgomery County, Maryland developed a series of fact sheets about various stormwater management practices, both gray and green, and the type of maintenance activities that are required. The County also offers several online subscriptions to get information about stormwater management for both landscape professionals and the general public. The Chesapeake Stormwater Network has a comprehensive library of training and outreach materials including videos, fact sheets, and webinars.[120] The Alliance for the Chesapeake Bay also provides training materials and workshops on operating and maintaining green infrastructure practices.

Recommendations to Improve Lack of Awareness or Poor Public Perception of Green Infrastructure

Throughout the Chesapeake Bay region, municipalities that incorporate green infrastructure practices into their stormwater management plans use a variety of strategies to reach out to the private property owners. Establishing homeowner incentive programs, providing opportunities to engage volunteers, and offering information and technical assistance for green infrastructure practices will help to mitigate lack of awareness or resistance from the general public. In Seattle, Washington the City faced significant push back with a Green Streets project that was fast tracked due to time constraints tied to funding under the American Recovery and Reinvestment Act (ARRA). As a result, the City was unable to conduct the typical outreach to neighbors and local residents that it had done with other green infrastructure projects. When rain gardens failed to perform as expected due to some technical problems, the City faced opposition from homeowners. This demonstrates that even in a city with a proven record of installing successful green infrastructure practices, careful planning and appropriate outreach to residents is critical to ensuring successful projects.[121] While this project was atypical due to its tight timeline, it highlights the importance of including public education and outreach to ensure effective maintenance of green infrastructure practices across the Chesapeake Bay region.

Establish a Homeowner Incentive Program

Homeowner incentive programs can be an effective way to increase the use of green infrastructure on private property and to inform community members about the problems of stormwater pollution. However, as some municipalities have identified, the increased number of green infrastructure practices located on private property can potentially exacerbate maintenance problems if homeowners aren't aware of the practices or don't know how to perform proper maintenance.[122] To mitigate this problem, homeowner incentive programs should require maintenance agreements to ensure that private property owners recognize and honor their maintenance responsibilities. These agreements should include the required maintenance activities, frequency of maintenance and inspections, data reporting requirements, notification requirements, and easements to ensure access for municipal staff for inspections as appropriate.[123, 124] While programs like the Rainscapes Program in Montgomery County, Maryland and RiverSmart Homes in Washington, DC acknowledge that there is little enforcement of these agreements, they serve as a reminder for homeowners and provide a record for the local government of green infrastructure practices being installed on private property. In addition, maintenance agreements should be valid for a discrete time period after which the homeowner must be required to renew the agreement after meeting an inspection and submitting updated documentation about the project. This is demonstrated by Seattle's RainWise Program which, by establishing a requirement to maintain the project for five years rather than the life of the

project, is designed to reflect that new homeowners may join the program as others leave. [125] By requiring maintenance agreements to be renewed, local governments can address the problem of changing home ownership and maintain homeowner engagement in the program. Additionally, local governments should provide participating homeowners with access to informal lists of contractors or practitioners that have completed training or received a certification as applicable in maintenance of green infrastructure practices. Not only will this provide a useful resource for homeowners who aren't able or willing to conduct maintenance themselves, but it will also help to increase demand for practitioners to become trained in operations and maintenance.

Improve Awareness about Where Green Infrastructure Practices are Located

In some cases, property owners may not be aware that there are any green infrastructure practices located on their property. Municipalities should consider sending out semi-annual or annual mailings to homeowners with practices on their property to ensure that homeowners are aware of the practices and their responsibilities. If a practice is installed on private property and tied to the deed, local governments would be able to work with the County Clerk's office to ensure that annual mailings are sent to the property with requests to update information in case it is sold.[126] Technical assistance through the local government should be made available to homeowners, homeowner associations, and businesses that may install green infrastructure. In addition, signage should be required on practices to explain the type of practice and ensure that they can be identified. Following Arlington County, Virginia's model, these signs should also include a phone number to report maintenance problems.[127] Outside of the Chesapeake Bay region, other communities can provide models to improve public awareness and engagement in green infrastructure practices. In Indianapolis, Indiana, homeowners can register their rain gardens with the City to be included in an interactive map and to receive a sign they can post. As part of the registration form, homeowners must include photographs of the rain garden and list the plants used.[128] This initial reporting requirement helps to engage participating homeowners and creates a record of practices installed on private property for the local government.

Offer Opportunities for Public Education about Green Infrastructure

A poor understanding of how green infrastructure works among the general public can be addressed through workshops and tours. Some municipalities offer workshops to help residents design and install rain gardens or rain barrels. These are critical resources to improve public education, but they must go further and include a discussion about the operations and maintenance of these practices. Setting up clear expectations for how the practice will look and function as well as describing the maintenance activities that homeowners may be responsible for will be critical to homeowner buy-in. Along with a discussion of how these practices will function and what homeowners are responsible for, workshops and tours should include the benefits that these practices can provide to clean water and the local community from reduced flooding to improved energy efficiency.[129] For instance, Onondaga County in New York holds a Clean Water Fair as part of its Save the Rain Program that includes a rain barrel workshop that gives an overview of installation and maintenance and a green infrastructure site tour.[130]

In addition to workshops and tours, fact sheets and online materials specifically about maintenance should be available to residents. Montgomery County, Maryland provides a regular e-newsletter in addition to the RainScapes Gazette for maintenance of stormwater best management practices designed for property managers, homeowners associations, and contractors.[131] The County is also using social media to highlight the program.[132] In Portland, Oregon, homeowners can access the *Operation and Maintenance for Property Owners* handbook that explains the importance of green infrastructure, legal requirements for property owners, sample maintenance logs, and detailed descriptions of key maintenance activities.[133] These programs should be clearly and consistently advertised to residents through print and online newsletters and at community centers, nature centers, and libraries as appropriate.

Offering opportunities to publicly discuss green infrastructure projects in the local area and the region is another way to improve public awareness. Beyond workshops and materials, municipalities and community groups should consider how to maximize their reach through news articles, coverage on local broadcasts and radio outlets, or social networking about successful local green infrastructure projects and opportunities available to the public for training and tours. Existing community events, such as Earth Day celebrations, should include booths or tours to highlight green infrastructure installation, operations, and maintenance. Innovative and creative approaches to public outreach should be considered by municipalities and outside groups. For instance, the organization Efficiency Vermont found success by printing a free column in local newspapers called "Ask Rachael" where people in communities across the state could ask questions related to energy efficiency.[134] Whether written by municipal staff or outside groups, this model could be adapted for people to ask questions about stormwater management and green infrastructure.

Establish Volunteer Maintenance Programs

Another approach to engage the general public is to establish an 'Adopt a BMP' program.[135] This could be modeled after the Center for Watershed Protection's 'Adopt-a-Pond' program designed with the Herring Run Watershed Association for the Baltimore County Department of Environmental Protection and Resources Management. Through this program, a watershed organization working with local neighborhood groups takes on the responsibility for inspections and maintenance of stormwater ponds. A survey conducted of seven similar programs across the country found several factors played a critical role in the creation of a successful program. Activities that built a sense of civic pride, incentives for participation, and training opportunities particularly about how homeowners were directly affected were important to increase engagement. Watershed groups played an important role in organizing community members and following up with participants to demonstrate successes through photographs and stories in newsletters and on websites.[136] Additionally, the Center for Watershed Protection report includes a step-by-step process for implementing the program including how to recruit volunteers, identify appropriate levels of adoption, technical training guidelines, and inspection and maintenance protocols.

Other examples of 'Adopt-a-Pond' programs include one in Tampa, Florida. This program enables homeowners to become part of a 'Pond Group' where they participate in meetings and maintenance days, mark storm drains, and complete inspection checklists.[137] Additionally, participants who adopt 'Florida-friendly landscape practices' that reduce water and fertilizer use, provide habitat for wildlife, and reduce invasive species are eligible for financial incentives to purchase equipment, hardware, or native plants for their pond through the Florida Yards and Neighborhoods Program.[138] In Rochester, Minnesota a similar 'Adopt-a-Pond' program exists where residents or commercial property owners can adopt a stormwater pond. The Rochester Public Works Department provides aerial photographs and maps to clearly show property boundaries, easements, and pond sites. Additionally, the Department provides a sign and recognizes participants on their website. In order to participate in both of these programs, volunteers must sign a liability waiver.[139]

These examples of 'Adopt-a-Pond' programs could be adapted for green infrastructure practices and allow for collaboration between local governments, watershed groups, and citizens in the operations and maintenance of these practices. Following the Tampa, Florida model, local governments should also consider incorporating incentives for volunteers to make their yards more 'Bay-friendly.'[140] Shifting the burden of basic maintenance activities, such as invasive species and litter removal, and inspections for some green infrastructure practices to watershed organizations and neighborhood groups could relieve pressure on limited municipal resources. Outside groups can also play a role providing education and outreach about the importance of maintaining green infrastructure. For example, a Maryland organization Friends of Sligo Creek in partnership with the Montgomery County RainScapes program helps to install rain gardens on private property including schools

and churches. RainScapes provides plants, soil, and mulch and Friends of Sligo Creek works to identify projects and determine the ability of property owners to perform maintenance. Although they assist with maintenance for some demonstration projects, their overall goal is to engage property owners and educate them to maintain their own projects. As a result, organizations like Friends of Sligo Creek can reduce the burden on local governments to educate and promote maintenance of these practices.[141]

One of the potential downsides of this approach, and volunteer programs generally, is the liability concerns that may be raised when residents conduct maintenance or inspections of these practices. The Center for Watershed Protection's proposal provides a liability waiver and emphasizes proper training in a 'Safety First' approach where appropriate gear must be worn and dangerous situations avoided.[142] Under the Maryland National Capital Park and Planning Commission, a chartered agency in both Montgomery and Prince George's Counties in Maryland, Montgomery Parks extends liability coverage to registered long-term volunteers that are screened, interviewed, and directly supervised by staff. However, volunteers who participate in shorter-term events, such as park clean ups, are generally not covered.[143] Fairfax County, Virginia requires participants in its 'Adopt-a-Field' program for its athletic fields to be responsible for their own liability insurance that complies with County codes and meets the County's Office of Risk Management standards. Volunteers with the County's Park Authority are covered by the Park Authority's indemnification policy.[144] Other volunteer programs that provide a model for how to handle liability concerns are those for invasive species management. Since maintenance for many green infrastructure practices, such as rain gardens or green roofs, requires plant identification, weeding, and removal of invasive species, these programs would require similar skills and may appeal to similar volunteers. The question of liability remains a significant concern for local governments in establishing volunteer programs to maintain or inspect green infrastructure. Local governments should consider working with their Risk Management offices or other appropriate departments to determine a consistent policy for liability insurance and any OSHA training or requirements that need to be followed.

Building public support and raising public awareness about green infrastructure can impact the success of these projects. Public support for financing proposals, such as stormwater utilities or infrastructure improvement districts, will be critical to paying for maintenance of green infrastructure. A basic understanding of how green infrastructure practices work and what they look like will also improve public engagement and support for properly maintaining them.

© Environmental Services, Portland Oregon

Volunteer with the Green Street Stewards Program in Portland, OR.

Green Street Stewards Program in Portland, OR

Community members in Portland, OR can volunteer to participate in the Green Street Stewards Program to help weed, remove trash, and occasionally water some of the City's green streets. While the City continues to monitor the green streets following implementation, volunteers provide basic maintenance to help keep the green streets functioning.[1] Interested volunteers participate in a free training involving a presentation and an outdoor demonstration and the City has developed a comprehensive resource outlining appropriate volunteer activities, best practices, plant lists with images, and safety guidelines.[2]

[1] Green Street Steward Program, City of Portland Bureau of Environmental Services, Accessed 21 March 2013, Available online at < http://www.portlandoregon.gov/bes/52501 >.

[2] The Green Street Stewards Maintenance Guide, City of Portland Bureau of Environmental Services, Accessed 21 March 2013, Available online at < http://www.portlandoregon.gov/bes/article/319879 >.

