MOUNT RAINIER URBAN GREEN INFRASTRUCTURE MASTER PLAN

October 2013

Acknowledgments

The project organizers gratefully acknowledge all of those who were involved with this project. The following organizations and persons provided considerable information and assistance with this project:

City of Mount Rainier - Mayor and City Council

Mayor Malinda Miles
Jesse Christopherson, Council Member, Ward 1
Jimmy Tarlau, Council Member, Ward 1
Ivy Thompson, Council Member, Ward 2
Brent Bolin, Council Member, Ward 2

City of Mount Rainier - City Staff

Jeannelle B. Wallace, City Manager
Luther Smith, Director, Public Works Department

In addition, considerable assistance and support was provided by the many members of the City of Mount Rainier's Volunteer Citizen Green Team. Without the contribution, determination, optimism, and sheer hard work of this group, this master plan would not have been possible.

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Funding

The work that provided the basis for this publication was supported by funding under a technical assistance award from the National Fish and Wildlife Foundation's Local Government Capacity Building Initiative. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the National Fish and Wildlife Foundation. Mention of trade names or commercial products does not constitute their endorsement by the National Fish and Wildlife Foundation.

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Executive Summary

The City of Mount Rainier, MD, has long understood that environmental sustainability, quality of life, and economic prosperity are related features of the most successful communities. In the early 1970s, the City committed itself to improve air and water quality and establish an environmentally friendly city. Through adopted legislation, municipal codes, and the implementation of a Sustainability Plan, the City has routinely shown that it supports greening initiatives and Maryland smart growth goals. This document is a working plan that provides a framework to guide community greening activities to improve the water quality of the Anacostia River.

The Mount Rainier Green Infrastructure Master Plan presents a set of tools to be utilized when selecting and implementing projects to improve and reduce urban stormwater runoff. Neighborhoods, single blocks, and even single lots can proactively use this document to identify tools and projects that will enhance their individual areas in stormwater management. These efforts signal Mount Rainier's continued commitment to collaboration and leadership on the environment.

The concept of Low Impact Development (LID) first took root in Prince George's County in the 1990s.

The successful implementation of this plan will require the commitment of both City officials and residents to participate in the creation and maintenance of the "green" projects. Residents will need to be educated about environmental and community health issues and the vital role they play in the environmental health of their communities. They will also need to become effective advocates in the creation and maintenance of green community projects. The master plan envisions that implementation of the green infrastructure projects will create a more appealing and pleasant community, and will foster neighborhood pride, social cohesion, and a unified neighborhood identity. Community organizing and partnership building between public and private entities will be key in the successful implementation of green infrastructure.

The Mount Rainier Urban Green Infrastructure Master Plan has been created to support the Maryland State and Prince George's County stormwater regulations and incorporates elements from studies conducted within the Chesapeake Bay region. The plan's primary focus is managing and improving stormwater runoff within the City. Broadly, it has five goals:

- Preserve, protect, enhance, and restore Green Infrastructure elements identified in the 2005 Prince George's County Green Infrastructure Plan
- Support Prince George's County in implementing the Phase II Watershed Implementation Plan (WIP)
- Establish a comprehensive set of Low Impact Development (LID) tools tailored to the City's different land use types
- Develop a definition for the level of stormwater improvement via the use of the term "Stormwater Neutral" and provide a method to easily measure achievement
- Support Mount Rainier's Tree City USA designation and Sustainable Maryland Certification

The management of stormwater runoff will be primarily implemented using LID tools. LID practices are small, site-specific practices that attempt to mimic a site's pre-development hydrologic conditions. This is generally achieved by retaining more stormwater runoff on-site and using evapotranspiration or infiltration to remove it rather than the traditional way of diverting it to storm sewer networks. The traditional way has led to more pollutants and higher stormwater volumes entering and degrading our streams. Reversing this trend is at the heart of LID practices, which limit the adverse impacts that are created by impervious ground cover, site grading to facilitate quick runoff, reduction in tree and forest canopies, and other environmental damages.

The plan proposes using a site's capacity to retain rainfall as the parameter to measure stormwater improvement. The minimum target retention amount that a site should attempt to retain is set as the first 1.0 inch of rainfall that falls on the site. While sites may attempt to retain even more, this target was set to establish a goal that property owners could strive to achieve, either on individual lots or larger parcels such as blocks. One inch of rainfall in the Mount Rainier region is considered as the 90th percentile storm, meaning that 90% of all storms that occur within a year are, on average, 1.0 inch or less. The amount of runoff generated by the 1.0 inch rainfall event is calculated based on land area and characteristics, allowing for sites of any size, whether residential lots, commercial properties, or even the street right-of-way (ROW), to be treated similarly. The term "Stormwater Neutral" is introduced to describe a site that is able to achieve the full retention of runoff generated from 1.0 inch of rainfall. Sites that do not achieve full stormwater neutral conditions still provide measurable and meaningful benefits to the greater Mount Rainier community. Therefore, all sites are encouraged to retain runoff to the greatest extent possible.

While many computer models exist to calculate and model surface runoff, this master plan uses the recently released EPA National Stormwater Calculator to model rainfall runoff conditions at sites in Mount Rainier. This software is a straightforward computer model that uses actual rainfall to simulate surface runoff based on site characteristics entered by the user. The following six LID practices were identified as being the most suitable practices applicable to the Mount Rainier environment:

- Rain Gardens
- Downspout Disconnections

- Rainwater Harvesting
- Green Roofs
- Permeable Pavements
- Stormwater Planters

Representative lot layouts were developed for the four commonly found land use types in Mount Rainier which resulted in the following land use categories and average compositions:

Common Land Use Types in Mount Rainier

Land Use Type	% Building	% Paved Surfaces	% Tree Cover	% Lawn
SFH	26	13	42	19
MFH	21	18	24	37
MU	30	45	15	10
ROW	0	72	13	15

SFH - Single-Family Housing, MFH - Multi-Family Housing, MU - Mixed-Use, ROW - Right-Of-Way

The rainfall runoff response for each representative land use site was modeled with the inclusion of different LID practices. Using suitable LID practices of a reasonable size for a site, an optimal combination of LID practices were developed for each site that enabled it to achieve stormwater neutrality or get as close as possible to stormwater neutrality. The table at the end of the page summarizes these findings for each of the modeled land use types.

It should be noted that many different combinations of suitable LID practices exist that would enable a site to become stormwater neutral. The table above only presents one such set of LID practices that were selected based on suitability and reasonable level of treatment. In general, approximately 80% of impervious surfaces on a site need to be treated with some type of LID practice for the site to be able to fully retain a 1.0 inch rainfall. Only "Mixed-Use" lot types are unable to achieve stormwater neutrality even at this level of impervious area treatment. For the most part, LID practices in the ROW are only possible on roads with a storm sewer pipe or on roads that are near an accessible storm sewer pipe. Having a storm sewer pipe nearby is important since LID practices on the ROW will need to be connected to them via an underdrain to ensure the LID practice can be adequately drained, especially in areas of low infiltration.

The effectiveness of this master plan is dependent on developing policies and strategies that are manageable, constructible, and measurable. The following policies can be enacted by the City to promote the implementation of the plan:

- Restore and preserve all unused vacant lots, underutilized parks, and other under-maintained green spaces
- Reduce impervious cover to the greatest extent possible and enhance and promote multimodal transportation
- Increase the urban tree canopy in all neighborhoods
- Promote green design in large development projects
- Provide incentives to residents to install LID practices most suitable to residential lots, such as downspout disconnects, rainwater harvesting, and rain gardens
- Promote outreach and education initiatives
- Enact pilot LID projects throughout the City to educate and inform the citizenry
- Identify appropriate funding sources for LID installations

With a strong commitment from residents and public officials to the Urban Green Infrastructure Master Plan, Mount Rainier will be able to successfully implement a wide-ranging "greening" program that significantly improves stormwater runoff and highlights the City's environmental ethic while enhancing the overall health, beauty, and social fabric of the community.

LID Controls and Achieved Retention Targets for Land Use Types

Land Use Type	LID Controls with Treated Impervious Surface %						Total Treated Impervious %	Achieved Rainfall Retention (inches)
	Downspout Disconnect	Rainwater Harvesting	Rain Garden	Stormwater Planter	Green Roof	Porous Pavement		
SFH	45	10	25	--	--	--	80	1.1
MFH	40	--	15	15	--	10	80	1.1
MU	15	--	--	30	20	20	85	0.6
ROW	--	--	--	40	--	43	83	1.0

A view down Rhode Island Avenue (looking NE) in 1929 shows the street car overhead wires and newly paved road.

Introduction

The streetcar provided public transportation access to the greater Washington, D.C. area. The area surrounding the streetcar station became the community's downtown.

Overview

Mount Rainier began as a small agrarian community on the northeast border of Washington, D.C. In the late 19th and early 20th century, Washington, D.C. experienced a period of urban expansion, creating a great demand for housing. Due to its close proximity and direct access to Washington, D.C. via the railroad and – starting in 1897 – a streetcar, Mount Rainier's population began to grow. Here, people could enjoy rural living with the amenities of a more urban lifestyle. In 1910, the town was incorporated by charter, and in 1945, the town of Mount Rainier became the City of Mount Rainier.

By the 1950s, the streetcar had been replaced with bus transit, and the City's population had increased to more than 11,000. In the late 1960s and early 1970s, the population began to drop, and smaller family size coupled with an older population living on fixed income caused the housing stock to be neglected. By the 1980s, however, younger families, attracted to the historic charm of Mount Rainier, began to move in and revitalize the community. The historical and architectural value of Mount Rainier became recognized, and in the 1990s the City was listed in the National Register of Historic Places.

Still dominated by residential housing, Mount Rainier maintains a small downtown core on Rhode Island Avenue and 34th Street. Targeted for renewal in several plans – the Town Center Urban Renewal Plan and the Mixed-Use Town Center Zone Development Plan – the downtown core boasts wide pedestrian friendly sidewalks, historic buildings, and affordably priced properties.

This image, which appears in the City of Mount Rainier MIxed-Use Town Center Zone Development Plan, provides a street view where improved pedestrian mobility, bike lanes, tree planting, and low impact development exist.

History of Sustainability

Mount Rainier's focus on building a more sustainable community began in the early 1970s when the City committed itself to initiating efforts to improve air and water quality for the benefit of its residents and visitors. Over the years, the City has embarked upon a number of sustainability initiatives to minimize its environmental footprint and enhance the community's quality of life. Many of these efforts have resulted from partnering with local business, academia, citizen volunteers, and many others to advance its sustainable practices.

In 1990, Mount Rainier was awarded a Tree City USA designation. Over the years, the City has continued its focus on maintaining and growing the City's diverse tree stock by planting native tree species, and has continued to retained its Tree City USA designation.

Starting around 2000, the City's efforts began moving beyond a focus on trees to embrace other aspects of sustainable communities. This included appointing an Environmental Protection Board, passing a "going green" ordinance, becoming a founding member of Sustainable Maryland Certified, establishing a Bicycle Co-op and a Green Home Initiative, building the first "green" police station in Maryland, and preparing a Sustainability Plan and implementing a Green Purchasing Policy.

Most recently, residents and city officials have directed additional attention to establishing a comprehensive network of urban green infrastructure projects to reduce stormwater runoff and improve the greater Anacostia River watershed's water quality. As a result, several green infrastructure pilot projects have been conducted throughout the town. These include a 2011 rain garden at the Mount Rainier Nature Center and a green street project to retrofit a portion of Buchanan Street in order to reduce localized flooding and polluted water runoff.

Purpose and Goal

The purpose of the Mount Rainier Urban Green Infrastructure Plan is to develop a comprehensive vision for implementing environmentally and financially sustainable stormwater management practices within the City which also enhance the community's social and economic well-being. The plan includes a set of tools to guide the City in selecting practices that reduce the City's stormwater runoff. Implementation of this plan will support the state and county's stormwater regulations.

At the outset, the initiative led with the goal of becoming a "Stormwater Neutral" community. Working with municipal staff, the following list of objectives was prepared:

- Develop a definition and establish target milestone for achieving a level of stormwater neutrality within the City
- Establish a comprehensive set of LID tools tailored to different land use types in Mount Rainier
- Support the City's Sustainability Plan, Tree City USA designation, and Sustainable Maryland certification
- Support Prince George's County Phase II Watershed Implementation Plan
- Preserve, protect, enhance, and restore elements identified in the 2005 Prince George's County Green Infrastructure Plan
- Develop a wide-ranging public participation effort

Defining Stormwater Neutral

A primary goal of this plan was to establish a definition for "stormwater neutral" for the City. Since retention of runoff is a relatively easy parameter to measure and an intuitive way runoff is improved by green infrastructure practices, the Mount Rainier Urban Green Infrastructure Master Plan proposes the use of retention volume of runoff as the parameter by which stormwater improvement is calculated. This provides a straightforward means to quantify stormwater improvements.

The One Inch Storm Event

Retaining the first 1.0 inch of rainfall within a site has many advantages in improving the water quality of stormwater runoff. Most of the rainfall events that occur are 1.0 inch or less in magnitude. In Maryland, the 1.0 inch storm is regarded as the 90th percentile storm event. This means that 90% of the rainfall events in a given year are 1.0 inch or less. By capturing the first inch, the amount of rainfall leaving a site in a given year is significantly reduced. Capturing the 1.0 inch storm provides the following two important stormwater runoff improvements:

- The first inch of runoff is often referred to as the "first flush" and is generally considered to contain the highest amount of pollutants. Retention of the first flush is as an important first step in improving runoff water quality.
- Treating the first inch of rainfall on-site not only reduces the total amount of runoff, but it reduces the speed with which it reaches streams. This reduces the potential for flooding and erosion further downstream.

The volume of stormwater runoff that a site can retain is specific to a site's land cover characteristics as well as its available land for LID retrofits. However, there is consistent evidence from pilot projects showing that green infrastructure can capture, retain, infiltrate, or evapotranspirate 90% or more of the rain from typical storms delivering an inch or less of precipitation. This is crucial because the majority of runoff pollutants are carried in the first inch of stormwater runoff. For Mount Rainier, "stormwater neutral" is defined as a site that retains the first 1.0 inch or more of rainfall on site via the installation of LID practices.