Limited Training and Certification Available for Practitioners

Another barrier to the operations and maintenance of green infrastructure can be a lack of appropriate training, often resulting in practices not being maintained correctly. Like gray infrastructure, green infrastructure requires frequent and consistent maintenance to continue functioning. However, practices like green roofs and rain gardens often require different maintenance activities and skill sets than traditional gray infrastructure.[145] For example, plant identification for invasive species removal is an important technical skill for the maintenance of many green infrastructure practices. Interviews with municipal staff and practitioners indicate that there are no existing standards for training or required certifications to conduct operations and maintenance for green infrastructure.[146] In addition, comprehensive technical information regarding the appropriate frequency and intensity of maintenance for different practices as well as associated costs is still emerging as green infrastructure becomes more widespread.[147]

Across the Chesapeake Bay region, many local government agencies are working to develop their own guidelines and informal trusted contractor programs to address these problems. For example, Montgomery County, Maryland conducts trainings for practitioners and maintains an informal list of trusted contractors that have completed green infrastructure maintenance training. This is particularly important as the number of green infrastructure practices on private property continues to grow. Similarly, Arlington County, Virginia also conducts trainings for landscape contractors to create a base of practitioners who are trained in operations and maintenance for green infrastructure and maintains an informal list of recommended contractors who have completed the training. While the County currently doesn't have a large number of green infrastructure practices, staff project that as more homeowners take advantage of their Stormwater Wise Landscapes program, that there will be an increased need for trained maintenance crews and contractors.[148]

Collaborations between local governments and community groups also help to address the lack of training available for green infrastructure operations and maintenance. For instance, Montgomery County's Department of Environmental Protection and other local groups worked with Montgomery College's Landscape Technology program to offer courses on stormwater maintenance for innovative practices, including green infrastructure. These courses are available to students and as Continuing Education credits for practitioners.[149] A similar effort is currently underway in Anne Arundel County in Maryland. In addition, the Chesapeake Stormwater Network received funding to develop the Chesapeake Bay Stormwater Training Partnership working with the Center for Watershed Protection, Stormwater Maintenance, LLC, District Department of the Environment, and other local Chesapeake Bay watershed partners. Over a three year period, the Partnership has provided more than 34,000 hours of training to stormwater professionals across the Chesapeake Bay watershed on installation, maintenance, and nutrient removal. While the scope of these trainings is broad, they included workshops and webinars on non-structural solutions and maintenance of green infrastructure practices.[150] Most recently, the Chesapeake Stormwater Network held a webinar in January 2013 entitled "Inspection Protocols for Maintaining and Verifying the Performance of LID Practices" and plans to release a number of tools including construction, inspection, and maintenance videos in English and Spanish,

Donald Tsusaki | Alliance for the Chesapeake Bay

Planting rain gardens with Howard County's READY Program in Maryland.

a spreadsheet tool for maintenance checklists, information about visual indicators for green infrastructure practices, and field training starting in summer of 2013.[151] Workforce development programs are also working to train young adults for maintenance work. Restoring the Environment and Educating Youth (READY) in Howard County, Virginia a collaboration of Howard County government, the Alliance for the Chesapeake Bay, People Acting Together in Howard (PATH), the University of Maryland Extension, Parks and People Foundation, will be training their second class of young adults in green infrastructure installation and maintenance in 2013.[152] In addition, North Carolina State University offers a Best Management Practice (BMP) Inspection and Maintenance Certification for commercial landscapers, property owners, municipal staff, homeowners associations, and other professionals. The training includes classes on green infrastructure BMPs such as green roofs and permeable pavement.

As green infrastructure practices become more common in the Chesapeake Bay watershed and across the country, local governments and other groups are finding different ways to meet training needs. Local governments are conducting training workshops and educating themselves about how best to conduct maintenance on green infrastructure practices in their area. In some places, like Arlington and Montgomery Counties, practitioners that go through these trainings are put on an informal 'trusted contractor' list that can be used by private or commercial property owners as a guide. Municipal training resources are supplemented by training workshops and online resources provided by outside groups, such as the Chesapeake Bay Stormwater Training Partnership or the North Carolina State University certification program.

Recommendations to Address Limited Training and Certifications

In order to address the challenge of limited certifications and trainings available to practitioners, local governments should consider developing maintenance standards for green infrastructure practices. Additionally, local governments should update maintenance handbooks or develop new resources specifically addressing maintenance practices for green infrastructure based on some of the existing examples available. These standards will provide a baseline for any certification or training program in the local community or region. To increase the demand for training and certifications and to ensure proper care of green infrastructure installations, local governments should also encourage and incentivize the hiring of trained workers by formalizing pre-approved contractor lists. Opportunities to leverage existing resources or expertise internally or from community groups should be explored to improve information sharing and increase the number of practitioners trained to operate and maintain green infrastructure practices.

Develop Maintenance Standards for Green Infrastructure

As green infrastructure practices become more common in the Chesapeake Bay region, it will be critical to ensure that there is a trained base of personnel able to operate and maintain these projects. Currently, some local governments and outside groups in the Chesapeake Bay region are working to develop training programs to address this need. However, with few guidelines or standards for maintenance of green infrastructure practices from the local government level, it will be difficult to create effective and more widespread training programs. Existing stormwater ordinances must be updated to include a requirement for the creation of consistent maintenance standards specifically for green infrastructure practices to improve compliance with MS4 permits and to create a baseline for green infrastructure maintenance best practices. Once these baselines are in place, local governments and outside groups can collaborate to create training programs and certifications for practitioners that are responsive to local needs.

At the minimum , these standards should include requirements for maintenance agreements between the property owner, contractor, and local government as appropriate for green infrastructure practices as part of the design process that clearly outline maintenance activities and who is responsible for them. These agreements should include the required maintenance activities, frequency of maintenance and inspections, data reporting requirements, notification requirements, easements to ensure reasonable access for municipal staff, and a requirement to prioritize hiring of pre-approved certified contractors or practitioners that have completed training in green infrastructure maintenance through the local government or through an alternative organization.[153, 154] Examples of maintenance agreements designed for green infrastructure practices include those under the Washington, DC District Department of the Environment's RiverSmart Homes Program and under Montgomery County, Maryland's Rainscapes Program.[155] See Appendix A. for a compendium of required maintenance activities and frequency of maintenance and inspections from the existing literature for various green infrastructure practices.

District Department of the Environment

Rain garden built through the RiverSmart Homes Program in Washington, DC.

Develop Maintenance Handbook or Guidelines for Green Infrastructure

In addition, maintenance standards should also require local governments to develop a green infrastructure maintenance handbook or guide for contractors, homeowners, and other parties responsible for maintenance. This handbook should include maintenance protocols for different practices, frequencies for maintenance activities, a list of routine and emergency maintenance activities, checklists for inspections, frequency of inspections, monitoring and data recording protocol, a list of pre-approved certified contractors or practitioners who have received training in green infrastructure maintenance, and plant identification guidelines. There are multiple maintenance handbooks in existence that include green infrastructure practices that should be used as guides and then tailored to specific needs of the local community (see Appendix B.). For example, Onondaga County in New York developed a Green Infrastructure Maintenance Training handbook that includes agendas and Power Point presentations for trainings on green infrastructure maintenance, technical fact sheets, standard maintenance procedures for green infrastructure practices like green roofs and rain gardens, sample maintenance report logs, and plant lists.[156] Seattle Public Utilities in Washington developed a Green Stormwater Operations and Maintenance Manual that summarizes routine maintenance activities for green infrastructure projects under the Natural Drainage System (NDS) program. This manual is designed for maintenance crews and provides written descriptions and photographs of different levels of maintenance for vegetation, hardscape, infrastructure, and infiltration rates.[157] As part of its Stormwater Management Manual, the City of Portland, Oregon includes a chapter on operations and maintenance of stormwater practices including ecoroofs, or green roofs, and pervious pavement.[158] The Washington State University Pierce County Extension developed guidelines for maintenance of green infrastructure practices in the Puget Sound region with routine maintenance schedules and activities for various practices.[159] See Appendix B. for more examples of maintenance manuals that include green infrastructure practices.

Establish Maintenance Training and Certification Program for Green Infrastructure

The development of consistent maintenance standards will provide a baseline that local governments and outside groups can use to create training programs for practitioners that will improve the quality of work performed on green infrastructure. Once the baseline is set for effective maintenance practices, local governments or outside groups would have the flexibility to design a tailored program to meet the needs of their community. Local governments could phase in the use of certifications by beginning with informal trusted contractor programs with voluntary training opportunities. This approach is already being used in Montgomery County, Maryland, Seattle, Washington, and Arlington County, Virginia. Once a practitioner has completed training through the local government on stormwater management including operations and maintenance of green infrastructure, they are put on a list that can be shared with homeowners. For some communities that are just beginning to implement green infrastructure practices, an informal list may be appropriate. However, this should be expanded and formalized by using the maintenance standards to design a certification process for landscape contractors and stormwater practitioners. Local governments can then steer work towards certified contractors by maintaining a list of pre-approved certified contractors. Ultimately, broader national standards could be developed with a certification that could be applied in multiple regions. However, this is likely infeasible currently and focusing on locally-specific training programs as appropriate will help to shape best practices for maintenance of green infrastructure.

These certification programs should be modeled after existing trainings held by municipalities like Montgomery County and through universities and community colleges which can offer the infrastructure to conduct certifications. For instance, North Carolina State University Cooperative Extension offers a Best Management Practice (BMP) Inspection and Maintenance Certification for commercial landscapers, property owners, municipal staff, homeowners associations, and other professionals. This program offers sessions about stormwater BMP functions, stormwater regulations, elements of maintenance, maintenance for green BMPs including bioretention and permeable pavements, licensing and certification, and a field tour of local BMPs.[160,161] As of 2010, there were around 10 cities and counties across North Carolina that require this certification for anyone who maintains or inspects stormwater BMPs.[162] The University of Minnesota Extension's Stormwater Education Program, known as Stormwater U, offers workshops for practitioners, engineers, developers, and field staff about stormwater issues for MS4 operators. As part of Stormwater U, the University offers an 'Advanced Stormwater BMP Maintenance' workshop for stormwater BMPs including green infrastructure with sessions about properly scheduling maintenance, designing BMPs for maintenance, stormwater plants and maintenance, essential elements of maintenance, and field assessments.[163] The Pratt Institute in New York City offers a Green Infrastructure Certificate through its Center for Continuing and Professional Studies in partnership with Pratt's Urban Environmental Systems Management Program and the New York City Soil and Water Conservation District. The program requires 21 hours of coursework specializing in green roofs, public right-of-way, or innovative green infrastructure study with core courses in design, construction, maintenance, and monitoring.[164] See Appendix E. for workshop agendas from these training programs.

Leverage Existing Municipal Resources

At the local level, many municipalities in the Chesapeake Bay region are building on existing expertise and programs to conduct maintenance. Leveraging resources will be critical to developing an effective and sustainable maintenance program for green infrastructure practices. For example, in James City County, Virginia the James City County/Williamsburg Master Gardeners are also trained to develop nutrient plans to reduce pollution in the Bay.[165] Existing organizations such as Master Gardener programs could be leveraged to include a component on inspections or basic maintenance of green infrastructure practices, such as weeding. Since one of the major maintenance activities with vegetated practices is the identification and removal of invasive

species, Master Gardeners would have the right set of skills to provide support to municipal staff. Anne Arundel County, Maryland offers training through its Watershed Stewards Academy. To become a Master Watershed Steward, residents must complete a certification program that includes training in pollution reduction strategies, rainscaping, and community outreach and education about stormwater runoff. Participants must also complete a Rainscaping Capstone Project to help manage stormwater and protect water quality. Operations, maintenance, and inspections for green infrastructure practices should be incorporated into this training to leverage volunteer resources. Master Watershed Stewards could also play an important role in educating the public about stormwater impacts and the need for consistent maintenance.[166] As mentioned previously, local governments may already have some of this expertise in other departments. A Parks Department with a robust invasive species removal program may have the ability to train stormwater maintenance crews in plant identification for green infrastructure practices. Working across departments and with related programs that may have different skill sets can strengthen existing maintenance programs.

Improve Collaborations with Community Groups

In addition, local governments and outside organizations should consider opportunities to collaborate to strengthen their reach. Partnerships such as the collaboration between Montgomery County and Montgomery College to offer courses on green infrastructure and stormwater management demonstrate how local governments and outside groups can work together to leverage resources and expand their reach. Montgomery County can provide its expertise in green infrastructure in the design of courses that will ultimately provide more trained practitioners who are able to use these types of practices. In Howard County, Maryland, several diverse groups worked together to develop the Restoring the Environment and Developing Youth (READY) program to provide training for young adults in the installation of green infrastructure. The Howard County government, the Alliance for the Chesapeake Bay, People Acting Together in Howard (PATH), the University of Maryland Extension, and the Parks and People Foundation all collaborated in the development of this program. PATH developed the original plan for the program and approached the County which brought in other outside groups with expertise in stormwater management. These diverse groups collaborated to create a program that led to multiple rain garden installations and a group of young adults trained and employed in green infrastructure.[167] These examples demonstrate that local governments can build upon existing resources to manage and maintain green infrastructure practices by coordinating with outside groups. In addition, local governments should look for opportunities to coordinate with community and workforce development groups to link trained workers with work opportunities. Prioritizing hiring of pre-approved certified contractors who complete training with the local government or with an accepted outside group for municipal work will help to increase the value of green infrastructure maintenance certifications.

Donald Tsusaki | Alliance for the Chesapeake Bay

Participants with Howard County's READY Program.

Explore Opportunities for Workforce Development

Importantly, operations and maintenance of green infrastructure represents an opportunity to create entry-level jobs for youth and disadvantaged communities. Workers skilled in landscaping, plumbing, horticulture, engineering, and construction will be in demand as more green infrastructure practices are implemented in the Chesapeake Bay and across the country. These skills can be applied to green infrastructure practices and create opportunities for job creation. Currently, many local governments have little experience with green infrastructure

and are often completing maintenance themselves, developing estimates for costs and resource requirements as they implement these practices. As a result, existing demand for workers trained in green infrastructure operations and maintenance is low. However, as more communities like Philadelphia and New York City invest in green infrastructure, there will be increasing opportunities for workers with relevant skills that can apply them to the maintenance of green infrastructure. The companion re port Staying Green and Growing Jobs: Green Infrastructure Operations and Maintenance as Career Pathway Stepping Stones provides more detail about opportunities to create entry-level jobs in operations and maintenance of green infrastructure and highlights case studies of programs that connect youth and disadvantaged communities to opportunities in green infrastructure maintenance work.