Because the retention target is defined based on rainfall, the size of a site could be any amount. What matters is calculating the amount of runoff generated per 1.0 inch of rainfall over the entire site. The site could be a residential lot, a block, a street section, or any such easily determined unit. To encourage participation on sites where the full stormwater neutral requirement cannot be met, the City could also classify sites as 50% or 75% stormwater neutral. Of primary importance is that all are encouraged to improve stormwater runoff to the maximum extent feasible.

Relevant Studies and Reports

The following is a list of reports, planning documents, and studies that were reviewed in the preparation of this plan in order to determine how and where green infrastructure had been considered or previously applied within the City's boundaries. In addition, Prince George's County and Maryland State environmental reports were reviewed, and state and local stormwater standards that Mount Rainier is required to meet were identified.

Mount Rainier Sustainability Plan

The Mount Rainier Sustainability Plan is a working document prepared in 2011 that reflects the City's priorities for improving energy efficiency, reducing waste, and fostering a healthy community through wellness and local economic development programs. It highlights specific actions that City leaders and residents can take to positively impact their surroundings. The main areas of focus are:

- Community Action
- Community-Based Food System
- Energy
- Greenhouse Gas
- Health and Wellness
- Local Economies
- Natural Resources
- Planning and Land Use

The Mount Rainier Urban Green Infrastructure Master Plan reiterates many of the recommendations in the Mount Rainier Sustainability Plan, and expands on recommendations in the Community Action, Greenhouse Gas, Local Economies, Natural Resources, and Planning and Land Use categories. This plan fully endorses the Sustainability Plan and serves as an expansion of ideas regarding stormwater management already outlined in the Sustainability Plan.

City of Mount Rainier Mixed-Use Town Center Zone Development Plan

In 2010, an update to the 1994 Mount Rainier Town Center Development Plan was approved and adopted. The plan established a mixed-use town center (MUTC) zone to promote reinvestment and redevelopment in the City's older, more established mixed-use areas. The MUTC Plan identifies tree boxes and low impact development as general recommendations for the MUTC zoning district. The Mount Rainier Urban Green Infrastructure Master Plan supports the recommendations outlined in the MUTC Plan and further emphasizes tree plantings and low impact development within Mount Rainier.

Town Center Urban Renewal Plan

In 2000, the City of Mount Rainier requested the assistance of the Maryland Department of Planning to complete the Town Center Urban Renewal Plan to indicate strengths, weaknesses, opportunities, and threats to the town center's continued success. This plan fully supports the guiding principles identified within the urban renewal plan:

- **Relationships** - build upon strong and supportive relationships and partnerships among businesses, property owners, residents, civic associations, locally-elected officials, government staff, churches, schools, and the arts community
- **Image** - create an attractive, vibrant, and unique image that reflects the City's historic, small town character and charm
- **Function** - establish a civic, commercial, and residential center for Mount Rainier and the surrounding communities
- **Mobility** - provide safe and convenient transportation alternatives including walking, bicycling, taking transit, and driving

This plan further supports the objectives of encouraging public transit and pedestrian circulation outlined in the Town Center Urban Renewal Plan.

Prince George's County General Plan

The 2002 Prince George's County Approved General Plan envisions a development pattern that integrates transportation with land use and maximizes the benefits of an affordable, efficient multimodal transportation system to reduce vehicle miles traveled. The 2002 General Plan includes the following growth and development visions, goals, and priorities, which are incorporated into the Mount Rainier Urban Green Infrastructure Master Plan:

- Encourage quality economic development
- Make efficient use of existing and proposed county infrastructure and investment
- Enhance the quality and character of communities
- Protect environmentally sensitive lands

The 2002 General Plan also includes specific objectives to preserve, enhance, and restore the natural environment and its ecological functions as the basic component of a sustainable development pattern:

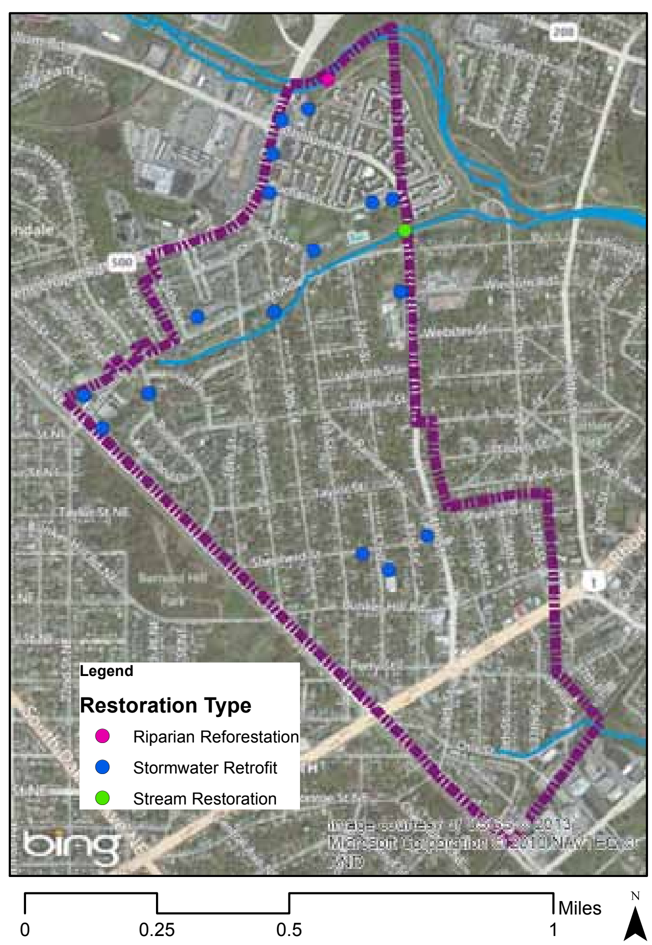
- Protect, preserve, enhance and/or restore designated green infrastructure components by 2025
- Protect and enhance water quality in watersheds by, at a minimum, maintaining the 2001 condition ratings of all watersheds countywide
- Meet or exceed a tree and forest canopy goal of 26% within the developed tier and 44% countywide
- Promote an awareness of environmental issues related to land use through the provision of environmental education and/or stewardship programs

The Mount Rainier Urban Green Infrastructure Plan further encourages the principles of sustainable communities.

Countywide Master Plan of Transportation

The 2009 Countywide Master Plan of Transportation addresses strategic issues for all modes of transportation within Prince George's County. The Mount Rainier Urban Green Infrastructure Master Plan fully supports the following

Anacostia River Watershed Restoration Plan projects within Mount. Rainier.



goals identified by the Master Plan of Transportation for the County's developed tier:

- Maintain medium to high density
- Encourage quality infill, redevelopment, and restoration
- Preserve and enhance the environment
- Maintain high bus and rail transit coverage
- Provide interconnected non-motorized modes of travel

The Mount Rainier Urban Green Infrastructure Master Plan further supports employment of the Master Plan of Transportation's concept of "complete streets," which places a priority on ensuring that all modes of transportation are safely accommodated along roadways. This is particularly important in the developed tier, where walkable communities and pedestrian safety are commonly cited as a community need and desire. Specifically, Rhode Island Avenue serves as a local bus hub, providing public transit options to many regional destinations and is identified as a corridor for the expanded 37-mile street car system. This plan fully embraces nine of the ten principles for complete streets, as set forth in the 2009 transportation plan:

- Encourage medians as pedestrian refuge islands
- Design turning radii to slow turning vehicles
- Find wasted space and better utilize it
- Time traffic signals to function for all modes
- Reduce crossing distances
- Increase crossing opportunities
- Encourage pedestrian-scaled land use and urban design
- Acknowledge that pedestrians will take the most direct route
- Ensure universal accessibility

The tenth principle – pursue targeted education and enforcement efforts to reduce bicycle and motor vehicle crashes – while necessary, is outside of the scope of the Mount Rainier Plan, but is covered by Mount Rainier's Bicycle Master Plan.

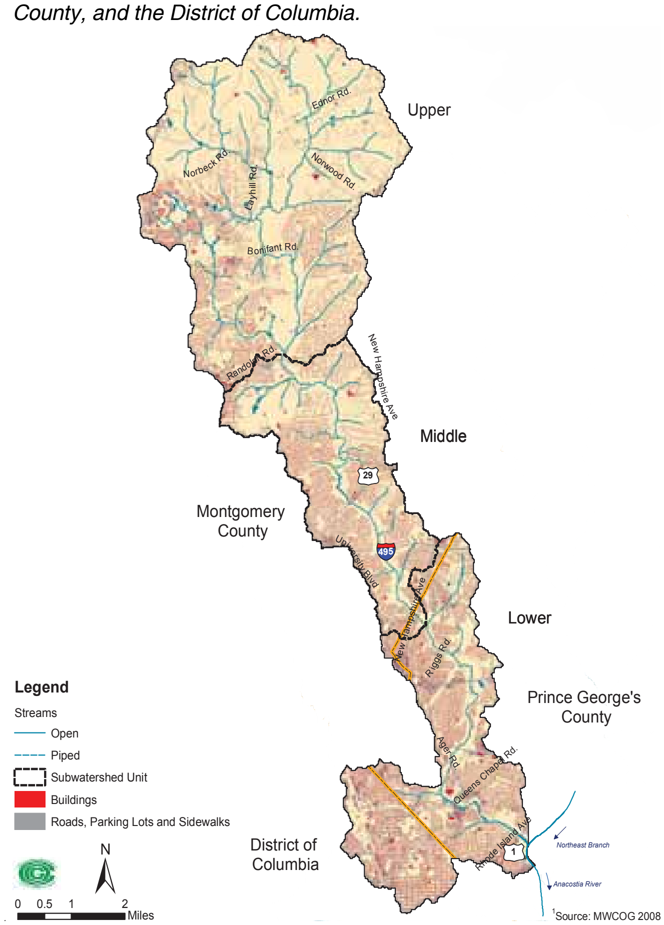
Anacostia River Watershed Restoration Plan

The Anacostia River Watershed Restoration Plan and Report, finalized in February 2010, is a multi-jurisdictional, ten-year restoration plan that identifies environmental and ecological restoration opportunities within the entire Anacostia River watershed.

The Northwest Branch subwatershed is considered to be the least densely urbanized of all the subwatersheds in the Anacostia River watershed with an impervious cover of only 19%. Of the 19%, approximately 10% contains some form of stormwater controls based on the study. Given its relatively smaller impervious cover, the study identified fewer improvement opportunities within the Northwest Branch subwatershed. However, it should be noted that the lower reaches of the subwatershed, where Mount Rainier is located, is quickly approaching full build-out conditions and have significantly higher impervious cover than the middle and upper reaches of the subwatershed. Therefore, within the subwatershed, the lower reaches of the Northwest Branch should be considered on a higher priority in terms of addressing stormwater runoff and improving its quality. The Anacostia Restoration Plan and a related supplementary document, the Northwest Branch Subwatershed Action Plan (SWAP), identify several problems facing the Northwest Branch as a whole. Changes to hydrology, poor aquatic habitats, and poor water quality top the list of impairments to the subwatershed (USACE, 2010). Candidate restoration sites to address these impairments are included as part of the restoration plan and include bioretention, green roofs, sand filters, underground pipe storage, permeable pavements, downspout disconnects, riparian reforestation, soft bottom channel creation, and stormwater management facility retrofits (USACE, 2010).

In total, the restoration plan identified 18 retrofit sites at a cost of $13.6 million for Mount Rainier. A full list of these restoration

The Northwest Branch of the Anacostia River Watershed is 53.5 mi^2 in size and includes portions of Montgomery County, Prince George's County, and the District of Columbia.



The rain garden above was installed at the Mount Rainier Nature and Recreation Center in 2011, and serves as an outreach and educational tool for the City.

sites is provided in Appendix A. Because the restoration projects are conceptual and require more detailed drainage and site analysis, facility size and costs are provided as approximations only.

Total Maximum Daily Loads of Trash for the Anacostia River

In September 2010, the U.S. Environmental Protection Agency (EPA), the District of Columbia, and the State of Maryland finalized a total maximum daily load (TMDL) or "pollution diet" for trash in the Anacostia River. During rain events, trash gets swept into roadways and enters storm drains, and then gets deposited in nearby streams. The result is not only unappealing, but endangers wildlife and pollutes waterways. In the Anacostia watershed, hundreds of tons of trash are delivered through stormwater runoff each year.

The TMDL highlights six high-priority trash reduction objectives and associated strategies. These include: using best management practices and best available trash reduction technologies; publicizing information, implementing pilot projects and proven technologies; and improving public awareness through storm drain stenciling and other educational and incentive-based programs (MDE and DCDOE, 2010). The TMDL also references trash reduction strategies included in the Anacostia Restoration Plan's subwatershed action plans.

Prince George's County Phase II Watershed Implementation Plan

Despite 25 years of efforts, the Chesapeake Bay and the region's streams, creeks and rivers have continued to suffered from excess pollution - particularly in the form of nitrogen, phosphorous, and sediments. In December 2010, a TMDL was issued for the Chesapeake Bay watershed in order to restore clean water, requiring each of the six Bay sates - Maryland included - and the District of Columbia to create Phase I Watershed Implementation Plans (WIPs) that identify how each will achieve needed improvements by the years 2017 and 2025. Immediately following, Prince George's County and other local governments began to to lay out more detailed reduction targets and specific strategies to meet the 2017 and 2025 targets.

Prince George's Phase II Watershed Implementation Plan was prepared by the Department of Environmental Resources and released in July 2012, and addresses how the county will reach the goals set by the Phase I WIP and the Chesapeake Bay TMDL. The purpose of the Phase II WIP is to:

- Identify local allocations for nitrogen and phosphorous
- Develop more cost-effective and lower cost strategies
- Assign specific responsibilities for pollution reduction at the local level

The Phase II WIP divides the County into four sectors: Agriculture, Septics, Point Sources, and Urban. The urban sector identifies 23 municipalities, including Mount Rainier, for which the County is responsible for stormwater management. For these areas, the County intents to retrofit 928 acres - or 20% - of the untreated impervious area with stormwater best management practices by 2017. The Mount Rainier Urban Green Infrastructure Master Plan supports the Phase II WIP and will help Mount Rainier in developing a plan to assist the County to achieve its retrofit goal.

Prince George's County Green Infrastructure Master Plan

In 2005, Prince George's County adopted a Countywide Green Infrastructure Master Plan to protect the integrity of ecological features of countywide significance through the planning, land acquisition, and land development processes. Its goal is to preserve, enhance, and/or restore an interconnected network of countywide significant environmental features that retain ecological functions, maintain or improve water quality and habitat, and support the desired development pattern of the 2002 General Plan.

Two primary objectives of the plan are to improve the water quality and stream habitat in each major watershed by at least one rating category by 2025, using as a baseline the 1999-2003 Benthic Index of Biological Integrity and habitat rating assessments completed by Prince George's County's Department of Environmental Resources. The Mount Rainier Plan serves to further these objectives by adopting a more inclusive definition of green infrastructure and by providing tools that can help achieve improved water quality while providing economic, environmental, and social benefits.

Prince George's County Urban Tree Canopy Assessment

In October of 2011, Prince George's County received a Tree Cover Assessment study conducted by the US Forest Service and the University of Vermont Spatial Analysis Lab. The tree canopy assessment provided the County with a detailed look at the makeup of its land through the use of satellite imagery and LiDAR data. The assessment classified land cover into seven basic categories:

- Tree Cover
- Grass Shrub
- Road / Railroad
- Other Pavement
- Building
- Water
- Bare Soil

This Plan utilizes the findings of the tree canopy assessment in its analysis and recommendations.

Principles of Green Infrastructure

Green Infrastructure and Low Impact Development Defined

"Green infrastructure" is a relatively new term that has different meanings at different scales. On the regional or county scale, Prince George's County defines green infrastructure as the interconnected network of waterways, wetlands, woodlands, and green spaces that maintain ecological integrity, manage stormwater, reduce flooding, capture pollution, and improve water quality. In more urbanized settings such as Mount Rainier, the definition of green infrastructure is extended to include nature and nature-like practices that enhance overall environmental quality, such as tree plantings, rain gardens, green roofs, and permeable pavements.

Whereas the Countywide Green Infrastructure Master Plan focuses on preserving, enhancing, and/or restoring an interconnected network of green areas, Mount Rainier's Urban Green Infrastructure Master Plan also places emphasis on incorporating these natural or nature-like processes into the built environment.

The application of green infrastructure to the built environment is called Low Impact Development (LID). LID – which first took root in Prince George's County in the 1990s – is increasingly used in urban areas throughout the country. The emphasis of LID is to incorporate landscape-based design controls into a site's design in order to intercept and treat stormwater before it reaches the storm drain. LID practices differ from traditional stormwater treatment methods in that they are smaller in scale, easier to construct, and emphasize practices that resemble natural hydrologic conditions.

Urban Green Infrastructure and Stormwater Management

Traditionally, the objective of stormwater management has been to move runoff away from properties as quickly as possible via a system of concrete gutters and sewers. Little attention was given to limiting the amount of pavement or other impervious cover being introduced. In urban environments, the combination of increased impeviousness and fast-moving stormwater has led to unintended consequences such as downstream flooding, erosion and sediment loading in streams, and less water being infiltrated into the ground to recharge aquifers.

Slowing down and retaining rain where it falls helps to address these issues. With LID, stormwater management emphasizes design controls that allow stormwater to be evapotranspirated (go up in the air), infiltrated (go down into the ground), stored for later use, and/or be slowly released downstream over time. In many cases, the stormwater is also filtered to remove specific pollutants.

As the use of LID becomes widespread, green infrastructure standards are increasingly being incorporated to meet regulatory requirements to reduce stormwater runoff. For example, in December 2010, the U.S. Environmental Protection Agency (EPA) established a Chesapeake Bay Total Maximum Daily Load (TMDL) -- or the bay's "pollution diet," limiting the amount of nitrogen, phosphorus, and sediment that can be discharged into local streams. As a result, Prince George's County prepared a Watershed Implementation Plan outlining how these reductions would be met. For municipalities such as Mount Rainier, the County outlined a plan to retrofit 20% of all impervious land with green infrastructure and LID practices in order to reduce runoff and treat stormwater on-site. These requirements were put in place not only to satisfy the Bay TMDL, but also in anticipation of a new Municipal Separate Storm Sewer System (MS4) permit to control stormwater discharges within the County and its many municipalities.

Communities like Mount Rainier are near full build-out condition and have little or no on-site stormwater management. However, projects like the planned Buchanan Green Street and the installed permeable parking lot adjacent to City Hall reflect Mount Rainier's commitment to environmentally sustainable stormwater management, and lay the groundwork for future initiatives. Retrofit and reconstruction projects, therefore, are the primary focus in this plan.

The Multiple Benefits of Green Infrastructure

While the focus of the Mount Rainier Urban Green Infrastructure Master Plan is to reduce the City's stormwater footprint, green infrastructure provides multiple ecological, community, and financial benefits. In Mount Rainier, the City's urban forest, for example, is part of a larger ecosystem which contributes significantly to air, noise, and visual pollution control. The existence of shade trees moderates climatic extremes and promotes sound energy conservation, and its aesthetic value positively impacts property values and quality of life. While the benefits may vary depending on the practice use, the site, and the context, below is a list of the expected environmental, community, and financial benefits.

Urban Green Infrastructure

Urban Green Infrastructure includes local and neighborhood scale planning strategies aimed at reducing urban stormwater runoff in the built environment. The focus of green infrastructure planning in the urban environment extends beyond enhancing, protecting and/or expanding a contiguous network of environmentally sensitive areas, to incorporate landscape-based design controls that restore, protect, and mimic natural hydrologic functions within an urban setting.

The Housing Initiative Partnership's (HIP) Artists' Housing in Mount Rainier includes rooftop decking and a green roof.

Environmental Benefits

Air Quality
Shading from trees and other vegetation common in green infrastructure landscape designs helps to reduce ground level ozone by limiting power plant emissions associated with air conditioning. Trees and vegetation also reduce the amount of particulate matter floating in the air by absorbing and filtering pollutants which, left unabated, can enter into the lungs and cause serious health problems. In the Washington metropolitan region, ozone and fine particulate matter can reach levels that exceed the National Ambient Air Quality Standards as set by the Clean Air Act. By increasing vegetation and reducing levels of impervious surface, green infrastructure offers a cost-effective way to manage polluted runoff while also mitigating poor air quality conditions.

Climate Change and Urban Heat Island
Over the past century, increases in fossil fuel consumption have led to a tremendous increase in greenhouse gases. This, in turn, has resulted in higher global temperatures, fluctuating climate patterns, and sea level rise. While there is little that can be done to reduce the impacts over the short-term, steps taken now to control greenhouse gas emissions and stabilize temperatures will lessen the severity of future impacts.

Localized Flooding

Localized flooding has long been a problem in Mount Rainier, where wet basements and flooded yards are not uncommon. In urban environments, an abundance of hard, non-porous surfaces limits the ability of rainwater to seep into the ground, and too little vegetative cover is present to slow the force of rainwater down. As a result, stormwater can often flow where it is not intended.

The application of green infrastructure and LID practices, however, allows rainwater to be captured and slowed in rain gardens, porous pavement, and street edge swales. This can be particularly effective in alleviating neighborhood-scale flooding. In late 2011, for example, the City replaced an asphalt alleyway and the Perry Street municipal parking lot with permeable pavers to address flooding issues in 12 nearby homes. Since its completion, the porous surface has been successful in containing runoff from adjoining properties when storm events occur.

Water Quality and Habitat

Water bodies are significantly influenced by urban environments, and the Anacostia River is no exception. For decades, the Anacostia River has suffered from the effects of urbanization. While the Northwest Branch subwatershed is the least densely urbanized of all of the Anacostia River's subwatersheds, the lower reaches of the watershed, where Mount Rainier is located, is quickly approaching full build-out conditions. Here, there are significantly higher levels of impervious cover than in the middle or upper reaches.

Green infrastructure helps decrease the amount of pollutants entering the Anacostia River by capturing the "first flush" of stormwater, where pollutant levels are most significant. In addition, slowing down and temporarily storing runoff minimizes the volume and force of water flowing into nearby streams. This helps protect channel stability and reduces the impact of fine sediment erosion on water quality and aquatic habitat downstream.

Community Benefits

Community Reference Points

Green infrastructure features such as pocket parks and green open spaces not only capture and treat stormwater runoff, but can also serve as community references or meeting points. For example, Mount Rainier's Perry Street parking lot was retrofitted with pervious pavers in late 2011 - early 2012 to address nearby flooding issues. By opting for aesthetically-pleasing, light colored permeable pavers with an open cell structure, the lot also stays cooler in the summer months, making it ideal for occasionally hosting weekend events.

Pedestrian Safety

As identified in the Mixed-Use Town Center Zone Development Plan, there are a number of intersections within the City's downtown core that are difficult for pedestrians to traverse. Green infrastructure features such as pervious bike lanes and crosswalks help to increase awareness of places where people bike and walk. Stormwater curb extensions and median/refuge islands also serve to reduce crossing distances and provide safe places for foot and bike traffic to wait for a safe opportunity to cross.

Recreational Opportunities

Interconnected green spaces help link people and neighborhoods, provide opportunities for exercise, and enhance cognitive well-being. In a 2009 Market Analysis for the Gateway Arts District and the Town Center, one notable weakness identified within the City's limits were the number of vacant and underutilized sites, as well as a limited number of green spaces. By planning for urban green spaces within the City and identifying urban connectors such as bikeways or green streets to the countywide green infrastructure network of stream valley parks, tremendous opportunities exist to improve City residents' quality of life.

Expected Economic Benefits

Avoided Capital and Treatment Costs

Green infrastructure often costs less than gray stormwater infrastructure to install, which is a benefit to developers (EPA, 2007). Increased infiltration or the uptake of water on-site also reduces costs in combined-sewer communities by reducing the amount of water being conveyed into wastewater treatment facilities. When properly placed, such features can also reduce inflow and infiltration into sewer lines otherwise burdened by wear, tear, and repair. Over time, these practices can reduce pressures to increase storm drain capacity.

Increased Property Values

Green infrastructure features such as increased plantings and street trees lead to more attractive neighborhoods and commercial areas. In Philadelphia, a recent study found that tree-lined streets can raise a house's value up to 9% and increase spending by 12%. In addition, studies have shown that access to green spaces and parks can inflate the value of property in a three-block radius, while also providing valuable recreation opportunities that boost communities. Such benefits can also translate into increased tax revenue for Mount Rainier.

Existing Conditions

The City of Mount Rainier poses both opportunities and challenges in its goal to achieve stormwater neutrality, which is defined as the ability to retain at a minimum the first 1.0 inch of rainfall on-site. The followign provides information on the City's existing environmental conditions, which was compiled from avaible Geographic Information Systems (GIS) data and cross-checked by using information collected from project team site visits and community-led Green Team meetings.

GIS modeling is an important tool used when planning for green infrastructure. GIS mapping allows complex models to be used to compare and analyze physical information such as impervious surface coverage, and planning information such as zoning districts. GIS can help define project objectives and strategies as well as provide a mechanism for measuring success. GIS information for analyzing existing conditions was collected from M-NCPPC, Prince George's County's GIS Department, U.S. Forest Service, and the U.S. Department of Agriculture Natural Resources Conservation Service. The following is a description of the assets compiled for the project.

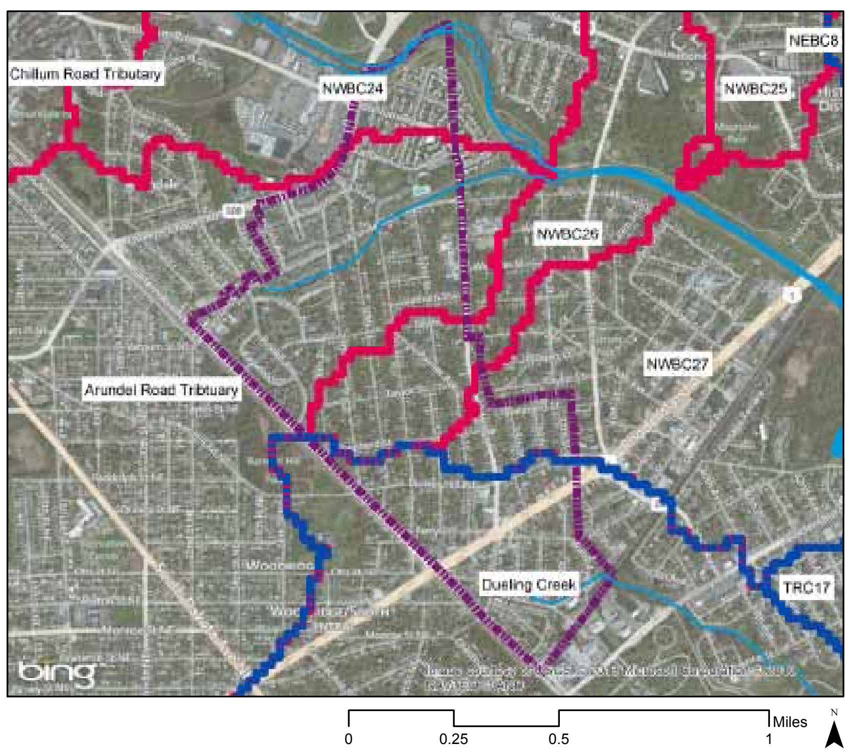
Municipal Boundary

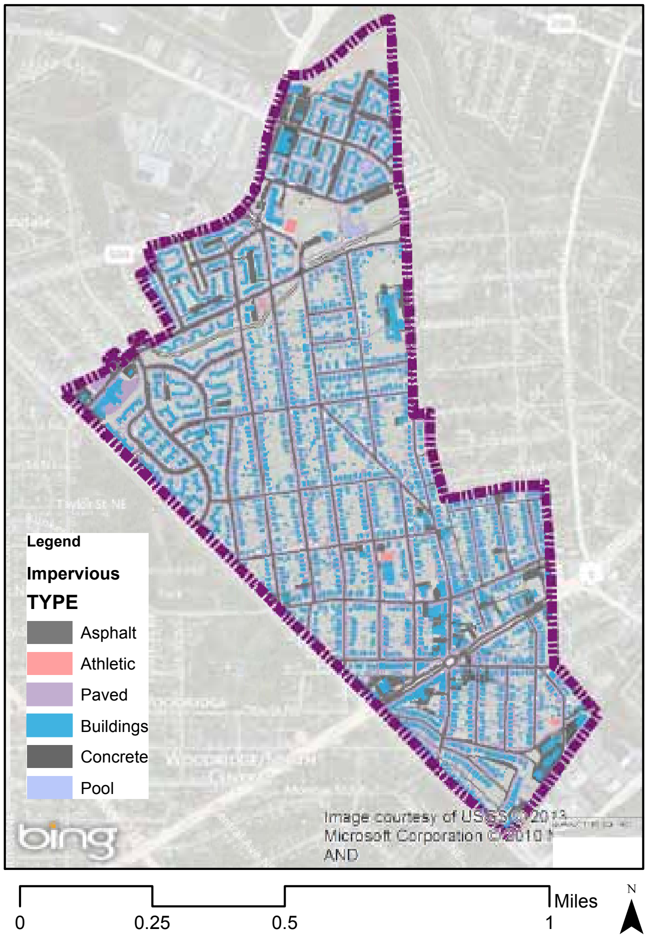
The municipal boundary outlines the incorporated area of the City of Mount Rainier. Mount Rainier is 320 acres, or 0.5 square miles.