In order to address the current lack of practitioners trained in operations and maintenance of green infrastructure, local governments should first look to updating their stormwater ordinances to include maintenance standards for green infrastructure requiring maintenance agreements and maintenance handbooks. Once these baselines are in place, local governments and outside groups can collaborate to create or expand upon training programs and certifications for practitioners specifically for green infrastructure operations and maintenance. With limited resources, local governments should consider leveraging existing programs such as Master Gardeners or Watershed Stewards to provide support to municipal staff. Collaboration between outside groups and local governments, as demonstrated in Howard County through the READY program, is critical to creating a base of practitioners trained in the operations and maintenance of green infrastructure and can help to create pathways connecting youth and disadvantaged communities to job opportunities in the green sector.

Seattle Conservation Corps

In 1986, the City of Seattle established the Seattle Conservation Corps under its Parks and Recreation Department. The Seattle Conservation Corps provides full-time paid employment for between 80 and 100 participants annually from disadvantaged communities. Participants receive additional services such as life skills training, mental health counseling, and transportation assistance through the program as well. In turn, the Seattle Conservation Corps bids for contracts with the public sector including Seattle Public Utilities, allowing approximately 75 percent of their budget to be raised through project revenue. An estimated 65 percent of participants complete the program and found permanent employment. These types of workforce development programs that provide services and opportunities for disadvantaged communities while at the same time performing needed maintenance of green infrastructure are examined in more detail in our companion report.[1]

[1] Andersen, Cathie, Seattle Conservation Corps, Personal Interview, 15 February 2013

Companion Report: *Staying Green and Growing Jobs*

To learn more about workforce development in the field of green infrastructure operations and maintenance, read our companion report *Staying Green and Growing Jobs: Green Infrastructure Operations and Maintenance as Career Pathway Stepping Stones.* As more green infrastructure practices are installed, there will likely be a significant opportunity to create entry-level jobs in the green sector, particularly for individuals from disadvantaged communities. Our companion report assesses existing and potential occupations in green infrastructure operations and maintenance, highlights existing workforce development programs that can provide models for local governments or community organizations, and recommends strategies to improve career opportunities and job quality in the field of green infrastructure operations and maintenance.

Minimal or Ineffective Enforcement and Inspection Procedures

Inspections and enforcement measures are critical to any effective maintenance program for stormwater management facilities. Without frequent inspections to identify problems and ensure that maintenance is occurring, both gray and green infrastructure can lose functionality and ultimately fail. Adapting maintenance programs to include appropriate inspection and enforcement measures specifically for green infrastructure will be critical to the successful adoption and implementation of these practices. For instance, practices such as bioretention or green roofs may require different inspection schedules than more conventional infrastructure. Because these practices are more dependent on vegetation than other types of gray infrastructure to function, it is necessary to tailor inspections around growing seasons to ensure plant health. In addition, inspections for green infrastructure practices will also require different technical expertise and skill sets, particularly for vegetated practices. Enforcement measures that ensure that parties responsible for maintenance perform the required maintenance activities will need to be re-examined and adapted for decentralized green infrastructure practices that may be more frequently built on private property. Several municipalities in the Chesapeake Bay region noted that determining inspection criteria as well as implementing enforcement measures represented a barrier for the widespread implementation of green infrastructure practices.

Local governments and watershed groups are beginning to address these concerns in different ways. Tracking and evaluation systems are key components of maintenance programs and become even more important with the potential for many decentralized green infrastructure practices. Requiring maintenance agreements for practices built on private property is the first step in developing a comprehensive database of practices. Once the record is created, local government staff can follow up and inspect or require private property owners to conduct inspections of the practice. Montgomery County, Maryland tracks its growing number of green infrastructure practices in a database. The County has also created an online interactive map of County-owned stormwater management facilities.[168] Albemarle County, Virginia uses GIS and associated databases to track its stormwater facilities.[169]

In addition to tracking the location of these practices, it is also important to properly evaluate the practice during inspections. Some communities have developed inspection checklists that can be used by local government staff, contractors, or private property owners to evaluate green infrastructure practices. The 2009 *Virginia Stormwater Management Handbook* includes operations and maintenance checklists for green roofs, rain barrels and cisterns, permeable pavement, and bioretention.[170] Other examples from outside the Chesapeake Bay region include checklists for different green infrastructure practices from Seattle Public Utilities, the *Minnesota Stormwater Manual*, and the Kingsport, Tennessee *Stormwater Management Manual.* [171,172,173,174] See Appendix C. for a list of post-construction checklists for various green infrastructure practices.

One innovative approach to inspections for green infrastructure is to develop volunteer programs to supplement municipal resources and engage private property owners. 'Adopt-a-Pond' programs adapted for green infrastructure, as discussed previously, can not only increase homeowner awareness, but have the potential to support municipal staff in conducting inspections of increasingly dispersed green infrastructure practices. In addition, more formalized watershed groups and associations can take on some inspection responsibilities as well. In Anne Arundel County, the Severn River Association partnered with the Community and Environmental Defense Services (CEDS) to conduct an audit of stormwater best management practices (BMPs) and Environmental Site Design (ESD), or green infrastructure, practices among other water quality activities in the Severn River watershed. The goal of this audit was to identify levels of compliance with regulated activities to protect clean water within the watershed. This example demonstrates how outside groups might work with local governments to inspect green infrastructure practices and determine if maintenance is being properly performed. Volunteer programs offer an innovative way to engage citizens and educate

homeowners about the operations and maintenance of green infrastructure practices. However, these programs raise liability concerns if volunteers attempted to access private property or easements where only municipal staff is allowed access. While most practices should be visible without trespassing, proper training and oversight must ensure that volunteers understand their role and limitations. As discussed previously, liability concerns are a critical factor in the development and implementation of a volunteer program.

The enforcement side of maintaining green infrastructure practices offers its own challenges. Traditionally for publicly owned facilities, maintenance is often enforced using a variety of compliance mechanisms. A maintenance agreement between the property owner and the local government creates a contract to ensure access to the property if maintenance is not occurring and that costs can be billed to the owner. A performance bond may be posted to ensure that enforcement action can be taken at the developer's or owner's expense. For example, Culpeper County in Virginia ensures that homeowners perform maintenance activities on stormwater practices by posting a bond.[175] A maintenance escrow can also be posted to cover the costs of maintenance. If the owner is not in compliance with required maintenance activities, the local government may send out a Notice of Violation (NOV) detailing the actions that need to be taken and a time frame during which they need to occur. The local government can then levy a civil or criminal penalty for non-compliance.[176] Provided that consistent inspection procedures are implemented, these enforcement measures could be adapted to publicly-owned and maintained green infrastructure practices.

Enforcing maintenance of voluntary green infrastructure practices built on private property represents an additional challenge. Communities such as Montgomery, Maryland and Seattle, Washington require maintenance agreements for their homeowner incentive programs to provide rebates for green infrastructure built on residential or commercial property. These agreements require the property owner to be responsible for all maintenance associated with the project, allow access to municipal staff for inspections, and require the property owner to notify the local government of any ownership changes.[177] However, interviews with program officials demonstrate that these maintenance agreements are rarely enforced, but rather serve as a reminder for private property owners.[178] Enforcing maintenance of such voluntary projects on private property will continue to remain a challenge for local governments. Seattle has attempted to address this by only requiring the homeowner to operate and maintain any practices built through its voluntary homeowner incentive program for five years. Program staff members expect that new homeowners will participate in the program as other homeowners either remove their practice after five years or cease to maintain it.[179]

Recommendations to Adapt Inspection and Enforcement Procedures for Green Infrastructure

As more communities adopt green infrastructure practices as part of the suite of approaches used to reduce polluted runoff, shifts in inspections and enforcement practices must occur. With the growth of voluntary incentive programs such as the Rainscapes Program in Montgomery County and the Chesapeake Bay Total Maximum Daily Load as a regulatory driver, it is likely that more green infrastructure practices will be put into the ground, many on private property. As a result, traditional inspection and enforcement procedures will need to be adapted to ensure that green infrastructure practices continue to function properly.

Establish Inspection Procedures and Schedules for Green Infrastructure

Local governments should establish inspection procedures and schedules to clearly evaluate and track maintenance for each type of green infrastructure practice as part of its updated maintenance handbook. Green infrastructure practices will require different inspection procedures and expertise than conventional gray

infrastructure practices. For example, plant identification is a critical skill to be able to determine plant health or the presence of invasive species and therefore to rate the functionality of the practice and what maintenance activities may be required. Inspecting rain gardens during the spring and summer months will enable maintenance crews to address problems from extended drought or disease.[180] As a result, inspection procedures for green infrastructure practices should be developed with clear checklists that can be easily integrated into a database to track the maintenance and function of each project. While the design of the checklist can be flexible, it should include key identifying information such as the date, location, owner, site plan or permit number, and date of the last inspection.[181] Additionally, it should include a narrative description of required maintenance activities and their frequency for different practices or elements of practices, what the practice should look like if maintenance activities are properly conducted, and any potential problems that may occur.[182] The checklist should provide space for inspectors to mark whether the practice meets the conditions that should exist, if any maintenance is required to address problems, who is responsible for addressing the problem, and how it will be fixed. Narrative descriptions about the practice and photographs should be included with the completed inspection checklist. [183] Inspection procedures could also be developed upfront for specific projects as part of the design plan. See Appendix B. for sample inspection and maintenance checklists.

Electronic Tracking of Green Infrastructure O&M in Spokane, Washington

The City of Spokane, WA received funding under the Green Project Reserve as part of the Clean Water State Revolving Fund (SRF) to construct thirty-seven rain gardens and 1,200 square yards of pervious pavement as part of the West Broadway Spokane Urban Runoff Greenways Ecosystem (SURGE) project.[1] Spokane uses an asset management system through the City's Sewer Maintenance Division to track O&M of these practices and other stormwater management practices. Maintenance workers can log into the system that uses a GIS platform on a laptop directly from the site to track maintenance tasks and needs. Entries are instantly uploaded and date stamped, minimizing duplication and increasing efficiency of tracking.[2]

[1] Case Study: Spokane Urban Runoff Greenways Ecosystem Innovative Stormwater Management, U.S. Environmental Protection Agency, Accessed 18 March 2013, Available online at < http://water.epa.gov/grants_funding/cwsrf/upload/Spokane-Green-Infrastructure-Case-Study.pdf >

[2] The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure: A Review of Green Infrastructure O&M Practices in ARRA Clean Water State Revolving Fund Projects, U.S. Environmental Protection Agency, Accessed 18 March 2013, Available online at < http://water.epa.gov/grants_funding/cwsrf/upload/Green-Infrastructure-OM-Report.pdf >.

Establish Inspection Training and Certification for Green Infrastructure

Based on the established inspection procedures, local governments alone or in collaboration with outside groups should hold trainings on inspections for green infrastructure practices. Specific training on inspection best practices could be combined with other workshops and trainings about operations and maintenance of green infrastructure. The North Carolina State University Best Management Practice (BMP) Inspection and Maintenance Certification training includes inspection practices and highlights the North Carolina State BMP Manual which includes inspection checklists for a number of stormwater management practices including some green infrastructure technologies. The Chesapeake Stormwater Network recently released a webinar on inspection protocols for maintaining green infrastructure practices for verifying performance under the Chesapeake TMDL. It describes a visual indicators approach assigning grades to key visual indicators with the goal of completing the inspection of a bioretention facility in less than ten minutes. The training includes multiple photographs and narrative descriptions of these indicators to allow assessment of the facility.[184] To complement this presentation, the Chesapeake Stormwater Network also released a video about inspecting green infrastructure practices available in both English and Spanish.[185] Certifications or training programs for inspections could be useful not only for municipal staff but also for landscape contractors or maintenance crews who may be able to easily conduct basic inspections of green infrastructure practices on a site where

they may already be conducting maintenance. As Montgomery County, Maryland, Arlington, Virginia, and other communities are doing with practitioner training, local governments should consider developing informal lists of inspectors who have completed this training. Opportunities to integrate inspections for green infrastructure with other existing inspection programs should be explored to leverage resources. Existing certification programs for inspectors should be expanded to include inspections for green infrastructure.

Evaluate Opportunities for Volunteer Inspection Programs

While not appropriate in every place, local governments should consider collaborating with local groups to develop volunteer inspection programs. These programs would be based on guidelines created by the local government and administered through local watershed or neighborhood groups. With appropriate training and oversight, interested volunteers could conduct visual inspections of practices without trespassing on private property. Volunteer programs could be further strengthened by tapping in existing groups with appropriate expertise, such as Master Gardener or Master Watershed Stewards programs. While these inspections may not be as thorough as those conducted by municipal or county maintenance crews, they could still provide critical documentation about the health and function of green infrastructure practices. In addition, such a volunteer program could also raise public awareness about green infrastructure practices, the importance of maintenance, and what to expect from different projects. The "Rain Garden and Bioretention Facility Audits" report provides a model handbook for volunteer inspectors to use. It includes an inspection checklist as well as narrative descriptions and photographs. Training homeowners who participate in voluntary green infrastructure installation programs is another opportunity to improve inspections. Once trained to identify their practice, how it functions, the maintenance needed to keep it functioning, and what it should look like if properly maintained, homeowners could conduct basic inspections and upload their reports into an online form.

Adapt Enforcement Procedures for Green Infrastructure

Once a consistent policy for inspection procedures is in place, existing enforcement measures should be altered as appropriate for green infrastructure practices to improve maintenance. A tiered enforcement system should be adopted, starting with the establishment of a maintenance agreement between the local government and private property owner. Once the practice is built, a maintenance agreement should be developed that sets the legal foundation to ensure that maintenance occurs and establishes the responsibilities of the property owner and the local government. While little enforcement for voluntary incentive programs may actually occur, these agreements can serve as a tool that local governments can use to encourage maintenance. Additionally, local governments should consider requiring a maintenance escrow or performance bond from the developer or property owner that would cover the costs of maintenance or replacement if the practice fails.[186] This would provide an additional financial incentive to ensure that maintenance occurs. If inspections demonstrate that maintenance isn't occurring, local governments should consider levying a fine in the form of higher property taxes until the property owner performs the maintenance. These types of enforcement mechanisms should be flexible and adaptable as the information relating to operations and maintenance of green infrastructure practices evolves. However, as more jurisdictions within the Chesapeake Bay watershed consider green infrastructure practices to meet their TMDL requirements, it will become critical to demonstrate that maintenance is enforceable.

Without adapting inspection and enforcement procedures, it will be very difficult to measure the effectiveness of other improvements, such as green infrastructure maintenance certifications, and to ultimately determine whether green infrastructure practices are functioning as designed. This is especially important when green infrastructure practices are included as strategies to meet regulatory requirements such as the Chesapeake Bay TMDL.

Montgomery County, MD

Green roof constructed under the RainScapes Program in Montgomery County, MD

Conclusion

While some communities in the Chesapeake Bay watershed are moving forward with implementing green infrastructure, others are hesitant in part because of concerns around operations and maintenance. Montgomery County, Maryland, Arlington, Virginia, and Washington, DC are three examples of forward-thinking communities that have adopted some level of green infrastructure practices and programs. Across the country, early adopters of green infrastructure such as Seattle, Washington and Portland, Oregon provide models and examples of more widespread implementation of these practices and the resulting maintenance challenges. Based on interviews with municipalities, watershed groups, and practitioners, four barriers directly related to operations and maintenance of green infrastructure emerged.

Primarily, paying for operations and maintenance was identified as a significant challenge for many local governments. While not available in every place, stormwater utilities offer a consistent source of funding for stormwater management including operations and maintenance that is equitably linked to impact and offers opportunities for private investment. Other financing mechanisms including beneficiary opportunity funds, public-private partnerships, infrastructure improvement districts, and dedicated funds for clean water should also be evaluated. A lack of awareness about green infrastructure and the importance of maintenance can be addressed through homeowner incentive programs, neighborhood outreach, workshops, and tours. Volunteer programs to adopt local green infrastructure practices offer another strategy to engage residents and improve public perception. Limited training and certification program make it more difficult for practitioners and local governments to conduct effective maintenance. Developing baseline standards to use to design tailored training programs will help to address this challenge. In addition, leveraging existing resources will strengthen the reach of training programs and certifications. Adapting inspection and enforcement procedures for green infrastructure is critical to properly track and evaluate these practices. Inspections offer another opportunity to engage community members through volunteer programs to leverage existing municipal resources.

More research is needed to track existing green infrastructure practices and evaluate their functionality. Better estimates for the costs of maintaining these types of practices, standardized maintenance guidelines, and more robust technical assistance are also needed. While these strategies can mitigate some of the primary challenges, operations and maintenance of green infrastructure will likely remain a barrier to its widespread implementation in many communities.

ENDNOTES

1 *Agriculture*, U.S. Environmental Protection Agency, Accessed 22 February 2013, Available online at < http://water.epa.gov/polwaste/nps/agriculture.cfm >, 2012.

2 *Managing Urban Runoff*, U.S. Environmental Protection Agency, Accessed 22 February 2013, Available online at < http://water.epa.gov/polwaste/nps/outreach/point7.cfm >, 2012.

3 *Stormwater Runoff*, Chesapeake Bay Program, Accessed 4 March 2013, Available online at < http://www.chesapeakebay.net/issues/issue/stormwater_runoff >.

4 Odefey, Jeff, Stacey Detwiler, Katie Rosseau, et. al., *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide*, American Rivers, ASLA, WEF, NRDC, Accessed 8 January 2013, Available online at < http://www.americanrivers.org/assets/pdfs/reports-and-publications/banking-on-green-report.pdf >, 2012.

5 Claggett, Peter R., Claire A. Jantz, Scott J. Goetz, and Carin Bisland, 2004, "Assessing Development Pressure in the Chesapeake Bay Watershed: An Evaluation of Two Land-Use Change Models,," *Environmental Monitoring and Assessement,* 94: 129-146, Accessed 22 February 2013, Available online at < http://www.whrc.org/resources/publications/pdf/ClaggettEnvMonAss.04.pdf >, 2004.

6 *The Chesapeake Bay Watershed*, The Chesapeake Bay Program, Accessed 22 February 2013, Available online at < http://www.chesapeakebay.net/discover/baywatershed>.

7 See e.g. *Barriers and Gateways to Green Infrastructure*, Clean Water America Alliance (now U.S. Water Alliance), Accessed 22 February 2013, Available online at < http://savetherain.us/wp-content/uploads/2011/10/Barriers-and-Gateways-to-GI_CWAA.pdf >, 2011.

8 *Stormwater Runoff*, Chesapeake Bay Program, Accessed 4 March 2013, Available online at < http://www.chesapeakebay.net/issues/issue/stormwater_runoff >.

9 *Protecting Water Quality from Urban Runoff*, U.S. Environmental Protection Agency, Accessed 22 January 2013, Available online at < http://www.epa.gov/npdes/pubs/nps_urban-facts_final.pdf >, 2003.

10 *Earth's Water: Runoff*, U.S. Geological Survey, Accessed 18 January 2013, Available online at < http://ga.water.usgs.gov/edu/runoff.html >.

11 Kloss, Christopher and Crystal Calarusse, *Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows*, Natural Resources Defense Council, 2006.

12 *Urban Stormwater Management in the United States*, National Research Council, The National Academies Press, Washington, DC, Accessed 17 January 2013, Available online at < http://www.epa.gov/npdes/pubs/nrc_stormwaterreport.pdf >, 2008.

13 *Protecting Water Quality from Urban Runoff*, U.S. Environmental Protection Agency, Accessed 22 January 2013, Available online at < http://www.epa.gov/npdes/pubs/nps_urban-facts_final.pdf >, 2003.

14 *Earth's Water: Runoff*, The USGS Water Science School, Accessed 7 January 2013, Available online at < http://ga.water.usgs.gov/edu/runoff.html >.

15 Booth, Derek B., "Urbanization and the Natural Drainage System-Impacts, Solutions, and Prognosis," *The Northwest Environmental Journal*, 7.1: 93-118, 1991.

16 *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorous, and Sediment*, U.S. Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLExecSumSection1through3_final.pdf >, 2010.

17 S. J. Gaffield, et al, "Public Health Effects of Inadequately Managed Stormwater Runoff," *American Journal of Public Health*, 93:9, 2003.

18 *Combined Sewer System*, DC Water District of Columbia Water and Sewer Authority, Accessed 7 January 2013, Available online at < http://www.dcwater.com/wastewater_collection/css/default.cfm >.

19 Combined Sewer Overflows, National Pollutant Discharge Elimination System (NPDES), U.S. Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://cfpub.epa.gov/npdes/home.cfm?program_id=5 >, 2012.

20 *Report to Congress: Impacts and Control of CSOs and SSOs*, U.S. Environmental Protection Agency, EPA 833-R-04-001, Accessed 17 January 2013, Available online at < http://cfpub.epa.gov/npdes/cso/cpolicy_report2004.cfm >, April 2004.

21 *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorous, and Sediment*, U.S. Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLExecSumSection1through3_final.pdf >, 2010.

22 *2000 National Water Quality Inventory*, US Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://water.epa.gov/lawsregs/guidance/cwa/305b/2000report_index.cfm >. The figures cited show levels of impairment in water actually assessed by state agencies.

23 Kloss, Christopher, Crystal Calarusse, *Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows,* Natural Resources Defense Council, 2006.

24 *Clean Watersheds Needs Survey 2008 Report to Congress*, U.S. Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://water.epa.gov/scitech/datait/databases/cwns/2008reportdata.cfm >, 2008.

25 *What is Nonpoint Source Pollution?,* U.S. Environmental Protection Agency, Accessed 17 January 2013, Available online at < http://water.epa.gov/polwaste/nps/whatis.cfm >, 2012.

26 *NPDES Wastewater & Stormwater Permits*, U.S. Environmental Protection Agency, Accessed 17 January 2013, Available online at < http://www.epa.gov/region9/water/npdes/stormwater.html >.

27 Clean Water Act of 1972, 33 U.S.C. 1342, Available online at < http://143.231.180.80/browse/prelim@title33/chapter26&edition=prelim >.

28 *Guidance for Municipal Stormwater Funding*, National Association of Flood and Stormwater Management Agencies, Accessed 1 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006.

29 *Stormwater Phase II Final Rule Fact Sheets*, U.S. Environmental Protection Agency, Accessed 1 February 2013, Available online at < http://cfpub.epa.gov/npdes/stormwater/swfinal.cfm >.

30 *Urban Stormwater Management in the United States*, National Research Council, The National Academies Press, Accessed 17 January 2013, Available online at < http://www.epa.gov/npdes/pubs/nrc_stormwaterreport.pdf >, 2008.

31 *Impaired Waters and Total Maximum Daily Loads*, U.S. Environmental Protection Agency, Accessed 7 January 2012, Available online at < http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm>, 2012.

32 Roseen, Robert M., Todd V. Janeski, Michael Simpson, et. al., *Economic and Adaptation Benefits of Low Impact Development, Conference Proceedings*, 2011 Low Impact Development Symposium, March 2012.

33 *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorous, and Sediment*, U.S. Environmental Protection Agency, Accessed 7 January 2013, Available online at < http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/CBayFinalTMDLExecSumSection1through3_final.pdf >, 2010.

34 Odefey, Jeff, Stacey Detwiler, Katie Rosseau, et. al., *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide*, American Rivers, ASLA, WEF, NRDC, Accessed 8 January 2013, Available online at < http://www.americanrivers.org/assets/pdfs/reports-and-publications/banking-on-green-report.pdf >, 2012.

35 Odefey, Jeff, Stacey Detwiler, Katie Rosseau, et. al., *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide*, American Rivers, ASLA, WEF, NRDC, Accessed 8 January 2013, Available online at < http://www.americanrivers.org/assets/pdfs/reports-and-publications/banking-on-green-report.pdf >, 2012.

36 *Reducing Urban Heat Islands: Compendium of Strategies. Green Roofs*, U.S. EPA, October 2008. Accessed 10 January 2012, Available online at <http://www.epa.gov/heatisland/resources/compendium.htm>.

37 *O'Hare Building Home to City's Largest Green Roof,* Media Release, October 2011. Accessed 2 December 2011, Available online at <http://abclocal.go.com/wls/story?section=resources/lifestyle_community/green&id=8383574>.

38 Odefey, Jeff, Stacey Detwiler, Katie Rosseau, et. al., *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide*, American Rivers, ASLA, WEF, NRDC, Accessed 8 January 2013, Available online at < http://www.americanrivers.org/assets/pdfs/reports-and-publications/banking-on-green-report.pdf >, 2012.

39 *Bread for the City's Rooftop Garden Projects*, Bread for the City, Available online at <http://www.breadforthecity.org/rooftopgarden/>.

40 Roseen, Rob, Todd Janeski, James Houle, et. al., *Forging the Link*, "Economics and LID Practices," University of New Hampshire Stormwater Center, Accessed 19 January 2013, Available online at < http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/FTL_Chapter3%20LR.pdf >.

41 *Rain to Recreation*, City of Lenexa, Accessed 10 January 2013, Available online at < http://www.lenexa.com/raintorecreation/index.html >.

42 Dunn, Alexandra Dapolito and Nancy Stoner, "Green Light for Green Infrastructure,," Pace University School of Law, Accessed 17 January 2013, Available online at http://digitalcommons.pace.edu/cgi/viewcontent.cgi?article=1493&context=lawfaculty&sei-redir=1&referer=http%3A%2F%2Fwww.google.com%2Furl%3Fsa%3Dt%26rct%3Dj%26q%3Dgreen%2520light%2520for%2520green%2520infrastructure%26source%3Dweb%26cd%3D1%26ved%3D0CDIQFjAA%26url%3Dhttp%253A%252F%252Fdigitalcommons.pace.edu%252Fcgi%252Fviewcontent.cgi%253Farticle%253D1493%2526context%253Dlawfaculty%26ei%3DKrn5UMmjNLG30QH6toDYAw%26usg%3DAFQjCNGH89yPxzTwBNlo1vocseGge-o01w%26bvm%3Dbv.41248874%2Cd.dmQ#search=%22green%20light%20green%20infrastructure%22 >, 2007.