Watersheds / Subwatersheds

The City of Mount Rainier lies in the Anacostia River watershed which flows into to the larger Chesapeake Bay watershed. Within the Anacostia River watershed, Mount Rainier belongs to two subwatersheds, the Northwest Branch subwatershed and the Lower Anacostia River subwatershed, with the majority of the City lying within the former subwatershed. The Northwest Branch subwatershed drains in an

Watershed and subwatershed boundaries within Mount Rainier.





Impervious surface classifications in Mount Rainier.

easterly direction into the Northwest Branch of the Anacostia River. The drainage is primarily via a storm sewer network and also includes the Arundel Road Tributary, a completely concrete lined open channel. The Arundel Road Tributary originates in the City near the border with the District of Columbia and includes flow from the District that is conveyed through underground pipes. It is approximately 3,600 feet long to its confluence with the Northwest Branch, of which about 2,500 feet lie within the City of Mount Rainier.

A small southern portion of Mount Rainier falls within the Lower Anacostia River subwatershed and drains in a southerly direction into Dueling Creek, a tributary of the Lower Anacostia River. As with the northern part, the southern part of Mount Rainier drains primarily along storm sewer lines, with the natural stream channel of Dueling Creek forming downstream of the boundary of Mount Rainier. Thus, no significant natural stream channels or ponds exist within the City boundaries. During wet periods, however, shallow flow channels will form to convey surface runoff into either the storm sewer inlets or directly into receiving water bodies. While the current drainage paths along storm sewer networks or roadways mostly follow topographic contours and still likely represent the general pre-development drainage alignment, urbanization has increased runoff volumes and velocities due to both impervious cover and pipe systems replacing natural stream channels.

Stormwater Neutral

Any site that retains at a minimum the first 1.0 inch of rainfall on-site.

Contours

The 2 foot contours, provided by Prince George's County, are used to help further delineate subwatersheds. Contours can help delineate site-specific drainage areas that would be good candidates for green infrastructure or LID practices, and can identify steep slopes where development is not desirable.

Urban Tree Canopy Assessment

An Urban Tree Canopy Assessment was developed by the U.S. Forest Service for Prince George's County that identifies existing tree cover (TC), impervious TC, potential TC, impervious area, and pervious ground.

Impervious Surface

Impervious surface in Mount Rainier includes buildings, asphalt, concrete, patio, and paved surfaces.

Zoning

The zoning classification data was provided by Prince George's County and is organized into 6 categories. They are commercial, industrial, mixed-use town center, multi-family housing, single-family housing, and open space.

Soil Type

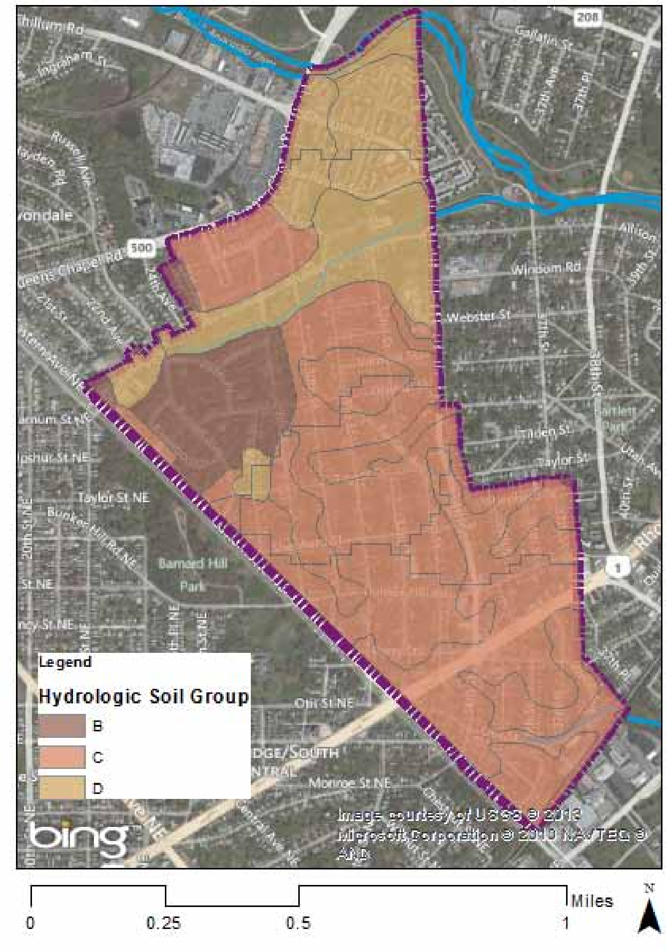
The soils data for the City was provided by Prince George's County and identifies specific soil types within Mount Rainier. This data was used to create the hydrologic soil group layer.

Hydrologic Soil Group

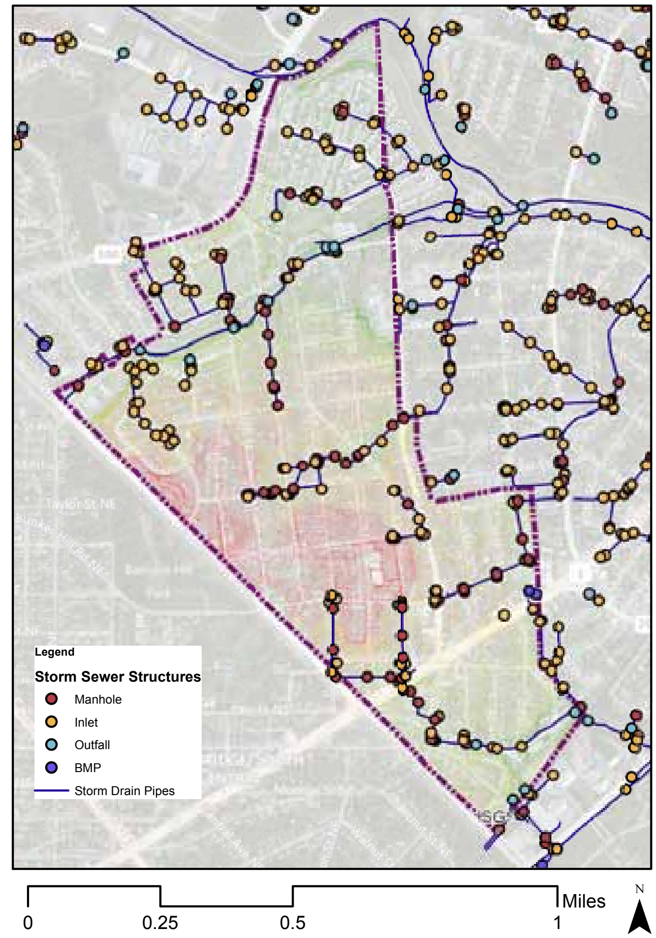
The hydrologic soil groups (HSG) relates to the infiltration capacity of soil. Soil associations are categorized in decreasing infiltration capacity from A to D. Mount Rainier contains B, C, and D soils, which are defined below.

Group B

Soils with moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. B soils have a moderate rate of water transmission.



Hydrologic soil groups present in Mount Rainier, MD.



Storm sewer network with 2 foot contours.

Group C

Soils with low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. C soils have a low rate of water transmission.

Group D

Soils with high runoff potential and very low infiltration rates when thoroughly wetted. D soils consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

Storm Sewer Network

The storm sewer network data was provided by Prince George's County. The storm sewer network includes storm drain pipes, manholes, inlets, outfalls, and existing information on stormwater best management practices. Due to the City's age, many parts of Mount Rainier do not have a system of under-street storm drain pipes.

Street trees possibly coming from the State Tree Nursery at the University of Maryland begin to take route in a state effort to promote forestry and park use (1930).

General Analysis

Overview

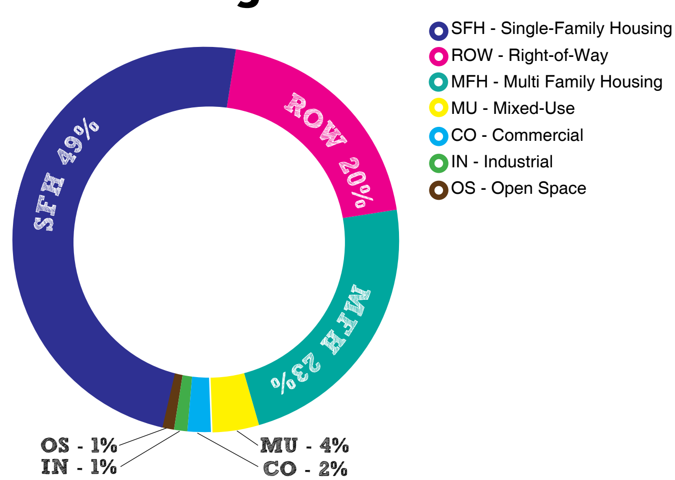
As mentioned previously, the total land area of the City of Mount Rainier is approximately 320 acres. The City has six different zoning categories, with more than 70% of the area being residential. In addition to these land uses, approximately 20% is comprised of right-of-way (ROW). ROW refers to the area managed by the city, county, or state for transportation services. A breakdown of the six different zoning types found in Mount Rainier, as well as the ROW, is shown in the figure below.

Zoning Categories

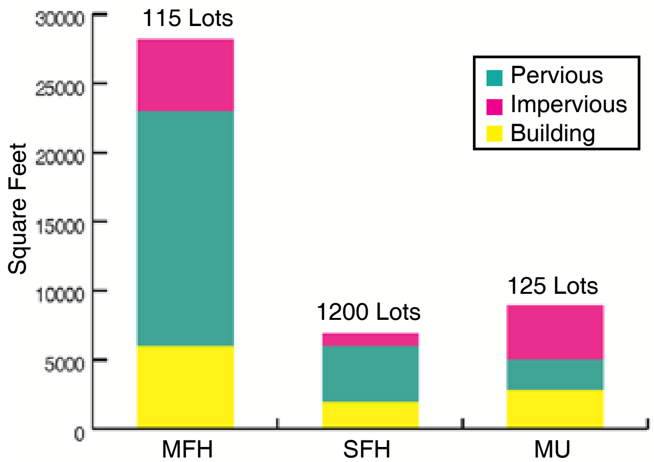
The nature of land cover on a site generally dictates the type of LID controls applicable for stormwater improvement. Since the zoning categories aptly described the different types of land cover in the City, they were used to divide up the City for analyzing stormwater runoff and potential LID retrofits. Of the six zoning types, only four were used in the analysis. Areas zoned as either open space or industrial were excluded due to their low prevalence (they cover less than 2% of the land area) within the City. The mixed-use town center (MUTC) and commercial (CO) zones are similar in their land cover composition and were therefore lumped together and analyzed jointly as mixed-use zoning type. Areas within the right-of-way were analyzed as a separate category. The following four categories were used in the analysis:

- Single Family Housing (SFH)
- Multi-Family Housing (MFH)
- Mixed-Use (MU)
- Right-of-Way (ROW)

Zoning Breakdown



Average Lot Composition by Major Zoning Category



The above chart shows the average size lot for each major zoning category within Mount Rainier (excluding the right-of-way), as well as the average amount of area dedicated to buildings, other impervious areas, and pervious/vegetated area.

Most of Mount Rainier consists of residential lots with the SFH zoning containing medium density residential lots and the MFH zoning containing high density residential lots. The MU zoning category is mostly aligned along Rhode Island Avenue and Queen's Chapel Road and is more urban in nature. The ROW consists of all the roadways within the City, including alleys. For the two zoning types not analyzed separately, the industrial zoning type can utilize similar recommendations to the mixed-use category, and open space zoning areas could be analyzed to determine their suitability for installing LID practices such as rain gardens to treat rainwater from on-site and nearby properties. Regardless of whether LID practices are utilized on open spaces, their contribution to runoff is less than any of the other zoning types, and emphasis should be placed on maintaining them to the maximum extent possible.

For each of the four zoning types to be used in the analysis for LID practices, a representative site for each land use category was developed. The representative lot estimated the typical impervious cover, building size, lawn/open space, and tree cover in each of the land use categories. This information along with GIS data was then used to develop the input data for the EPA National Stormwater Calculator for each of the four land use types.

Single-Family Housing

Nearly half of the land area in Mount Rainier consists of single-family housing (SFH). This makes the placement and/or promotion of green infrastructure and LID practices on private property essential in the City's attempt to improve its stormwater runoff. The SFH lots contain the least impervious cover per lot at 38%. However, with more than 1,200 lots, SFH is also the highest total source of impervious cover in the City at almost 40%. The relatively small amount of impervious surface per SFH lot allows for LID treatments to be small and inexpensive. Many of the homes already have disconnected downspouts with water from roofs directed to lawns. When directed to the street, the existing storm drain network's limited capacity often leads to problems with standing water.

SFH lots also contain the largest percentage of tree cover within Mount Rainier at 42%, based on the Urban Tree Canopy Assessment data, and offer the greatest amount of land available to support additional tree plantings. According to the Tree Canopy Assessment, 29% of the non-wooded area on SFH lots is appropriate for additional tree plantings.

Multi-Family Housing

Multi-family housing in Mount Rainier is the second largest land use at roughly 30% of the total land area. MFH lots typically include one to five buildings, sidewalks, and some on-site parking.

Since MFH parcels vary widely in size and composition, a representative lot was developed by looking at all of the MFH parcels, and then calculating the average lot size, average number of building units, average amount of impervious surfaces, etc. The resulting representative lot consisted of a single MFH structure with adjacent parking, sidewalks, and some open space.

Right-of-Way (ROW)

The right-of-way is defined as an easement that is reserved for transportation services such as roads, rail lines, sidewalks, or trails and is typically administered by the local, county, or state government. When present, the ROW conveys stormwater through catch basins and storm sewer lines under the street. Some assumptions and generalizations were required to model the ROW using the EPA Stormwater Calculator. This was due to the linear nature of the ROW, which did not easily translate to the standard lot type for which the calculator was primarily designed. Recommendations in the ROW vary widely based on several factors including proximity to storm sewer networks, fire and emergency vehicle turning requirements, and width of roadway.

Mount Rainier owns all of the roads within its boundary, with the notable exceptions of Rhode Island Avenue and Queens Chapel Road. Owning and operating roads is a significant benefit for Mount Rainier, since it reduces the approval process of road improvements to city government and community stakeholders. With roughly 20% of Mount Rainier being in the ROW, it provides ample opportunity for LID and GI. Presently, 77% of the area in the ROW is impervious.

The proximity of this Mount Rainier street to the storm drain network, combined with the tremendous amount of stormwater runoff experienced during and directly after storm events, makes it a strong candidate for the installation of LID features

Because Mount Rainier is an older community, many of the City streets lack a system of storm drains and storm sewer pipes to collect stormwater from the roadway. While the absence of a storm network may contribute to localized flooding or standing water during rain events, it also limits the types of LID features that can be installed within the ROW to alleviate such issues.

Typically, soils in the ROW are heavily compacted, limiting their infiltration potential, and increasing the need for connecting to a storm sewer network to pipe excess water out of the LID feature. Most often, the connection is usually made from the LID feature's underground storage layer to the storm pipe network. The further the site is away from an existing network, the more expensive it is to make the necessary connection.

In those limited cases where soils within the ROW are found to have adequate infiltration rates, LID practices that do not directly connect to the storm sewer network may be implemented. This, however, will require a detailed soil analysis as well as discussions with the County's Department of Public Works to ensure all concerns have been fully addressed. For this report, streets with storm sewers and streets adjacent to those with storm sewers have been identified as having the highest potential for LID and GI practices.

Mixed-Use

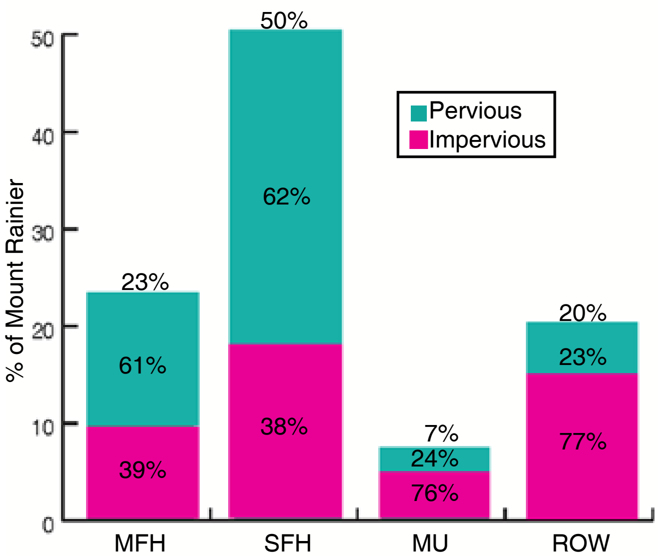
The mixed-use (MU) category combines both the mixed-use town center and commercial zoning categories, with commercially zoned properties including a mix of ancillary commercial, commercial office, and commercial shopping center properties. While uses vary widely in these categories, the building sizes, lot sizes, amount of open space, and amount of impervious cover are largely consistent.

Parcels in the MU category generally front a major thoroughfare and their lot lines end where the sidewalk begins. This leaves the sidewalk space in the ROW and provides an opportunity for the city to invest in streetscape improvements to help spur development, as well as address stormwater management outside of the travel lanes. These practices include permeable pavement, stormwater planters, street trees, and stormwater curb extensions.

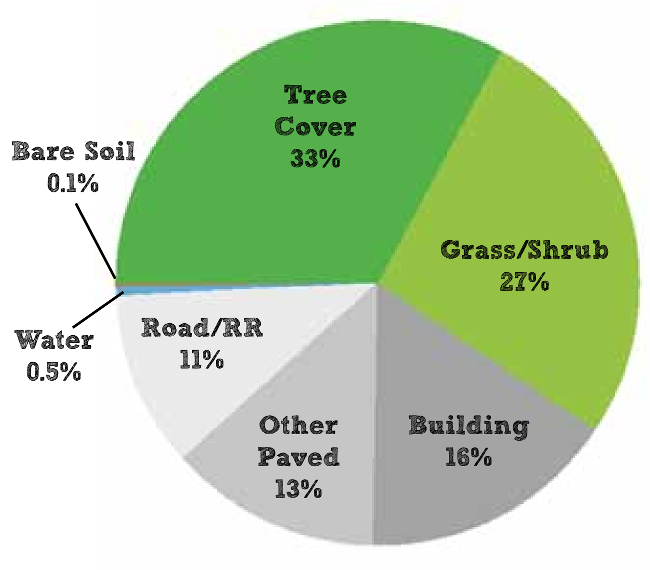
Discussion

Prior to analyzing the individual land use categories, GIS was used to compare the characteristics of the four zoning categories that were the focus of this study. Several data sets

Total % Impervious by Major Zoning Categories



Major Land Cover Types within Mount Rainier



were utilized in this analysis, including tree cover, impervious coverage, and lot composition.

Total Percent Impervious Area by Zoning Category

The land cover by zoning category figure shows the ratio of pervious and impervious land by both its percentage of the total land area in Mount Rainier and of its land use category. The mixed-use and right-of-way categories contain large amounts of impervious cover compared to their total land areas – 76% and 77%, respectively. As a percentage of Mount Rainier's total land area, the amount of impervious cover from the MU and ROW categories is smaller than for SFH at 11% and 32%, respectively. Single- and multi-family housing are similar with roughly 39% of their land area being impervious. However, since Mount Rainier has significantly more SFH lots, there is more impervious cover within the City due to this lot type.

Lot Composition

The lot composition figure illustrates the typical lot makeups for single- and multi-family housing, as well as the mixed-use zoning category. These percentages illustrate the typical pavement, building, and pervious areas of each lot. Single-family housing has the smallest average lot size at 6,700 square feet and has the smallest percentage of impervious surface per lot at 38%. Multi-family housing has the same percentage of impervious surface; however, the typical lot size is roughly 28,000 square feet. Mixed-use has the most impervious coverage at 75% for an average 8,800 square foot property. This lot composition was used in the EPA model to identify and size LID practices to best manage the stormwater runoff created from the individual lots.

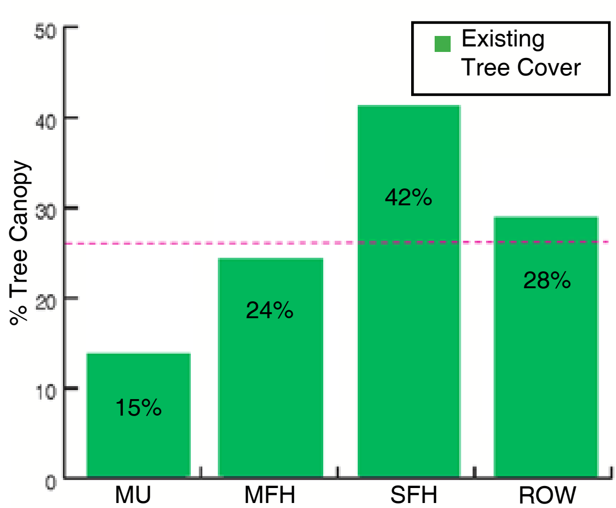
Tree Cover

In October of 2011, the US Forest Service and the University of Vermont Spatial Analysis Lab completed an Urban Tree Canopy Assessment for Prince George's County. The assessment provided the County with a detailed look at the makeup of its land through the use of satellite imagery and LiDAR data. The assessment classified land cover into seven basic categories:

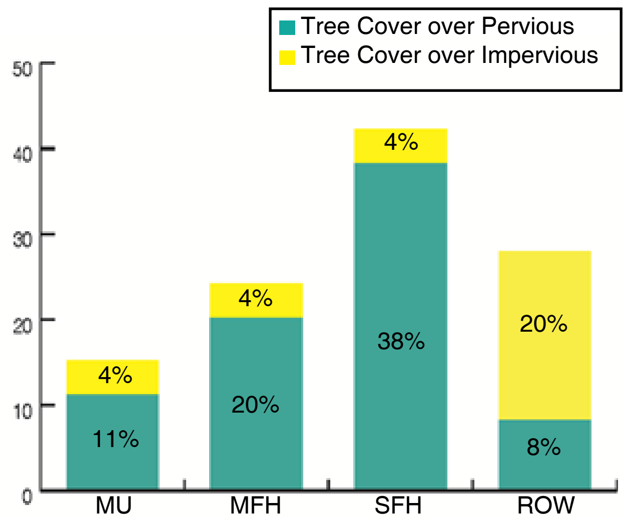
- Tree Cover
- Grass Shrub
- Road / Railroad
- Other Pavement
- Building
- Water
- Bare Soil

The land cover figure above shows the breakdown of the seven categories within Mount Rainier. With 33% total tree and forest cover, Mount Rainier exceeds the 26% tree and forest cover as outlined in the 2002 Prince George's General Plan. However, when the individual land use categories are analyzed for tree cover, only two categories, SFH and ROW, meet or exceed the County's 26% tree and forest cover goal

Percent Urban Tree Cover by Zoning Category



Percent Tree Cover over Pervious and Impervious



Overall, Mount Rainier exceeds the county's 26% tree and forest canopy goal for developed areas. However, the majority of this coverage is due to individual urban trees, and not urban forest, which are a minimum of 10,000 square feet in size. The chart at the right shows how much of the tree cover extends over impervious surfaces such as roads, driveways, and parking lots. Increasing the tree canopy - including where it extends over impervious surfaces - helps to reduce the amount of rainwater entering the storm drains.

(see figure above). The MFH and MU categories fall short at 24% and 15%, respectively. In addition, the majority of this canopy coverage is due to individual urban trees, and not urban forest canopy. In Prince George's County, a forest is defined as having a minimum width of 50 feet and a minimum area of 10,000 square feet. Hardly any of the canopy within Mount Rainier meets this criteria, meaning that those benefits attributed with a forest canopy are not realized within the City.

When the tree cover over impervious area is analyzed by the different categories, roughly 4% of the tree canopy in the SFH, MFH, and MU categories overlap existing impervious areas. ROW contains a much higher percentage of impervious area overlapped by tree cover at 20%. The presence of tree canopies over impervious areas is important since they help to limit the urban heat island effect and reduce the amount of stormwater that reaches the pavement, thus decreasing runoff.

The City's goal to become stormwater neutral is one of many ways it is creatively approaching community revitalization. On April 9, 2011, artists and community members temporarily converted Mount Rainier's historic 34th Street business district into a vibrant, eclectic "Main Street" to showcase its unique resources. As a result, two previously vacant storefronts were permanently occupied and community art installations are now a common sight.

Stormwater Impacts by Land Use

Overview

Several computer models exist that help determine the amount of stormwater retained on a site. While the use of any widely accepted method is suitable, this plan utilized the publicly available EPA National Stormwater Calculator model to calculate retention volumes. This calculator, or model, was selected because of its ability to calculate the retention volumes of LID practices in a quick and easy way.

EPA National Stormwater Calculator

The EPA National Stormwater Calculator is a simple desktop based tool used for computing small site hydrology for any location within the United States. Using the well-established Storm Water Management Model (SWMM), the calculator estimates stormwater runoff generated from a site using eight parameters:

- Location of site
- Soil type
- Soil hydraulic conductivity
- Slope of site
- Monitoring station for hourly rainfall and for daily temperature (used to estimate evaporation rates)
- Land cover for the scenario being analyzed
- LID control options, along with their design features, to deploy within the site
- Long-term hydrological analysis (dependent upon the duration of available data at the selected monitoring station)

Once a baseline condition for a site is established, different scenarios can be developed and evaluated using a combination of seven types of LID practices, which are:

- Downspout Disconnects
- Rainwater Harvesting
- Rain Gardens
- Street Planters
- Infiltration Basins
- Porous Pavements
- Green Roofs

The model generates a multitude of outputs that help analyze and compare a scenario against the baseline condition to develop an optimal method of stormwater treatment for a site.

The seven LID practices included in the calculator are regarded as the more common LID practices available and are well-suited to Mount Rainier's semi-urban setting. However, other LID practices are available to Mount Rainier and are included in this plan's Stormwater Design Toolbox section. The adoption of these and other LID practices is outlined in the next section, Recommendations and Implementation Strategies.

Using the EPA National Stormwater Calculator, it is possible to quickly calculate the effectiveness of different LID controls in treating stormwater from a given site. While the developed optimal treatment scenario for a site is primarily based on attempting to retain the first 1.0 inch of rainfall using LID controls that are suitable on that type of site, it should be noted that there usually are multiple ways to achieve stormwater neutrality in a reasonable manner. Using this software, or suitable alternative, residents, business owners, and property managers, can explore other alternative scenarios for stormwater capture.

The model was set up to account for the abundance of downspout disconnects already employed within Mount Rainier in the SFH, MFH, and MU pre-LID integration phase (baseline cases).

Assumptions & Limitations

It is assumed in the model that tree cover is classified as forest cover rather than grass/shrub cover. While there are specific differences between simple tree cover versus forest cover, the model does not allow for this distinction. Tree cover was modeled as forest cover so that the importance of tree cover was not excluded from the model and was fully accounted for.