43 Roseen, R.M., T.V. Janeski, J.J. Houle, et al. *Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decision.,* University of New Hampshire Stormwater Center, Virginia Commonwealth University, and Antioch University New England. July 2011.

44 A.J. Erickson, J.S. Gulliver, J. Kang, et. al., "Maintenance for Stormwater Treatment Practices," *Journal of Contemporary Water Research and Education*, 146: 75-82, December, 2010.

45 *Draft 2009 Virginia Stormwater Management Handbook*, Chapter 9, Virginia Department of Conservation, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

46 *Dry Detention Ponds*, U.S. Environmental Protection Agency, Accessed 11 January 2013, Available online at < http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=67 >.

47 *Clark County Public Works Department*, Clark County, Washington, Accessed 22 January 2013, Available online at < http://www.clark.wa.gov/water-resources/documents/Manuals/StormwaterFacilityMaintenanceManual.pdf >, 2009.

48 See *Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan*, Philadelphia Water Department, 2012; Environmental Site Design Manual, Queen Anne's County, Centreville, MD, Available online at < http://www.qac.org/Docs/PublicWorks/esdm/QAC_ESDM.pdf > December 2007; Onondaga County, NY *Save the Rain Program Green Infrastructure Maintenance Manual*, Onondaga County, NY, Accessed 7 January 2012, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.

49 See *Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan*, Philadelphia Water Department, 2012; Environmental Site Design Manual, Queen Anne's County, Centreville, MD, Available online at < http://www.qac.org/Docs/PublicWorks/esdm/QAC_ESDM.pdf > December 2007; Onondaga County, NY *Save the Rain Program Green Infrastructure Maintenance Manual*, Onondaga County, NY, Accessed 7 January 2012, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.

50 *Resources on Invasive Plants*, Department of Parks and Recreation, Arlington County, Virginia, Accessed 22 January 2013, Available online at < http://www.arlingtonva.us/departments/ParksRecreation/scripts/parks/ParksRecreationScriptsParksInvasiveResources.aspx >, 2012.

51 *Fairfax County Stewardship: Invasive Management Area*, Fairfax County, Virginia, Accessed 22 January 2013, Available online at < http://www.fairfaxcounty.gov/parks/resources/ima/ >, 2011.

52 *The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure: A Review of Green Infrastructure O&M Practices in ARRA Clean Water State Revolving Fund Projects*, U.S. Environmental Protection Agency, Accessed 21 March 2013, Available online at < http://water.epa.gov/grants_funding/cwsrf/upload/Green-Infrastructure-OM-Report.pdf >, 2013.

53 COMAR 26.17.02.04, Available online at < http://www.dsd.state.md.us/comar/getfile.aspx?file=26.17.02.04.htm >.

54 *Delaware's Phase II Chesapeake Bay Watershed Implementation Plan*, Delaware's Chesapeake Interagency Workgroup, Accessed 10 January 2013, Available online at < http://www.dnrec.delaware.gov/swc/wa/Documents/ChesapeakePhaseIIWIP/Final_Phase2_CBWIP_03302012A.pdf >, March 2012.

55 Minton, Gary R., *A Survey of Installation and Maintenance Costs of Stormwater Treatment Facilities*, Resource Planning Associates, Accessed 23 January 2013, Available online at < http://www.scvurppp-w2k.com/permit_c3_docs/0803_BASMAA_Treatment_Control_Cost_Survey3.pdf >, 2003.

56 *Estimating Stormwater System Annual Maintenance and Repair Costs – A GIS Approach*, Brown and Caldwell, Accessed 19 March 2013, Available online at < http://www.seswa.org/files/Services/Conference/2011%20Annual%20Conference/17%20-%20Lewallen.pdf >, October 2011.

57 *Municipal Stormwater Toolbox for Maintenance Practices*, Cleveland State University, Accessed 19 March 2013, Available online at < http://webcache.googleusercontent.com/search?q=cache:UW4erx1rHigJ:urban.csuohio.edu/glefc/training/toolbox/stormwater.doc+&cd=3&hl=en&ct=clnk&gl=us&client=firefox-a >.

58 *Planning and Cost Estimating Criteria for Best Management Practices,* Rouge River National Wet Weather Demonstration Project, Accessed 19 March 2013, Available online at < http://www.rougeriver.com/pdfs/stormwater/sr25.pdf >, 2001.

59 *Oil-Grit (Gravity) Separator*, Knox County Tennessee Stormwater Management Manual, Accessed 19 March 2013, Available online at < http://www.knoxcounty.org/stormwater/pdfs/vol2/4-4-7%20Oil-Grit%20Separator.pdf >.

60 *Debris Removed from Milwaukee's Deep Tunnel,* Stormwater Solutions, Accessed 19 March 2013, Available online at < http://www.estormwater.com/debris-removed-milwaukees-deep-tunnel >, 2012.

61 *BMP Inspection and Maintenance*, U.S. Environmental Protection Agency, Accessed 23 January 2013, Available online at < http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=91>, 2012.

62 *BMP Inspection and Maintenance*, U.S. Environmental Protection Agency, Accessed 23 January 2013, Available online at < http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=91>, 2012.

63 *Note on Adjusting Dollar Variables for Inflation*, Minnesota Population Center, University of Minnesota, Accessed 21 February 2013, Available online at < https://usa.ipums.org/usa/cpi99.shtml >.

64 *Maintenance of Low Impact Development: Communities are Easily Managing LID Practices*, U.S. Environmental Protection Agency, Accessed 8 February 2013, Available online at < http://water.epa.gov/polwaste/green/upload/bbfs6maintenance.pdf >.

65 *User's Guide to the BMP and LID Whole Life Cost Models Version 2.0*, Water Environment Research Federation, Accessed 23 January 2013, Available online at < http://www.werf.org/i/a/Ka/Search/ResearchProfile.aspx?ReportId=SW2R08 >, 2009. See Tab 7 of spreadsheet tools for design and cost information and Tab 8 for references.

66 *User's Guide to the BMP and LID Whole Life Cost Models Version 2.0*, Water Environment Research Federation, Accessed 23 January 2013, Available online at < http://www.werf.org/i/a/Ka/Search/ResearchProfile.aspx?ReportId=SW2R08 >, 2009. Note: These default numbers for maintenance costs used in the model reflect data collected from agencies and, when not available, engineering estimates. For the permeable pavement default, the model doesn't account for the relationship between size and cost due to very limited data particularly for corrective maintenance. For green roofs, bioretention, and rain gardens the default model costs are scaled to reflect hours per maintenance activity in relation to the surface area of the facility. These maintenance costs also reflect estimates based on capital costs of replacing growing media and other materials. The in-curb planter vault maintenance default costs were scaled based on the number of vaults installed. Maintenance costs for cisterns were estimated by scaling labor costs by hours required for maintenance of the roof depending on roof size and pump replacement is reflective of the capital cost estimate.

67 Wossink, Ada and Bill Hunt, "The Economics of Structural Stormwater BMPs in North Carolina," WRRI Project, North Carolina State University, Accessed 25 March 2013, Available online at < http://www.bae.ncsu.edu/stormwater/PublicationFiles/EconStructuralBMPs2003.pdf >, 2003.

68 *NYC Green Infrastructure Plan*, New York City Department of Environmental Protection, Accessed 11 February 2013, Available online at < http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_LowRes.pdf >, 2010.

69 O'Dell, Colleen, *Green Infrastructure Regional Maintenance Alliance*, Research Report for Metro Blooms, University of Minnesota, January 2011.

70 Wossink, Ada, and Bill Hunt, North Carolina State University, North Carolina Cooperative Extension Service, Accessed 25 March 2013, Available online at < http://www.bae.ncsu.edu/people/faculty/hunt/bmpcosts&benefits.pdf >, 2003.

71 Houle, James J., Robert M. Roseen, Thomas P. Ballestero, et. al., *A Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management*, University of New Hampshire Stormwater Center.

72 Odefey, Jeff, Stacey Detwiler, Katie Rosseau, et. al., *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide*, American Rivers, ASLA, WEF, NRDC, Accessed 8 January 2013, Available online at < http://www.americanrivers.org/assets/pdfs/reports-and-publications/banking-on-green-report.pdf >, 2012.

73 *Guidance for Municipal Stormwater Funding*, National Association of Flood and Stormwater Management Agencies, Accessed 4 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006.

74 *2009 Infrastructure Fact Sheet*, American Society of Civil Engineers, Accessed 4 February 2013, Available online at < http://www.infrastructurereportcard.org/sites/default/files/RC2009_waste_water.pdf >, 2009.

75 *Clean Watersheds Needs Survey 2008 Report to Congress*, The U.S. Environmental Protection Agency, Accessed 4 February 2013, Available online at < http://water.epa.gov/scitech/datait/databases/cwns/2008reportdata.cfm >, 2008.

76 *Stormwater,* City of Fort Collins, Accessed 7 February 2013, Available online at < http://www.fcgov.com/utilities/what-we-do/stormwater?key=stormwater/poudre-history.php >.

77 *Guidance for Municipal Stormwater Funding*, National Association of Flood and Stormwater Management Agencies, Accessed 6 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006.

78 *Western Kentucky University Stormwater Survey 2012*, Western Kentucky University, Accessed 20 February 2013, Available online at < http://www.wku.edu/engineering/documents/swusurveys/swusurvey-2012.pdf >, 2012.

79 *Guidance for Municipal Stormwater Funding*, National Association of Flood and Stormwater Management Agencies, Accessed 6 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006, *Stormwater Strategies: Community Responses to Runoff Pollution, Chapter 4: Funding and Gaining Support for Stormwater Programs*, Natural Resources Defense Council, Accessed 6 February 2013, Available online at < http://www.nrdc.org/water/pollution/storm/chap4.asp >

80 Mulcahy, Laura Anne, *The Effectiveness of Stormwater Utilities in Mitigating Stormwater Runoff in the United States*, Unpublished Thesis, Brown University, Accessed 6 February 2013, Available online at < http://envstudies.brown.edu/theses/archive20072008/lauramulcahythesis.pdf >, 2009.

81 *Stormwater Utility Fees: Considerations & Options for Interlocal Stormwater Working Group (ISWG)*, New England Environmental Finance Center, Accessed 6 February 2013, Available online at < Guidance for Municipal Stormwater Funding, National Association of Flood and Stormwater Management Agencies, Accessed 6 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006.

82 *Funding Stormwater Programs*, U.S. Environmental Protection Agency, Accessed 6 February 2013, Available online at < http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/FundingStormwater.pdf >, 2009.

83 *Stormwater Utility Fees: Considerations & Options for Interlocal Stormwater Working Group (ISWG),* New England Environmental Finance Center, Accessed 6 February 2013, Available online at < Guidance for Municipal Stormwater Funding, National Association of Flood and Stormwater Management Agencies, Accessed 6 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006.

84 *Changes to District's Stormwater Fee*, District Department of the Environment, Accessed 21 February 2013, Available online at < http://green.dc.gov/service/changes-districts-stormwater-fee>; Impervious Area Charge, DC Water, Accessed 21 February 2013, Available online at < http://www.dcwater.com/customercare/iab.cfm >.

85 *RiverSmart Rewards Program Overview*, District Department of the Environment, Accessed 21 February 2013, Available online at < http://ddoe.dc.gov/service/riversmart-rewards-program-overview >.

86 *Impervious Area Charge*, DC Water, Accessed 21 February 2013, Available online at < http://www.dcwater.com/customer-care/iab.cfm >.

87 *Stormwater Utility Fees: Considerations & Options for Interlocal Stormwater Working Group (ISWG),* New England Environmental Finance Center, Accessed 6 February 2013, Available online at < Guidance for Municipal Stormwater Funding, National Association of Flood and Stormwater Management Agencies, Accessed 6 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006.

88 *Water Quality Protection Charge*, Montgomery County, MD, Accessed 21 February 2013, Available online at < http://www6.montgomerycountymd.gov/dectmpl.asp?url=/content/dep/water/wqpc.asp

89 *Stormwater Utility Fees: Considerations & Options for Interlocal Stormwater Working Group (ISWG),* New England Environmental Finance Center, Accessed 6 February 2013, Available online at < Guidance for Municipal Stormwater Funding, National Association of Flood and Stormwater Management Agencies, Accessed 6 February 2013, Available online at < http://www.nafsma.org/Guidance%20Manual%20Version%202X.pdf >, 2006.

90 O'Dell, Colleen, *Green Infrastructure Regional Maintenance Alliance*, Research Report for Metro Blooms, University of Minnesota, January 2011.

91 Koontz, Tomas M. and Craig W. Thomas, "Measuring the Performance of Public-Private Partnerships: A Systematic Method for Distinguishing Outputs from Outcomes,," *Public Performance and Management Review*, 35(4):769-786, 2011.