Also not available in the model is the ability to link multiple LID practices in series. For instance, a situation where a downspout disconnect is connected to a rain barrel and overflow from the rain barrel is connected to a rain garden, cannot be modeled. If this type of practice is utilized, it is possible to capture additional stormwater above what the model predicts.

Interpreting the Model Results

The stormwater calculator estimates the potential stormwater benefits that LID controls will have on a given site. It outputs a series of tables and graphs that provide the user with the necessary information to discern the level of stormwater improvement. Generally, a baseline model is run first to estimate existing conditions. Several scenarios can then be run that incorporate various LID controls. These scenarios can then be compared against the baseline model to show the level of stormwater improvement resulting from each LID control.

LID Controls

In the model, each LID control is shown with two numbers representing the percent impervious area treated and its capture ratio.

The model assumes that LID controls will be designed to treat only the runoff received from impervious surfaces. In the model, this is shown as a percent of the site's total impervious area. For instance, a SFH lot that is 6,700 square feet in size might only contains 2,650 square feet of impervious area. Therefore, disconnecting 1,500 square feet of roof area would be modeled as treating 45% of the impervious area.

The capture ratio is the ratio of the size of the LID control (such as a rain garden) to the size of the impervious area that drains to it. For instance, in the modeled SFH lot, 25% of the impervious area - or 660 square feet - is treated with a rain garden. If the rain garden is sized at 60 square feet, its capture ratio is 9% (i.e., it's size is 9% of the size of the impervious area that drains into it).

Statistics

The following statistics were prepared for this report in order to in determine a site's stormwater treatment levels:

- Average Annual Rainfall (inches)
- Average Annual Runoff (inches)
- Percent of All Rainfall Retained
- Days Per Year With Rainfall
- Days Per Year With Runoff
- Percent of Wet Days Retained
- Smallest Rainfall With Runoff (inches)
- Largest Rainfall Without Runoff (inches)
- Maximum Retention Volume

Percent of All Rainfall Retained

This is the percentage of the total volume of rainfall retained on-site to the total volume of all rainfall during a year.

Percent of Wet Days Retained

This is the percentage of days where all rainfall was retained on-site to the total days in the year with rainfall. No runoff is generated when all rainfall is retained.

Smallest Rainfall with Runoff

This is the smallest rainfall event that produced runoff. These storms are of a short duration and high intensity.

Largest Rainfall without Runoff

This is the largest rainfall event that the site was able to fully retain on-site. These storms are typically long-duration, low-intensity storms. This statistic was used to determine the level of a site's stormwater neutrality. If a one-inch storm is retained without producing any runoff, the site can be considered stormwater neutral.

Maximum Retention Volume

This is the maximum volume of rainfall retained by the site in a given storm event that still produced runoff. These storms are the more extreme rainfall events which are typically long duration and of high intensity.

For more information on the EPA's National Stormwater Calculator, visit www.epa.gov/nrmrl/wswrd/wq/models/swc/.

Single-Family Housing

Typical Lot

The typical features of a single-family housing lot were developed by analyzing the features of representative SFH lots in Mount Rainier and calculating average values. SFH lots are typically 6,700 square feet with a main building footprint of 1,500 square feet, accessory structure of 250 square feet, and paved impervious surfaces of 900 square feet.

Trees on SFH lots generally cover about 42% of the lot. Mostly covering permeable surfaces, tree canopy covers only 4% of impervious surfaces. This results in a land cover breakdown of 42% forest, 19% lawn, and 38% impervious cover.

Suitable Practices

Suitable LID practices for single-family housing include:

Downspout Disconnects

A majority of the homes and streets in Mount Rainier are not connected directly to a storm sewer network, leaving stormwater to run over lawns and pavements and either infiltrate into the ground, form puddles, or to eventually make their way to a storm drain.

Allowing stormwater to infiltrate over existing lawns is a significant advantage Mount Rainier has when considering stormwater retention. The baseline model assumes that the average SFH lot has 50% of its roof disconnected. The 50% number was derived from site visit observations where it was discovered that, while many of the downspouts are disconnected from the sewer, a significant amount are left to drain onto pavement and ultimately to the street.

Slot drains can capture and direct stormwater from a driveway or patio to rain gardens.

Rain Harvesting

Rain barrels are an inexpensive method to capture and store rainwater. In the model, rain barrels were sized at 100 gallons, with a ratio of 1 barrel per 1,000 square feet of roof.

Typical roofs produce roughly 900 gallons of stormwater for the 1.0 inch storm. 100 gallon rain barrels on each downspout could capture 400 gallons, or 44% of the 1.0 inch storm from a roof.

Rain Gardens

Residential rain gardens typically range from 50-150 square feet and can be molded into many shapes to fit site restrictions. To treat driveways and other paved surfaces, for example, slot drains installed at the bottom of the driveway slope can direct runoff into rain gardens.

Porous Pavement

Porous pavement can reduce the amount of impervious cover on a property while still providing a hard surface for vehicles and outdoor activities. Porous pavements can have varied construction costs based on soil and slope conditions and whether or not an underdrain is needed. In the event that porous pavements are not applicable, simple pavement reduction or directing stormwater off pavements onto landscaped areas can help improve infiltration and pollutant removal.

Model

The model uses NRCS soil data to make assumptions for several parameters, and requires some limited user input in relation to years analyzed, land cover, and LID Controls. The SFH model assumed the following parameters and conditions.

Parameter	
Hydrologic Soil Group	C
Hydraulic Conductivity (inch/hour)	0.093
Surface Slope (%)	5
Precipitation Data Source	National Arboretum
Evaporation Data Source	National Arboretum
% Forest	42
% Lawn	19
% Impervious	39
Years Analyzed	10
Ignore Consecutive Wet Days	False
Wet Day Threshold (inch)	0.10

Baseline

The baseline scenario for SFH lots has the highest retention of any of the modeled land use types. Assuming the retention of a half an inch of rainfall, the baseline SFH lots are able to retain 66% of all annual rainfall. Given the amount of disconnected downspouts already present on SHF lots, half of the rooftop is assumed to already be disconnected.

Scenario 1

In the first scenario, the 50% of the rooftop that is assumed to be connected in the baseline assumptions is disconnected and directed onto a landscaped area that directs water away from pavement and driveways. A simple and easy treatment such as this reduces the number of days per year with runoff from 21 to 16 days.

Scenario 2

Scenario 2 starts with disconnecting the remaining downspouts, as was done in Scenario 1, but also includes rain harvesting features to help store additional water from the roof. The model was run to show the effects of two 100 gallon rain barrels connected to downspouts. The additional stormwater benefits of rainwater harvesting in this case are relatively low. However, the stored water can then be utilized in landscape irrigation and other suitable household needs.

Scenario 3

The last scenario includes the LID practices utilized in Scenario 2 and adds a rain garden to help capture runoff from the site's paved surfaces (for example, patios, driveways, and sidewalks). Unlike Scenarios 1 and 2, which focused solely on the capture of rainwater hitting the building's roof, Scenario 3 also treats water running off other paved surfaces. In this scenario, adding a rain garden that treats 75% of the pavement resulted in an added retention of 0.42 inches. With a capture ratio of 9%, this rain garden is roughly 60 square feet in size. Scenario 3, if implemented, results in a stormwater neutral site, since the site is capable of capturing 1.1 inches of rainfall.

Recommendations

- Ensure all downspouts are disconnected and drain to adequately sized landscape areas or rain gardens. Where downspouts are connected to rain barrels to capture water for reuse, ensure excess water is diverted to appropriately sized landscaped areas or adjacent rain gardens.
- Design rain gardens to capture stormwater from paved surfaces including driveways, patios, and excess downspout disconnect runoff. Slot drains installed at the downslope of a driveway can divert stormwater to an adjacent rain garden.
- Plant trees wherever possible. If enough room is available, encourage trees to be planted in clusters in order to meet or exceed the County's forest cover definition, which are wooded areas at least 50 feet in width and 10,000 square feet in size.

Single-Family Housing

Average Lot Size: 6,700 square feet (0.15 ac)

Tree Cover: 42%

Stormwater Neutral Site: 45% Disconnection
10% Rain Harvesting
25% Rain Gardens

LID Control	Baseline	Scenario 1	Scenario 2	Scenario 3
Disconnection (DD)	28/100	45/100	45/100	45/100
Rain Harvesting (RH)	0	0	10/7	10/7
Rain Gardens (RG)	0	0	0	25/9
Statistic				
Average Annual Rainfall (inches)	44.30	44.30	44.30	44.30
Average Annual Runoff (inches)	14.80	13.47	12.20	9.73
Percent of All Rainfall Retained	66.60	69.6	72.46	78.04
Days per Year with Rainfall	74.46	74.46	74.46	74.46
Days per Year with Runoff	20.69	16.49	14.09	8.70
Percent of Wet Days Retained	50.48	60.53	66.35	79.24
Smallest Rainfall w/ Runoff (inches)	0.38	0.51	0.54	0.63
Largest Rainfall w/o Runoff (inches)	0.48	0.57	0.66	1.08
Max. Retention Volume	1.67	1.71	1.76	1.84
Added Retention (inches)		**0.09**	**0.08**	**0.42**

Multi-Family Housing

Typical Lot

A typical multi-family housing (MFH) lot was developed by determining the average building footprint, adjacent land, and pavement for MFH within Mount Rainier. The resulting typical MFH lot is 28,000 square feet, and includes a building footprint of 5,800 square feet and paved impervious area of 11,000 square feet in size.

Tree canopy covers roughly 24% of the modeled MFH lot. This results in a land cover breakdown of 24% trees, 37% lawn, and 39% impervious cover.

Suitable Practices

Suitable LID practices for MFH lots include the following:

Downspout Disconnects

The majority of downspouts in the MFH lots are disconnected. Since some of the downspouts run onto landscaped areas and some are directed toward impervious surfaces, the baseline model assumed that 50% of the building footprint (20% of the overall impervious area) is fully disconnected.

Rain Gardens

Rain gardens are a versatile LID tool that can be tailored to fit most site restrictions. Rain gardens can be integrated with landscaped buffers or decorative landscape features to act as both a stormwater and community feature.

Street Planters

Street planters are typically located along the street edge and capture stormwater flowing down the curb and gutter. Usually located in the ROW, street planters are constructed and maintained by the city, county, or state government. However, some road and parking areas in the MFH lots are owned and operated by property managers, making street planters a viable LID option.

Porous Pavement

Utilizing porous pavement in parking stalls, driveways, plazas, or walkways are all potential retrofits for multi-family housing.

Porous pavement typically requires an underdrain to dewater the pavement section adequately. However, if soil conditions are suitable, underdrains may be unnecessary, reducing construction costs.

Model

The model uses soil data to make assumptions of several parameters and requires some limited user input in relation to years analyzed and land cover. The MFH model assumed the following parameters and conditions.

Parameter	
Hydrologic Soil Group	B
Hydraulic Conductivity (inch/hour)	0.108
Surface Slope (%)	10
Precipitation Data Source	National Arboretum
Evaporation Data Source	National Arboretum
% Forest	24
% Lawn	37
% Impervious	39
Years Analyzed	10
Ignore Consecutive Wet Days	False
Wet Day Threshold (inch)	0.10

Baseline

The baseline scenario assumes that 20% of the impervious cover is currently being treated by downspout disconnects. The MFH closely resembles the SFH baseline, where almost 65% of all rainfall is retained.

Scenario 1

Scenario 1 proposes fully disconnecting the remaining downspouts which currently drain toward impervious areas by redirecting all runoff to lawn areas. In addition, Scenario 1 adds approximately 150 square feet of rain gardens in order to treat the first 0.65 inches of rain. Given the large amount of pervious surface in MFH lots, the disconnects and rain gardens together can capture upwards of 70% of all rainfall in this scenario.

Scenario 2

Scenario 2 incorporates those practices identified in Scenario 1, but also adds street planters to treat road and parking runoff. Street planters have the additional benefit of adding tree cover. Street planters treat an additional 0.22 inches of rainfall.

Scenario 3

The final Scenario 3 involves retrofitting existing impervious pavements to porous pavement, in addition to those practices included in Scenario 2. Retrofitting existing parking areas, sidewalks, and/or patios with porous pavements in the modeled MFH lot increases the capture of all rainfall to 78%.

Scenario 3, if implemented, results in a stormwater neutral site, where the site is capable of capturing 1.1 inches of rainfall.

Recommendations

- Ensure that all downspouts are disconnected and drain to adequately sized landscape areas or adjacent rain gardens.
- Install rain gardens to treat parking, sidewalk, and/or patio impervious surfaces.
- Implement porous pavements wherever possible.
- Remove underutilized pavement wherever possible.
- Plant trees wherever possible. If enough room is available, encourage trees to be planted in clusters in order to meet or exceed the County's forest cover definition, which are wooded areas at least 50 feet in width and 10,000 square feet in size.
- Although not modeled, if intensive green roof retrofits are utilized, install on flat roofed buildings.

Multi-Family Housing

Lot Size: 28,000 square feet (0.64 ac)
Building Impervious: 5,800 square feet (0.13 ac)
Paved Impervious: 5,200 square feet (0.12 ac)
Total Impervious: 11,000 square feet (39%)
Total Pervious:17,000 square feet (61%)
Tree Cover: 24%

LID Control	Baseline	Scenario 1	Scenario 2	Scenario 3
Disconnection (DD)	20	40	40	40
Rain Gardens (RG)	0	15/9	15/9	15/9
Street Planters (SP)	0	0	15/5	15/5
Porous Pavement (PP)	0	0	0	10/12
Statistic				
Average Annual Rainfall (inches)	44.30	44.30	44.30	44.30
Average Annual Runoff (inches)	15.73	12.33	10.73	9.45
Percent of All Rainfall Retained	64.49	72.17	75.79	78.67
Days per Year with Rainfall	74.56	74.56	74.56	74.56
Days per Year with Runoff	40.08	27.88	20.79	17.29
Percent of Wet Days Retained	46.10	62.65	72.16	76.84
Smallest Rainfall w/ Runoff (inches)	0.29	0.30	0.30	0.30
Largest Rainfall w/o Runoff (inches)	0.47	0.65	0.87	1.08
Max. Retention Volume (inches)	1.77	1.85	1.91	1.96
Added Retention (inches)		**0.18**	**0.22**	**.21**

Mixed-Use

Typical Lot

The typical mixed-use (MU) lot was modeled by averaging the typical features located on all MU lots within Mount Rainier. A MU lot is, on average, 8,800 square feet in size, with a main building footprint of 2,600 square feet, a paved impervious area of 4,000 square feet, and 2,200 square feet of pervious cover. The land cover breakdown for MU is 15% forest, 10% lawn, and 75% impervious cover. Given the large amount of impervious cover on mixed-use lots, it becomes increasingly difficult to achieve stormwater neutrality on-site.

Suitable Practices

Suitable LID practices for MU properties include the following:

Downspout Disconnects

A majority of the downspouts in the MU category are disconnected. However, many of the downspouts direct stormwater to paved surfaces that eventually drain to the storm sewer network. Because of the limited amount of pervious space, the use of downspout disconnects, unless draining to a street planter, is limited. The capture ratio for the downspouts in the MU category is set to 85% because the amount of roof area exceeds the amount of pervious surface available.

Green Roofs

Existing structures may or may not have the ability to sustain the extra weight of a green roof. If lots are redeveloped, the roofs could be designed to handle the load of a green roof.

Street Planters

Street planters are typically located along the street's edge and capture stormwater flowing down the curb and gutter. Stormwater planters, similar to street planters, can also be located at the building edge, capturing stormwater from downspouts.

Porous Pavement

Installing porous pavement on MU lots is a common practice used to capture stormwater. The prevalence of parking and/or loading areas associated with some MU lots provide ample area for porous pavements. On some lots along Rhode Island Avenue, where pavement is scarce, porous pavement is not as applicable.

Model

The model uses soil data to make assumptions of several parameters, and requires some limited user input in relation to years analyzed and land cover. The MU model assumed the following parameters and conditions.

Parameter	
Hydrologic Soil Group	C
Hydraulic Conductivity (inch/hour)	0.336
Surface Slope (%)	10
Precipitation Data Source	National Arboretum
Evaporation Data Source	National Arboretum
% Forest	15
% Lawn	10
% Impervious	75
Years Analyzed	10
Ignore Consecutive Wet Days	False
Wet Day Threshold (inch)	0.10

Baseline

The baseline scenario is modeled with 15% downspout disconnection. Due to the small amount of pervious cover in MU lots, a majority of the downspouts, although disconnected, run onto pavement, where the runoff is then directed to storm drains. Overall, it was determined that the modeled MU lot captures about 40% of all rainfall, prior to the addition of LID practices in the scenarios identified below.

Scenario 1

Scenario 1 modifies the baseline MU conditions by adding street planters. The street planters increase the site's retention abilities by 0.06 inches and reduces the number of days with runoff by 8 days. Retaining 57% of the rainfall – an increase of 17% – street planters enable the MU lot to capture a large amount of the small intensity, long duration rainfalls.

Scenario 2

In Scenario 2, which retains the street planters identified in Scenario 1, parking lots, patios, and sidewalks are retrofitted with porous pavement. By adding porous pavement, an additional 20% of impervious cover was treated, increasing the percent of all rainfall retained by 11%.

Scenario 3

Scenario 3 starts with Scenario 2 and adds an extensive green roof to the modeled MU lot. Green roofs are not always applicable, especially in retrofit conditions. However, with the majority of the lot taken up by building and impervious cover, the roof provides the greatest amount of space available for retrofits. Aside from the stormwater benefits, green roofs helps reduce the urban heat island effect and insulate buildings, which decreases HVAC costs.

In Scenario 3, the site is able to capture the first 0.6 inches of rainfall. While the site does not reach stormwater neutral status, it does achieve 65% of the stormwater neutral goal.

Recommendations

- Due to a lack of pervious cover for downspout disconnects, utilize street planters to help infiltrate roof runoff.
- If parking is a major source of imperviousness, add street planters and/or permeable pavements to capture runoff.
- Wherever possible, plant street trees.
- If structurally possible, implement green roofs on new construction or reconstruction sites.
- Utilize cisterns or rain barrels to collect additional stormwater for irrigation or gray water infrastructure.
- Work with the City to implement permeable sidewalks to add additional stormwater capture.

Mixed-Use

Lot Size: 8,800 square feet (0.2 ac)
Building Impervious: 2,600 square feet (0.06 ac)
Paved Impervious: 4,000 square feet (0.09 ac)
Total Impervious: 6,600 square feet (75%)
Total Pervious: 2,200 square feet (25%)
Tree Cover: 15%

LID Control	Baseline	Scenario 1	Scenario 2	Scenario 3
Disconnection (DD)	15/85	15/85	15/85	15/85
Green Roofs (GR)	0	0	0	20
Street Planters (SP)	0	30/4	30/4	30/4
Porous Pavement (PP)	0	0	20/9	20/9
Statistic				
Average Annual Rainfall (inches)	44.30	44.30	44.30	44.30
Average Annual Runoff (inches)	25.86	18.78	13.82	10.68
Percent of All Rainfall Retained	41.63	57.62	68.80	75.88
Days per Year with Rainfall	74.66	74.66	74.66	74.66
Days per Year with Runoff	53.97	45.87	34.98	28.58
Percent of Wet Days Retained	27.61	38.47	53.08	61.66
Smallest Rainfall w/ Runoff (inches)	0.16	0.20	0.30	0.30
Largest Rainfall w/o Runoff (inches)	0.27	0.33	0.48	0.63
Max. Retention Volume (inches)	1.27	1.52	1.76	2.13
Added Retention		**0.06**	**0.15**	**0.15**

Right-of-Way

Typical Lot

The right-of-way lot was modeled based on the most typical street section. In Mount Rainier, a typical street contains two lanes of traffic, one parking lane, sidewalks, and landscape strips. The average area of a street ROW between two blocks is approximately one acre. In the model, the ROW lot size was modeled as one acre, or 43,560 square feet. The ROW is primarily impervious at 77%, with the remaining 23% being pervious land and tree cover. Curb and gutter systems in the ROW help to ensure the capture of stormwater by directing and channelizing stormwater to nearby storm drains.

Unlike the other model categories, 20% of the impervious area in the ROW is presently covered with trees. The model does not have a way for accounting the stormwater benefits of tree cover over impervious areas, so 5% of the impervious surface was modeled as tree cover. This makes the model breakdown 13% tree cover, 15% lawn, and 72% impervious.

Suitable Practices

Suitable LID practices for the right-of-way include the following:

Street Planters

Street planters are typically located along the street edge and capture stormwater flowing down the curb and gutter.

Porous Pavement

Porous pavements in the right-of-way are typically located in the parking lane or sidewalk. Depending on traffic volume, porous pavements can be also be used in travel lanes, intersections, crosswalks, and alleys.

LID Control	Baseline	Scenario 1	Scenario 2
Street Planters (SP)	0	40/5	40/5
Porous Pavement (PP)	0	0	43/13
Statistic			
Average Annual Rainfall (inches)	44.30	44.30	44.30
Average Annual Runoff (inches)	29.32	21.47	11.13
Percent of All Rainfall Retained	33.82	51.53	74.87
Days per Year with Rainfall	74.66	74.66	74.66
Days per Year with Runoff	56.27	46.97	19.59
Percent of Wet Days Retained	24.43	36.91	73.69
Smallest Rainfall w/ Runoff (inches)	0.16	0.18	0.30
Largest Rainfall w/o Runoff (inches)	0.25	0.32	0.95
Max Retention Volume (Inches)	0.75	1.06	1.52
Added Retention		**0.07**	**0.63**

Model

The model uses soil data to make assumptions of several parameters, and requires some limited user input in relation to years analyzed and land cover. The ROW model assumed the following parameters and conditions.

Parameter	
Hydrologic Soil Group	C
Hydraulic Conductivity (inch/hour)	0.093
Surface Slope (%)	10
Precipitation Data Source	National Arboretum
Evaporation Data Source	National Arboretum
% Forest	13
% Lawn	15
% Impervious	72
Years Analyzed	10
Ignore Consecutive Wet Days	False
Wet Day Threshold (inch)	0.10

Baseline

In the modeled baseline scenario, the ROW contained no LID controls. With more than 70% impervious area, the ROW is only capable of retaining 0.25 inches of stormwater. This largely takes place in the tree canopy and the landscape strips along the sidewalk.

Scenario 1

In Scenario 1, 30% of the ROW is treated by adding roughly 670 square feet of street planters. Eight 100 square feet (5' x 20') street planters appropriately sited along the street will retain 52% of all rainfall and will reduce the number of days with runoff from 56 to 47. Allowing water to flow into planters from the sidewalk can help treat additional stormwater.

Scenario 2

In Scenario 2, both street planters and permeable pavement were utilized. Retrofitting ROW areas such as parking lanes or storm gutters with porous pavement increases the retention potential by 0.63 inches of rainfall and reduces the number of days per year with runoff to just below 20. At a 13% capture ratio, the 43% of impervious surface treated by porous pavements equates to roughly 1,900 square feet of porous pavement.

Right-of-Way (ROW)

Total Area: 82 ac
Total Impervious: 63 ac (77%)
Total Pervious: 19 ac (23%)
Tree Cover: 28%

Retrofitting sidewalks with porous pavement should only occur when an adequate amount of stormwater can be treated in the pavement section. Otherwise, pooling may occur.

Using the stormwater calculator for Scenario 2, it was estimated to be capable of capturing 1.0 inches of rainfall, resulting in a stormwater neutral site.

Recommendations

- Plant street trees wherever possible to cover impervious surface.
- Add street planters wherever possible to capture stormwater from both the street and sidewalk.
- Add permeable pavements to parking lanes, gutters, and/or sidewalks wherever feasible.
- Analyze the potential to reduce pavement, particularly for sidewalks. Reclaimed sidewalk space can be utilized for landscaping and gardening.

The ROW, unlike the other land use categories, varies widely in its form. The discussion above was based on the most typical ROW section. The following section details several representative samples of different ROW sections found in Mount Rainier. Because of the varied width and placement of travel lanes, parking lanes, sidewalks, and landscape strips, it was important to review the potential limitations and installation opportunities in each representative section.

Green Streets

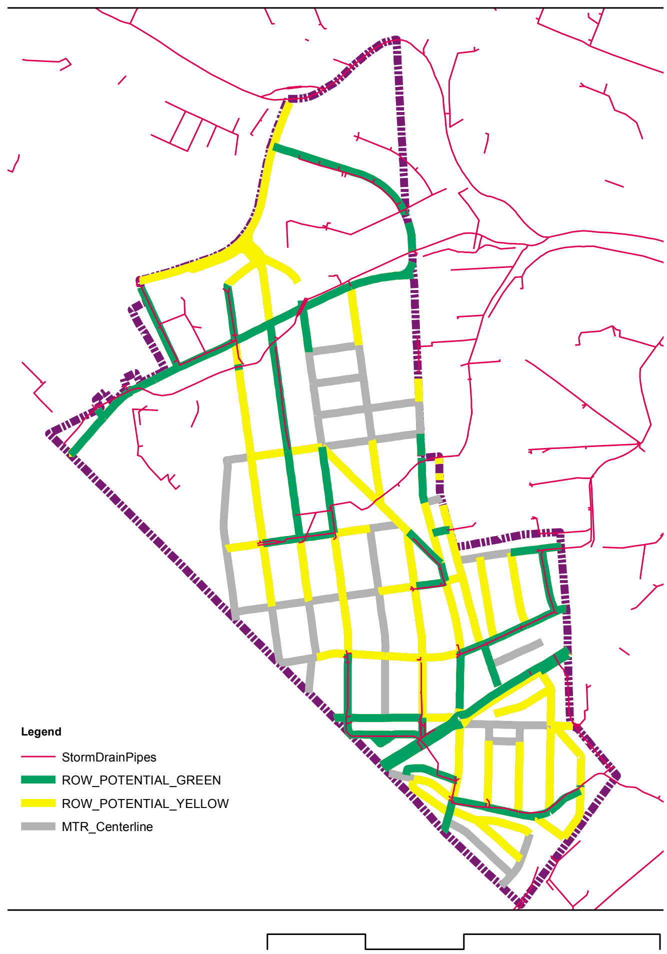
The installation of LID controls in the ROW is one of the major features of "green street" designs. A green street is constructed to slow stormwater down in order to either infiltrate or to treat it for pollutants prior to entering the storm drain. Some of the LID controls outlined in the model are practices utilized in green streets. Other features include creating median or refuge islands, narrowing streets, installing bike lanes and energy-efficient lighting, and providing traffic calming devices.

To prioritize the potential green street locations in Mount Rainier, the roads were analyzed based on their distance to a storm sewer network. Many of the LID controls utilized in the ROW require a connection to the storm sewer network. The farther away a road is from current storm sewer infrastructure, the greater the increase in cost to retrofit. Therefore, roads containing a storm sewer line were given the highest green street potential.

Roads draining to a street with existing storm sewer infrastructure have the second highest potential, as storm sewer infrastructure could easily be connected to or added to the street section. Roads that did not contain or drain to a street with storm sewer infrastructure are not recommended for green street retrofits, as construction costs would be prohibitively high. However, LID measures that do not require an underdrain are still applicable to these streets.

The following are guidelines and considerations for applying green street practices on streets and alleyways within the City.

Streets containing a storm sewer line (in green) provide the highest potential for green street retrofits. Roads that drain to streets with existing storm sewer networks are highlighted in yellow.