92 *Combined Sewer Overflows: Guidance for a Long Term Control Plan*, U.S. Environmental Protection Agency, Accessed 8 February 2013, Available online at < http://www.epa.gov/npdes/pubs/owm0272.pdf >, 1995.

93 *Rainleader Disconnect Public-Private Partnership,* Lynchburg, Virginia, Wiley|Wilson, Accessed 8 February 2013, Available online at < http://www.wileywilson.com/RainleaderDisconnectPublicPrivatePartnership.aspx >.

94 *Green Infrastructure: Leading the Way Towards Sustainable Communities*, Pennsylvania Environmental Council, Accessed 21 February 2013, Available online at < http://www.pecpa.org/sites/pecpa.org/files/downloads/GI_State_rev_9-20.pdf >, 2011.

95 *PEC Seeks Bid for Ohiopyle Green Infrastructure Project, Pennsylvania Environmental Council*, Accessed 21 February 2013, Available online at < http://www.pecpa.org/node/786 >, 2009.

96 *Ohiopyle Green Streets Ribbon Cutting, Pennsylvania Environmental Council*, Accessed 21 February 2013, Available online at < http://www.pecpa.org/ohiopyle-joint-master-plan-and-implementation-strategy/updates/20100823 >, 2011.

97 *Rockefeller Foundation Announces Support for* RE.Investment *Initiative*, PR Newswire, Accessed 21 February 2013, Available online at < http://www.prnewswire.com/news-releases/rockefeller-foundation-announces-support-for-reinvest-initiative-187439401.html >, 2013.

98 *Starting a Business Improvement District in Philadelphia*, The City of Philadelphia Department of Commerce and Drexel University's Center for Public Policy, Accessed 12 February 2013, Available online at < http://www.drexel.edu/~/media/Files/publicpolicy/Starting%20a%20BID%20in%20Philadelphia.ashx>, 2012.

99 Monacell, James P., *Bond Practice: Community Improvement Districts as a Tool for Infrastructure Financing*, Smith, Gambrell, & Russell, LLP, Accessed 12 February 2013, Available online at < http://www.sgrlaw.com/resources/briefings/bond_practice/452/>, 2002.

100 *NE 97th Avenue Green Street LID*, City of Portland, Accessed 12 February 2013, Available online at < http://www.portlandoregon.gov/transportation/article/303101>.

101 *Gateway URA: Overview, Portland Development Commission*, Accessed 12 February 2013, Available online at < http://www.pdc.us/our-work/urban-renewal-areas/gateway/overview.aspx >, 1% for Green, Portland Bureau of Environmental Services, Accessed 12 February 2013, Available online at < http://www.portlandoregon.gov/bes/article/341452 >,

102 *Beautifying and Cleaning Germantown Avenue*, Mount Airy Business Improvement District, Accessed 12 February 2013, Available online at < http://mtairybid.com/>.

103 Betesh, Marc E. and Nancy M. Davids, *Negotiating Common Area Maintenance Costs, Probate & Property*, Accessed 12 February 2013, Available online at < http://www.goulstonstorrs.com/portalresource/Article_ABAProbateProperty_N.Davids_5/09 >, June 2009.

104 *Clean Water, Land, and Legacy Amendment*, Minnesota Department of Natural Resources, Accessed 12 February 2013, Available online at < http://www.dnr.state.mn.us/news/features/amendment.html>.

105 *FY2013 Clean Water Fund Competitive Grants Policy*, Minnesota Board of Soil and Water Resources, Accessed 12 February 2013, Available online at < http://www.bwsr.state.mn.us/cleanwaterfund/FY13_CWF_Competitive_Grants_Policy_FINAL.pdf >.

106 Rice, Becky, Metro Blooms, Email Communications, 11 February 2013.

107 1*% for Green*, Portland Bureau of Environmental Services, Accessed 13 February 2013, Available online at < http://www.portlandoregon.gov/bes/article/341452 >.

108 Dunlap, Ivy, Portland Bureau of Environmental Services, Sustainable Stormwater Management, Email Communications, 13 February 2013.

109 "RiverSmart Homes Overview," District Department of the Environment, Available online at < http://ddoe.dc.gov/service/riversmart-homes-overview>.

110 Guillaume, Jennifer, District Department of the Environment, Personal Interview, 4 January 2013.

111 *Arlington StormwaterWise Landscapes Program*, Environmental Services, Arlington, Virginia, Available online at < http://www.arlingtonva.us/departments/EnvironmentalServices/Sustainability/page83039.aspx >.

112 *RainWise Rebates*,", City of Seattle, Available online at < https://rainwise.seattle.gov/city/seattle/rainwise_rebates >.

113 *Rainwise Rebates for Cisterns and Rain Gardens*, Seattle Public Utilities, 2012, Available online at < http://www.seattle.gov/util/MyServices/DrainageSewer/Projects/GreenStormwaterInfrastructure/ResidentialRainWise/Rebates/index.htm >, Tackett, Tracy, Personal Interview, 24 October, 2012.

114 Tackett, Tracy, Seattle Public Utilities, Personal Interview, 24 October, 2012.

115 *TurfLov*e, James City County, Virginia, Available online at < http://www.jamescitycountyva.gov/jccpride/pages/turf.html >.

116 *James City County/Williamsburg Turf Love/Garden Love Program*, Virginia Cooperative Extension Master Gardeners, Available online at < http://jccwmg.org/turflove.htm >.

117 *RiverSmart Homes Success Stories*, District Department of the Environment, Accessed 5 March, 2013, Available online at < http://green.dc.gov/service/riversmart-homes-success-stories >.

118 *Beautifying Your Yard for Healthy Streams – Residential Rain Gardens*, Northern Virginia Regional Commission, Available online at < http://www.novaregion.org/index.aspx?NID=977 >.

119 Jolicouer, Christin, Personal Interview, 3 January 2013.

120 *Bay-friendly Tips*, Chesapeake Stormwater Network, Accessed 22 January 2013, Available online at < http://chesapeakestormwater.net/category/bay-friendly-tips/ >, 2013.

121 *Rain Garden Goof in Ballard*, Sightline Institute, Accessed 22 February 2013, Available online at < http://daily.sightline.org/2011/05/02/rain-garden-goof-in-ballard/ >, 2011.

122 Burlin, Matt, City of Portland, Personal Interview, DATE.1 February 2013. Tackett, Tracy, Seattle Public Utilities, Personal Interview, 24 October, 2012.

123 "BMP Inspection and Maintenance," *Stormwater Best Management Practices Manual*, North Carolina Division on Water Quality, Accessed 27 December 2012, Available online at < http://portal.ncdenr.org/web/wq/ws/su/bmp-manual >, 2007.

124 Hirschman, David J. and John Kosco, *Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program*, Center for Watershed Protection, July 2008.

125 Tackett, Tracy, Seattle Public Utilities, Personal Interview, 10 December 2012.

126 *Draft 2009 Virginia Stormwater Management Handbook*, Chapter 9, Virginia Department of Conservation, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

127 Jolicouer, Christin, Arlington County, Personal Interview, DATEOctober 2012.

128 *Rain Garden and Native Planting Area Registration Form, SustainIndy*, Indianapolis Department of Public Works, Accessed 28 December 2012, Available online at < http://www.indy.gov/eGov/City/DPW/SustainIndy/GreenInfra/Documents/0752-1075%20SI%20RainGardenRegisForm07-11.pdf >, 2008.

129 Odefey, Jeff, et. al., *Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide*, American Rivers, American Society of Landscape Architects, Water Environment Federation, ECONorthwest, Available online at < http://www.americanrivers.org/assets/pdfs/reports-and-publications/banking-on-green-report.pdf >, 2012.

130 2012 Clean Water Fair, Save the Rain Program Onondaga County, New York, Accessed 12 March 2013, Available online at < http://savetherain.us/2012fair/ >.

131 *Stormwater BMP Maintenance e-Newsletter*, Montgomery County, MD, Accessed 13 February 2013, Available online at < http://www6.montgomerycountymd.gov/content/dep/downloads/stormwater/November_2011.pdf>, 2012.

132 English, Ann, E-mail Communication, 21 March 2013.

133 *Stormwater Management Facilities Operation and Maintenance for Private Property Owners*, Environmental Services, City of Portland, Available online at < http://www.portlandonline.com/bes/index.cfm?a=54730&c=34980 >, 2006.

134 Shultz-Buechner, Chris, Leigh Winterbottom, Jan Schaeffer, *Selling Efficiency amid the Green Revolution: Innovative Marketing Approaches at Three Statewide Efficiency Programs*,", ACEEE Summer Study on Energy Efficiency in Buildings, Available online at < http://www.aceee.org/files/proceedings/2008/data/papers/6_149.pdf >, 2008.

135 *Draft 2009 Virginia Stormwater Management Handbook, Chapter 9*, Virginia Department of Conservation, Accessed 20 December 2012, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

136 *Adopt-a-Pond Program Document Draft*, Center for Watershed Protection, Herring Run Watershed Association, 2005.

137 *Adopt-a-Pond Program*, Hillsborough County & City of Tampa, Accessed 29 January 2013, Available online at < http://www.hillsborough.wateratlas.usf.edu/AAP/ >.

138 Incentives for Florida Friendly Yards in Adopt-a-Pond Drainage Areas, Hillsborough County & City of Tampa, Accessed 29 January 2013, Available online at < http://www.hillsborough.wateratlas.usf.edu/upload/documents/461_Incentives%20for%20Florida%20yards-revised2-11-10.pdf >.

139 *City of Rochester Adopt-a-Pond Program*, City of Rochester, Minnesota, Accessed 4 March 2013, Available online at < http://www.rochesterstormwater.com/Full%20Text%20Packet.pdf >.

140 Living Lightly on the Bay, Chesapeake Stormwater Network, Accessed 29 January 2013, Available online at < http://chesapeakestormwater.net/category/bay-friendly-tips/>.

141 Murtagh, Ed, Email Communications, 1 February 2013; *Managing Stormwater in Sligo Creek*, Friends of Sligo Creek, Accessed 5 March 2013, Available online at < http://www.fosc.org/StormwaterMgmt.htm >.

142 *Adopt-a-Pond Program Document Draft,* Center for Watershed Protection, Herring Run Watershed Association, 2005.

143 Hench, Jayne and Lynn Vismara, InterviewEmail Communications, 25 January 2013.

144 *Fairfax County Park Authority Policy Manual*, Accessed 24 January 2013, Available online at < http://www.fairfaxcounty.gov/parks/parkpolicy/FCPAPolicyManual.pdf >, 2008.

145 *Maintenance of Low Impact Development Facilities*, Washington State University Pierce County Extension, 2007.

146 See Amy Stevens, Montgomery County, Personal Interview, 12 September 2012; Jolicouer, Christin, Personal Interview, October 2012; Tackett, Tracy, Seattle Public Utilities, Personal Interview, 10 December 2012.

147 Houle, James J., Robert M. Roseen, Thomas P. Ballestero, et. al., *A Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and* Convetional*Conventional Stormwater Management*, University of New Hampshire Stormwater Center.

148 Jolicouer, Christin, Personal Interview, October 2012.

149 *Landscape Technology*, Montgomery College, Accessed 5 March 2013, Available online at < http://cms.montgomerycollege.edu/edu/plain.aspx?id=13303; >; Amy Stevens, Montgomery County, Personal Interview, 12 September 2012.

150 *Technical Memorandum*, Center for Watershed Protection, 2011.

151 *Inspection Protocols for Maintaining and Verifying LID Practices Webcast*, Chesapeake Stormwater Network, Accessed 29 January 2013, Available online at < http://chesapeakestormwater.net/2013/01/inspection-protocols-for-maintaining-and-verifying-the-performance-of-lid-practices-webcast/ >.

152 Etgen, Lou, Personal Interview, February 2013.

153 "BMP Inspection and Maintenance," *Stormwater Best Management Practices Manual*, North Carolina Division on Water Quality, Accessed 27 December 2012, Available online at < http://portal.ncdenr.org/web/wq/ws/su/bmp-manual >, 2007.

154 Hirschman, David J. and John Kosco, *Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program,* Center for Watershed Protection, July 2008.

155 See *RiverSmart Homes Program Maintenance Agreement*, District Department of the Environment; Rockville Rainscapes Rewards Property Owner Agreement, City of Rockville, Accessed 27 December 2012, Available online at < http://www.aquabarrel.com/media/images/rain_barrel_rebates/Maryland_Rockville_Prop_Owner_Agreement_2010.pdf >

156 *Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual*, Onondaga County, NY, Accessed 7 January 2012, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.

157 *Green Stormwater Operations and Maintenance Manual*, Seattle Public Utilities, Accessed 27 December 2012, Available online at < http://www.seattle.gov/util/groups/public/@spu/@usm/documents/webcontent/spu02_020023.pdf >, 2009.

158 "Chapter 3: Operations and Maintenance," *City of Portland Stormwater Management Manual*, Accessed 21 December 2012, Available online at < http://www.portlandoregon.gov/bes/article/202884 >, 2008.

159 *Maintenance of Low Impact Development Facilities*, Washington State University Pierce County Extension, 2007.

160 *Stormwater BMP Inspection & Maintenance Certification*, NC State University Cooperative Extension, Accessed 13 February 2013, Available online at < http://www.bae.ncsu.edu/stormwater/bmpworkshop.html >.

161 *NCSU BMP Inspection and Maintenance Certification*, NC State University Cooperative Extension, Accessed 13 February 2013, Available online at < http://www.bae.ncsu.edu/topic/bmp-im/agenda.html >.

162 Lord, William G. and William F. Hunt, "Stormwater BMP Inspection and Maintenance Program in North Carolina – A 3 Year Update," American Society of Civil Engineers, *Low Impact Development 2010*: pp. 612-618.

163 *Stormwater Education Program: Advanced Stormwater BMP Maintenance*, University of Minnesota Extension, Accessed 13 February 2013, Available online at < http://www.extension.umn.edu/stormwater/past31July12.html >, 2012.

164 *Urban Green Infrastructure: Green Systems Clean Water*, Pratt Institute, Accessed 13 February 2013, Available online at < http://www.pratt.edu/academics/continuing_education_and_professional/professional_studies/pro_certificate_programs/green_systems_clean_water/>.

165 http://jccwmg.org/

166 Become a Master Watershed Steward, Anne Arundel County Maryland, Accessed 29 January 2013, Available online at < http://www.aawsa.org/get-involved/become-a-master-watershed-steward.html >.

167 Etgen, Lou and Don Tsusaki, Alliance for the Chesapeake Bay, Personal Interview, 31 October, 2012.

168 Stormwater Facility Maintenance Program, Montgomery County Department of Environmental Protection, Accessed 19 December 2012, Available online at < http://www6.montgomerycountymd.gov/dectmpl.asp?url=/content/dep/water/stormwaterfacility.asp#whereare>

169 *Managing Stormwater in Your Community*, Center for Watershed Protection, Accessed 29 Janaury 2013, Available online at < http://www.cwp.org/documents/cat_view/76-stormwater-management-publications/90-managing-stormwater-in-your-community-a-guide-for-building-an-effective-post-construction-program.html >, 2008.

170 *Draft 2009 Virginia Stormwater Management Handbook*, Chapter 9, Virginia Department of Conservation, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

171 *Natural Drainage Systems Landscape Maintenance Categories (LMC) and Characteristics Checklist*, Seattle Public Utilities, Accessed 19 December 2012, Available online at < http://www.seattle.gov/util/groups/public/@spu/@usm/documents/web-content/spu02_020019.pdf >.

172 *Draft 2009 Virginia Stormwater Management Handbook*, Chapter 9, Virginia Department of Conservation, Accessed 20 December 2012, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

173 *City of Kingsport Stormwater Management Manual*, Accessed 20 December 2012, Available online at < http://publicworks.kingsporttn.gov/files/publicworks/swm.pdf>

174 *The Minnesota Stormwater Manual*, Minnesota Pollution Control Agency, January 2008.

175 Howard, Paul, Personal Interview, 22 October 2012.

176 *Draft 2009 Virginia Stormwater Management Handbook*, Chapter 9, Virginia Department of Conservation, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

177 *Gaithersburg Rainscapes Rewards Natural Drainage Project Rebate Application*, Accessed 21 December 2012, Available online at < http://www.gaithersburgmd.gov/Documents/environment/rainbarrels.pdf>.

178 Tackett, Tracy, Seattle Public Utilities, Personal Interview, 10 December 2012.

179 Tackett, Tracy, Seattle Public Utilities, Personal Interview, 10 December 2012.

180 *Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual*, Onondaga County, NY, Accessed 7 January 2012, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.

181 See the following for examples: *Draft 2009 Virginia Stormwater Management Handbook*, Chapter 9, Virginia Department of Conservation, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

182 See *Natural Drainage Systems Landscape Maintenance Categories (LMC) and Characteristics Checklist*, Seattle Public Utilities, Accessed 19 December 2012, Available online at < http://www.seattle.gov/util/groups/public/@spu/@usm/documents/web-content/spu02_020019.pdf >.

183 *Draft 2009 Virginia Stormwater Management Handbook*, Chapter 9, Virginia Department of Conservation, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>

184 *Inspection Protocols for Maintaining and Verifying LID Practices*, Chesapeake Stormwater Network, Accessed 30 January 2013, Available online at < http://chesapeakestormwater.net/wp-content/uploads/downloads/2013/01/CSN-Revised-VI-Indicators-Webcast-NXPowerLite_FINAL.pdf >.

185 *Stormwater BMP Maintenance*, Chesapeake Stormwater Network, Accessed 30 January 2013, Available online at < http://chesapeakestormwater.net/training-library/design-adaptations/stormwater-bmp-maintenance/ >.

APPENDIX A. INSPECTION AND MAINTENANCE ACTIVITIES FOR SELECT GREEN INFRASTRUCTURE PRACTICES

Rain Gardens

Monthly

Maintenance Activity	Frequency	Source(s)
Remove trash, sediment, and debris that block inlets or outlets or that inhibit plant growth	Every other month Twice a year	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012 Environmental Site Design Manual, Queen Anne's County, Centreville, MD, 2007.

Semi-Annually

Maintenance Activity	Frequency	Source(s)
Prune trees and shrubs to maintain plant condition and public safety	Semi-annually, or as needed	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Weed rain garden	Three times per year (Spring, Summer, and Fall) minimum Every other week or monthly, depending on season and aesthetic	Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, 2012 Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Observe infiltration rates after rain events	Semi-annually in Spring and Fall	http://rfcd.pima.gov/pdd/lid/pdfs/07-ky-msd-louisville-green-infrastructure-manual-chapter18-20.pdf
Inspect mulching depth	Semi-annually	Green Infrastructure Design Manual: Green Management Practices and Design Strategies to Manage Stormwater in Our Community, 2011
Prune trees and shrubs to maintain plant condition and public safety	Semi-annually, or as needed	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012

Annually

Maintenance Activity	Frequency	Source(s)
Mulch planted areas	Annually, March	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012 Environmental Site Design Manual, Queen Anne's County, Centreville, MD, 2007. Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, 2012
Treat diseased target species; Replace dead or diseased target species	Annually, or as needed	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Inspect rain gardens	Annually, late May to early July and/or late August to early September	Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, 2012
Cut down perennial plantings	At end of growing season	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012

As Needed

Maintenance Activity	Frequency	Source(s)
Water target species during extended periods of drought	As needed	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Stabilize eroded or undermined features	As needed	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Perform repairs to structural features	As needed	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Perform percolation test if rain garden not infiltrating properly	2-3 years	Green Infrastructure Design Manual: Green Management Practices and Design Strategies to Manage Stormwater in Our Community, 2011

Bioretention

Semi-annually

Maintenance Activity	Frequency	Source(s)
Watering: drip irrigation system maintained, water by hand as needed	Twice annually (May and July), or as needed based on plant health	Pierce County Stormwater Maintenance Manual for Private Facilities, Pierce County, Washington
Clean curb cuts: Remove accumulation of debris	Twice annually (October and January)	Pierce County Stormwater Maintenance Manual for Private Facilities, Pierce County, Washington
Remove and/or prune vegetation	Once or twice annually	Pierce County Stormwater Maintenance Manual for Private Facilities, Pierce County, Washington
Weeding	Usually twice annually (before major weed species disburse seeds)	Pierce County Stormwater Maintenance Manual for Private Facilities, Pierce County, Washington
Trash removal	Twice annually	Pierce County Stormwater Maintenance Manual for Private Facilities, Pierce County, Washington
Inspect to determine if runoff is infiltrating properly	Twice a year during storm events	Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007

Annually

Maintenance Activity	Frequency	Source(s)
Mulching: replace or add mulch to depth of 2-3 inches	Once annually or every two years (depending on whether high pollutant loads are likely)	Pierce County Stormwater Maintenance Manual for Private Facilities, Pierce County, Washington
Maintain access, clear vegetation	Once annually	Pierce County Stormwater Maintenance Manual for Private Facilities, 2009
Test pH of soil to maintain at neutral level (range of 6.5-7.5)	Once annually	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Observe and identify invasive species; map location, species type, and frequency; include photo-documentation	May/June	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012
Remove invasive species	May/June	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012

As Needed

Maintenance Activity	Frequency	Source(s)
Erosion gullies observed during growing season should be filled with topsoil until vegetation is established	As needed	Draft 2009 Virginia Stormwater Management Handbook, Chapter 9, Virginia Department of Conservation, Accessed 19 December 2012, Available online at < http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>, 2009
Trim vegetation and remove weeds	As needed	Stormwater Quality Design Manual for the Sacramento and South Placer Regions, Department of Water Resources Stormwater Utility Stormwater Quality Program, Accessed 3 January 2013, Available online at < http://www.msa2.saccounty.net/dwr/Documents/SWQ_DesignManual_May07_061207.pdf >, 2007.
Remove woody vegetation within 15 feet of toe embankment or 25 feet from principal spillway or other structural features	As needed	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, Philadelphia Water Department, 2012, summarizing from a collection of maintenance manuals
Remove litter and debris	As needed	Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Remove or replace topsoil and sand/peat layer if infiltration is significantly reduced	Every 5 to 10 years, depending on sediment loads	Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Reconstruct or replace when it is no longer functioning	See design specifications for lifespan of project	Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007

Green Roofs

Monthly

Maintenance Activity	Frequency	Source(s)
Maintain vegetation to 90% plant cover: replace plants as needed	Once per month, as needed	Stormwater Management Manual, City of Eugene, 2008

Semi-Annually

Maintenance Activity	Frequency	Source(s)
Remove trash and debris, weed, prune, replenish bare media, only fertilize if total soluble nitrogen levels fall below 5 ppm	Twice annually (Spring and Fall)	Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, 2012

Annually

Maintenance Activity	Frequency	Source(s)
Replace dead plants	Once per year in the fall	Stormwater Management Manual, City of Eugene, 2008

As Needed

Maintenance Activity	Frequency	Source(s)
Operate and maintain structural components in accordance with manufacturer's requirements; Clear inlet pipe when clogged and determine condition	As needed	Stormwater Management Manual, City of Eugene, 2008
Remove debris and litter to prevent clogging of inlet and interference with plant growth	As needed	Stormwater Management Manual, City of Eugene, 2008
Stabilize erosion channels in soil substrate/growth medium with addition plants and soil substrate/growth medium	As needed	Stormwater Management Manual, City of Eugene, Accessed 28 December 2012, Available online at < http://www.eugene-or.gov/DocumentCenter/Home/View/4567 >, April 2008.
Remove invasive or nuisance species	As plants are discovered	Stormwater Management Manual, City of Eugene, 2008
Manual weeding without herbicides or pesticides	Remove regularly to prevent accumulation	Stormwater Management Manual, City of Eugene, 2008
Irrigation during establishment period (1-3 years) not to exceed ¼ inch of water every 3 days		Stormwater Management Manual, City of Eugene, 2008
Aesthetics maintained, correcting damage and removing vandalism	As needed	Stormwater Management Manual, City of Eugene, 2008
Remove standing water manually	As needed	Stormwater Management Manual, City of Eugene, 2008
Correct and prevent spills from mechanical systems on roofs	Corrected as soon as identified	Stormwater Management Manual, City of Eugene, Accessed 28 December 2012, Available online at < http://www.eugene-or.gov/DocumentCenter/Home/View/4567 >, April 2008.
Irrigation through hand watering or automatic sprinkler	Irrigate until established, then as needed	Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007

Porous Pavement

Monthly

Maintenance Activity	Frequency	Source(s)
Vacuum clean followed by high pressure water washing	Monthly	http://www.roanokecountyva.gov/DocumentCenter/Home/View/205

Semi-Annually

Maintenance Activity	Frequency	Source(s)
Inspect to ensure proper function and to identify clogging	Quarterly and after every major rain event until performance verified, then annually	http://www.roanokecountyva.gov/DocumentCenter/Home/View/205
Regularly sweep or vacuum pervious concert or asphalt, modular or cobblestone Block pavement	Three or four times a year	Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Vacuum porous pavement	Twice a year in spring and fall (annually for porous pavers in the spring)	Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, Onondaga County, NY, Accessed 7 January 2012, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.
Sweep pavement	At least twice annually	Maryland Stormwater Design Manual, 2009, http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Documents/www.mde.state.md.us/assets/document/Design%20Manual%20Chapter%205%2003%2024%202009.pdf
Inspect to ensure proper function and to identify clogging	Quarterly and after every major rain event until performance verified, then annually	http://www.roanokecountyva.gov/DocumentCenter/Home/View/205

Annually

Maintenance Activity	Frequency	Source(s)
Restore aggregate	March-May	Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, 2012

As Needed

Maintenance Activity	Frequency	Source(s)
Power wash porous pavement	Once every 3 years in March-May	Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, 2012
Keep surface clean and free of leaves, debris, and sediment		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Mow, irrigate, fertilize, and reseed grasses planted in pavement		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Mow grass to less than 4 inches and remove clippings		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Eliminate any standing water to reduce vectors		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Reconstruct or replace when no longer functioning properly		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007

Trees

Semi-Annually

Maintenance Activity	Frequency	Source(s)
Inspect tree health	Every 3 months and within 1 week of ice storms or high wind events until trees reach maturity	New York State Stormwater Management Design Manual, August 2010.

As Needed

Maintenance Activity	Frequency	Source(s)
Mulching, watering, and protection of young trees during the first three years	As needed	New York State Stormwater Management Design Manual, New York Department of Environmental Conservation, Available online at < http://www.dec.ny.gov/chemical/29072.html>, August 2010.
Rake and remove fallen leaves to prevent material from entering storm drains; Remove dead and nuisance vegetation		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007, Available online at < http://www.msa2.saccounty.net/dwr/Documents/SWQ_DesignManual_May07_061207.pdf >
Pruning conducted by certified arborist or qualified professional, or homeowner should learn proper methods		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
4-6 inches of hardwood mulch should be added around newly planted trees (avoid redwood and cedar mulch)		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Install irrigation system to establish tree		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Minimize use of fertilizers, consider using mulch instead		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Plant evergreen shrubs and ground cover near tree		Stormwater Quality Design Manual for the Sacramento and South Placer Regions, 2007
Inspect to determine survival rate and replace	As needed	New York State Stormwater Management Design Manual, August 2010.

Rain Barrels and Cisterns

Annually

Maintenance Activity	Frequency	Source(s)
Above ground systems should be disconnected, drained, and cleaned to prevent freezing	Beginning of winter	Maryland Stormwater Design Manual, 2009, http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Documents/www.mde.state.md.us/assets/document/Design%20Manual%20Chapter%205%2003%2024%202009.pdf
Underground systems should be checked for frozen line and ice blockages	Winter	Maryland Stormwater Design Manual, 2009, http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Documents/www.mde.state.md.us/assets/document/Design%20Manual%20Chapter%205%2003%2024%202009.pdf

As Needed

Maintenance Activity	Frequency	Source(s)
Replace damaged components	As needed	Maryland Stormwater Design Manual, 2009, http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Documents/www.mde.state.md.us/assets/document/Design%20Manual%20Chapter%205%2003%2024%202009.pdf
Inspect and clean storage lids and mosquito screens	As needed	Maryland Stormwater Design Manual, 2009, http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Documents/www.mde.state.md.us/assets/document/Design%20Manual%20Chapter%205%2003%2024%202009.pdf

APPENDIX B. SAMPLE OPERATIONS AND MAINTENANCE MANUALS INCLUDING GREEN INFRASTRUCTURE PRACTICES

Title	Location	Source	Date
City of Portland Stormwater Management Manual	Portland, OR	"Chapter 3: Operations and Maintenance," City of Portland Stormwater Management Manual, Accessed 21 December 2012, Available online at < http://www.portlandoregon.gov/bes/article/202884 >, 2008.	2008
Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan	Philadelphia, PA	Green City, Clean Waters Green Infrastructure Maintenance Manual Development Process Plan, City of Philadelphia Combined Sewer Overflow Long Term Control Plan Update, Accessed 27 December 2012, Available online at < http://phillywatersheds.org/ltcpu/Green%20Infrastructure%20Maintenance%20Manual%20Development%20Process%20Plan.pdf >	2012
Stormwater Best Management Practices Manual	Raleigh, NC	"BMP Inspection and Maintenance," Stormwater Best Management Practices Manual, North Carolina Division on Water Quality, Accessed 27 December 2012, Available online at < http://portal.ncdenr.org/web/wq/ws/su/bmp-manual >, 2007.	2007
Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual	Onondaga County, NY	"Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual," Onondaga County, NY, Accessed 7 January 2012, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.	2012
Green Infrastructure Design Manual: Green Management Practices and Design Strategies to Manage Stormwater in Our Community	Louisville, KY	Green Infrastructure Design Manual: Green Management Practices and Design Strategies to Manage Stormwater in Our Community, Louisville and Jefferson County Metropolitan Sewer District, Accessed 8 January 2013, Available online at < http://rfcd.pima.gov/pdd/lid/pdfs/07-ky-msd-louisville-green-infrastructure-manual-chapter18-20.pdf >, 2011.	2011
Maintaining Stormwater Systems: A Guidebook for Private owners and Operators in Northern Virginia	Virginia	Maintaining Stormwater Systems: A Guidebook for Private owners and Operators in Northern Virginia, Northern Virginia Regional Commission, Accessed 23 January 2013, Available online at < http://www.novaregion.org/DocumentView.aspx?DID=1675 >, 2007.	2007

APPENDIX C. RESOURCES FOR SAMPLE OPERATIONS AND MAINTENANCE CHECKLISTS BY GREEN INFRASTRUCTURE PRACTICE

Green Infrastructure Practice	Location	Source	Date
Green roofs, Bioretention, Rain barrels and cisterns, Permeable pavement	Virginia	**Draft 2009 Virginia Stormwater Management Handbook, Chapter 9, Virginia Department of Conservation, Accessed 19 December 2012, Available online at <** http://www.dcr.virginia.gov/laws_and_regulations/documents/swmhndbkdrft_ch09.pdf>	2009
Bioretention	Kingsport, TN	**City of Kingsport Stormwater Management Manual, Accessed 20 December 2012, Available online at <** http://publicworks.kingsporttn.gov/files/publicworks/swm.pdf>	
Rain gardens, Porous pavement, Bioretention	Libertyville, IL	Maintenance Plan Stormwater Management System Ryerson Woods Conservation Area – Visitors Center, Lake County Forest Preserves, Accessed 20 December 2012, Available online at < http://arkansaswater.org/319/pdf/05-1100%20Urban%20Low%20Impact%20Appendix%204.pdf>, July 2004.	2004
Bioretention	St. Paul, Minnesota	The Minnesota Stormwater Manual, Minnesota Pollution Control Agency, January 2008.	2008
Bioretention	Seattle, WA	Natural Drainage Systems Landscape Maintenance Categories (LMC) and Characteristics Checklist, Seattle Public Utilities, Accessed 19 December 2012, Available online at < http://www.seattle.gov/util/groups/public/@spu/@usm/documents/webcontent/spu02_020019.pdf >.	
Rain barrels and cisterns	Pierce County, WA	Pierce County Stormwater Maintenance Manual for Private Facilities, Pierce County, Washington, Accessed 20 December 2012, Available online at http://www.co.pierce.wa.us/archives/129/maintenance%20manual.pdf, 2009.	2009
Green roofs	Indianapolis, IN	City of Indianapolis: Stormwater Design and Specification Manual, Accessed 20 December 2012, Available online at < http://www.uwrwa.org/bmpTool/factSheets/4_1_Green_Roofs.pdf >	
Rain gardens, Bioretention	Annapolis, MD	Klein, Richard, Rain Garden & Bioretention Facility Audits, Community & Environmental Defense Services, 4 May 2012.	2012
Porous pavement, Porous paver, Green roof	Onondaga County, NY	Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual, Onondaga County, NY, Accessed 7 January 2013, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.	2012

APPENDIX D. SAMPLES OF EDUCATION AND OUTREACH MATERIALS FOR PRIVATE PROPERTY OWNERS AND THE PUBLIC

Title	Location	Source	Date
Stormwater Solutions: Pervious Pavement, Pervious Pavers, Trees, Roof Gardens, EcoRoofs, Cisterns, Rain Barrels	Portland, OR	Stormwater Solutions, City of Portland Bureau of Environmental Services, Accessed 27 December 2012, Available online at < http://www.portlandoregon.gov/bes/31870 >, 2012.	2012
Maintaining Your Stormwater Management Facility Home Owner Handbook	Portland, OR	Maintaining Your Stormwater Management Facility Home Owner Handbook, City of Portland Bureau of Environmental Services, Accessed 27 December 2012, Available online at < http://www.portlandoregon.gov/bes/article/54728 >	
Operation and Maintenance for Private Property Owners	Portland, OR	Operation and Maintenance for Private Property Owners, City of Portland Bureau of Environmental Services, Accessed 27 December 2012, Available online at < http://www.portlandoregon.gov/bes/article/54730 >, 2006	2006
Maintaining Stormwater Systems: A Guidebook for Private Owners and Operators in Northern Virginia	Virginia	Maintaining Stormwater Systems: A Guidebook for Private Owners and Operators in Northern Virginia, Northern Virginia Regional Commission, Accessed 10 January 2013, Available online at < http://www.novaregion.org/DocumentView.aspx?DID=1675>, 2007.	2007
Rainwise Program	Seattle, WA	Whys and Ways to be Rainwise, Accessed 22 February 2013, Available online at < https://rainwise.seattle.gov/city/seattle/rainwise_solutions >	2011
Stormwater BMP Maintenance		Stormwater BMP Maintenance, Chesapeake Stormwater Network, Accessed February 2013, Available online at < http://chesapeakestormwater.net/training-library/design-adaptations/stormwater-bmp-maintenance/ >	2013
Rainscapes: Rain Gardens	Montgomery County, MD	Rainscapes: Rain Gardens, Montgomery County, MD, Accessed 22 February 2013, Available online at < http://www6.montgomerycountymd.gov/content/dep/downloads/Rainscapes/MocoRainGardens.pdf >	
Rainscapes: Green Roofs	Montgomery County, MD	Rainscapes: Green Roofs, Montgomery County, MD, Accessed 22 February 2013, Available online at < http://www6.montgomerycountymd.gov/content/dep/downloads/Rainscapes/MocoGreenRoofs.pdf>	

Rainscapes: Permeable Pavers	Montgomery County, MD	Rainscapes: Permeable Pavers, Montgomery County, MD, Accessed 22 February 2013, Available online at < http://www6.montgomerycountymd.gov/content/dep/downloads/Rainscapes/MocoPermPavers.pdf >
Rainscapes: Rain Barrels and Cisterns	Montgomery County, MD	Rainscapes: Rain Barrels and Cisterns, Montgomery County, MD, Accessed 22 February 2013, Available online at < http://www6.montgomerycountymd.gov/content/dep/downloads/Rainscapes/MocoRainbarrels.pdf >
Rain Gardens	Arlington, VA	Rain Gardens, Department of Environmental Services, Arlington, VA, Accessed 22 February 2013, Available online at < http://www.arlingtonva.us/departments/EnvironmentalServices/Sustainability/PDFfiles/file84387.pdf >
Urban Waterways: Rainwater Harvesting Guide for Homeowners	Raleigh, NC	Urban Waterways: Rainwater Harvesting Guide for Homeowners, North Carolina State University, Accessed 22 February 2013, Available online at < http://www.bae.ncsu.edu/stormwater/PublicationFiles/WaterHarvestHome2008.pdf >
Urban Waterways: Permeable Pavements, Green Roofs, and Cisterns	Raleigh, NC	Urban Waterways: Permeable Pavements, Green Roofs, and Cisterns, North Carolina State University, Accessed 22 February 2013, Available online at < http://www.bae.ncsu.edu/stormwater/PublicationFiles/BMPs4LID.pdf >
Maintaining Your Rain Barrel (video)	Rockville, MD	Maintaining Your Rain Barrel, City of Rockville, MD, Accessed 8 March 2013, Available online at < http://www.youtube.com/watch?v=s2kNeLKvyqA&feature=youtu.be >

APPENDIX E. AGENDAS FROM TRAINING PROGRAMS

Organization	Location	Sessions	Source
Save the Rain	Onondaga County, NY	• Green infrastructure technology overview including porous pavement, infiltration bed, cistern/rain barrel, green roof, rain garden, bioretention, green street, inlet filter inserts • How to read a site plan and determine the location and maintenance of green infrastructure practices • Review of specific green infrastructure maintenance tasks for porous pavement, stormwater structures, landscape features, green roofs	"Onondaga County, NY Save the Rain Program Green Infrastructure Maintenance Manual," Onondaga County, NY, Accessed 7 January 2012, Available online at < http://savetherain.us/wp-content/uploads/2012/03/MaintenanceTrainingBinder.pdf >, 2012.
University of Minnesota Extension	Brainerd, MN	• Realities of maintenance and scheduling maintenance • Field inspections • Rules and regulations of maintenance • Design for maintenance • Essential elements of maintenance	"Advanced Stormwater BMP Maintenance," Stormwater Education Program University of Minnesota Extension, Accesed 19 March 2013, Available online at < http://www.extension.umn.edu/stormwater/past31July12.html >, 2012.
Pratt Institute	New York, NY	• Drainage and hydrology in New York City • Green infrastructure data and calculations • Green roof construction, maintenance, and monitoring • Innovative green infrastructure construction, monitoring, and maintenance	"Urban Green Infrastructure: Green Systems Clean Water, Pratt Institute, Accessed 19 March 2013, Available online at < http://www.pratt.edu/academics/continuing_education_and_professional/professional_studies/pro_certificate_programs/green_systems_clean_water/ >
North Carolina State University Cooperative Extension	Raleigh, NC	• Watershed basics • Stormwater and clean water regulations • BMP function • Elements of BMP maintenance • Retention ponds, bioretention, level spreaders, green roofs, permeable pavement, wetlands, swales, cisterns	"NCSU BMP Inspection and Maintenance Certification," North Carolina State University Cooperative Extension, Accessed 19 March 2013, Available online at < http://www.bae.ncsu.edu/topic/bmp-im/agenda.html >