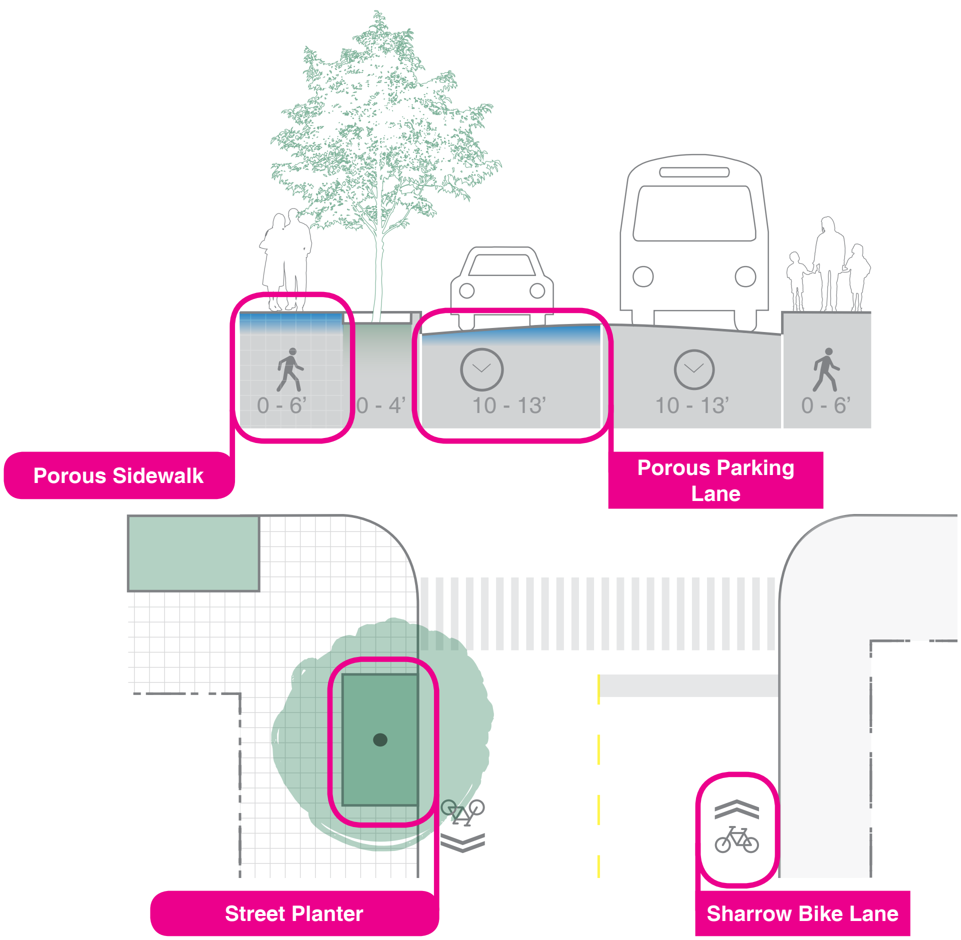
Applying Green Street Practices to Narrow Roads and Alleyways

Narrow roads are defined as roadways where either there are two travel lanes, or there is one travel lane and one parking lane flanked by either a sidewalk and/or a landscaped strip. Road widths on narrow roads are typically 20-25 feet, and sidewalks vary from 4-5 feet with 2-4 foot landscape buffer. Alley roads also fall under this category.

Given the limited width of the ROW, green street practices on narrower roads often focus on planting street trees and installing street planters for stormwater capture. Where appropriate, sidewalks can be converted to porous pavement. Porous pavements are also an option for the gutter and/or parking lane, when present, and for alleys. In the case of Mount Rainier, the alley adjacent to the Perry Street municipal parking lot was retrofitted with porous pavers in late 2011 - early 2012.

Other Considerations

- Due to the narrow right-of-way, bike lanes should use sharrows, as full width bike lanes are not possible.
- Depending on the width of the street and parking lane, stormwater curb extensions can be implemented if the remaining width is sufficient for emergency vehicles.



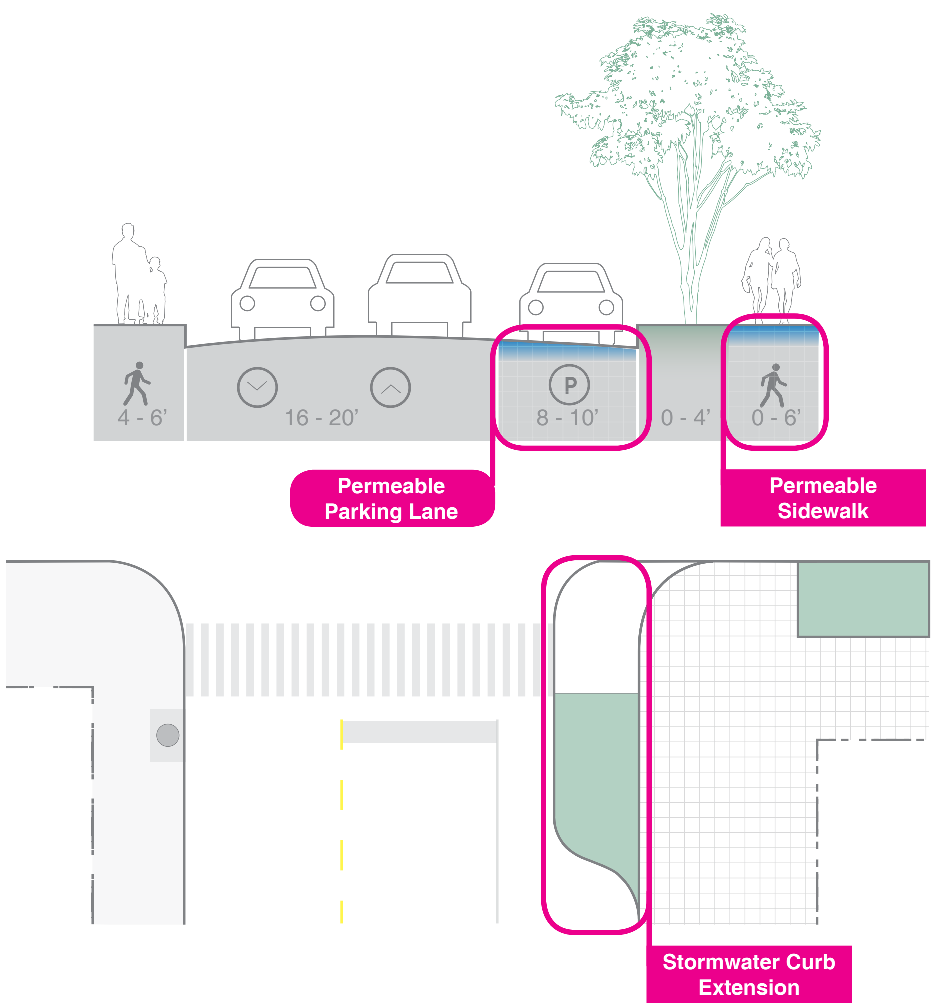
Applying Green Street Practices to Medium-sided Roadways

As the width of a roadway increases, there are additional options for utilizing green street practices. Here, wider, local roads are defined as having two travel lanes and one parking lane, with a ROW that includes the roadway, the sidewalk, and a small landscape strip. This is the most common road type in Mount Rainier. Varying in width across the City, the typical road section is 30 to 50 feet wide. Sidewalks and landscape widths can also vary from street to street.

For this size of roadway, it is possible to place planters on either side of the street in the sidewalk. However, Americans with Disabilities Act (ADA) accessibility requirements must be maintained regarding sidewalk widths. Stormwater curb extensions, similar to street planters, can be installed at intersections to reduce crossing distances. This results in improved pedestrian safety while providing additional area for infiltration and storage. In addition, porous pavements can be implemented in the parking lane, sidewalk, and/or gutter.

Other Considerations

- Bike lanes can be integrated into the travel lane with the use of a sharrow or a dedicated lane, depending on width constraints.
- Stormwater curb extensions are applicable in the parking lane when the street width allows.



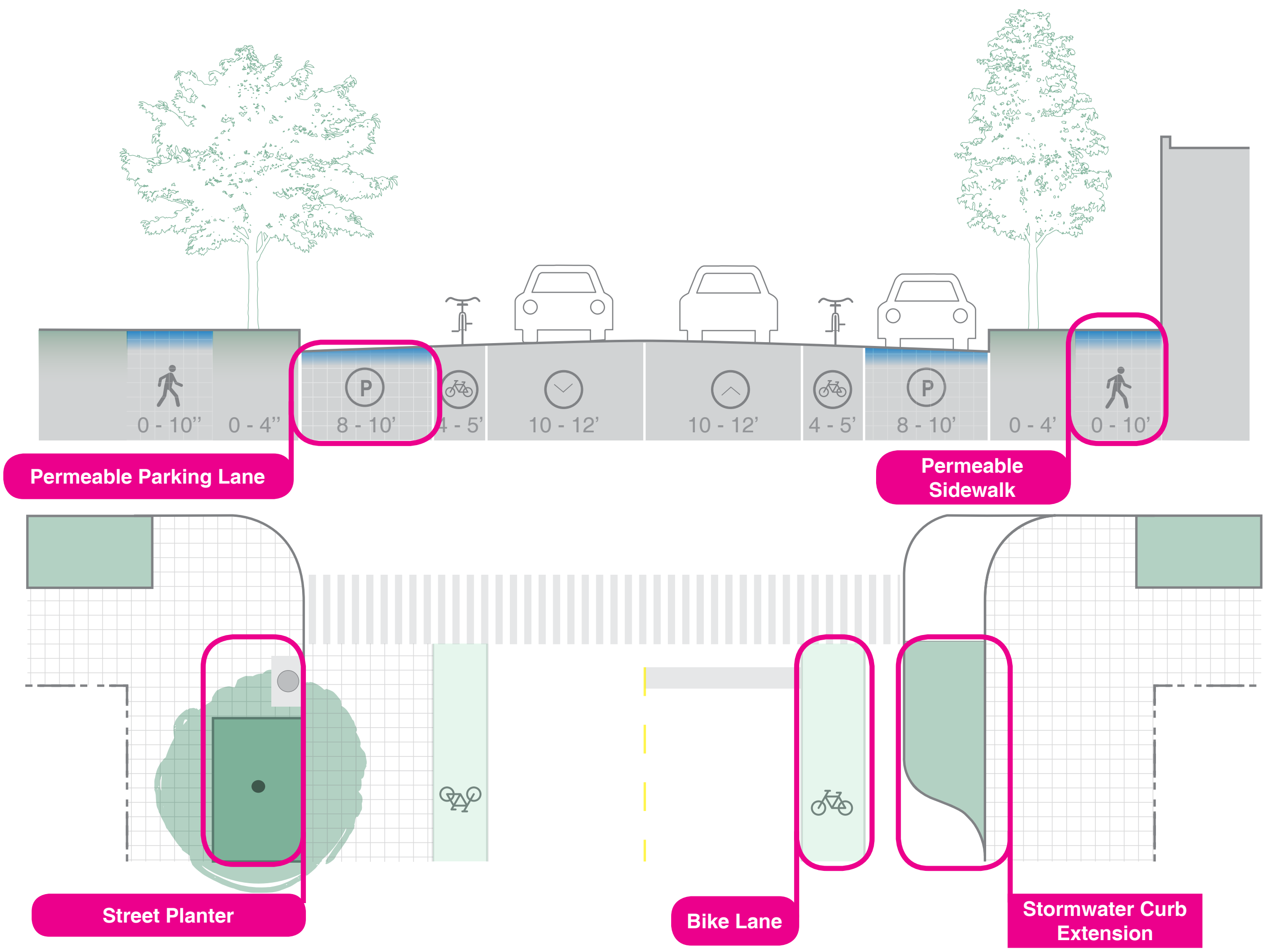
Applying Green Street Practices to Wide Roadways

Wide roads in Mount Rainier are defined as roadways with two travel lanes and two parking lanes. Lanes in this scenario are typically 10-12 feet wide each, flanked by 8-10 foot wide parking lanes on either side. Sidewalks are common. Where present, they are typically constrained by buildings on either side, and vary in width from 4-10 feet. When not constrained by buildings, sidewalks are typically buffered by a 2-4 foot landscape strip. In some instances, the parking lane is perpendicular to the travel lane.

With a wide ROW, these roadways provide ample opportunities for installing LID controls. Porous pavements can be installed in the sidewalk to help treat runoff from adjacent impervious surfaces. Parking lanes and gutters can be retrofitted with porous pavements to help infiltrate stormwater from the travel lanes. Street planters and stormwater curb extensions can also be implemented to add additional retention and infiltration of stormwater.

Other Considerations

- Dedicated bike lanes utilizing lane diets could decrease vehicle speeds while incorporating bike infrastructure.
- Stormwater curb extensions could be coupled with raised or high visibility crosswalks to increase pedestrian safety.



Cedar Waxwing are one of several hundred species of birds that spend time in the Anacostia Watershed.

Concept Plan

The following concept plan, or case study, was developed to demonstrate and evaluate the tools and design elements that support the City's environmental sustainability efforts. This concept was developed to identify the level of LID controls required at the scale of a city block to improve its stormwater runoff, and builds upon the previous site-specific analyses that focused on individual use types.

For this analysis, an entire drainage area to a storm drain inlet was identified and targeted with the goal of achieving stormwater neutrality. The concept focuses on the block scale for two important reasons. First, evaluation at the block scale allows for LID controls on multiple lots of different land uses to be included in the assessment. The lots included both private (residential) and public (ROW) land. Second, the analysis at the block scale allowed using a storm drain inlet as the outlet point, which makes the model more realistic.

The selected project site for the concept plan was the 4200 block of 32nd Street. Both the street section and associated block are representative samples of the most common type of street and block in Mount Rainier. The 4200 block of 32nd Street falls between Upshur Street to the north and Rainier Avenue to the south. The following factors make this block ideal for the development of the concept plan model:

- 32nd Street allowed for a combination of both residential and public ROW LID controls to be modeled. The street is flanked on both sides with single-family housing, which is the most prevalent land use in Mount Rainier.
- The street itself – with two travel lanes and one parking lane – is the most common street type in Mount Rainier.
- 32nd Street drains to the south towards two storm drain inlets that are located on either side of the street at the intersection with Rainier Avenue. In addition to providing a tangible outlet point for the concept plan, the storm drain inlets increase the potential for LID controls within the ROW, where underdrains are required to ensure LID facilities can be adequately drained. The presence of a storm drain inlet nearby allows for the underdrain to be directly connected to it and helps keep costs down, as installing additional storm drain networks is avoided.
- With an approximate drainage area of 1.5 acres, the 32nd Street block provides a substantial and representative area of both pervious and impervious land cover, with lawns, buildings, tree cover, and paved surfaces.

Model

The 4200 block of 32nd Street was divided into two drainage areas, one for each storm drain inlet (catch basin) located at the intersection of 32nd Street and Rainier Avenue. Similar to the previous analyses, the EPA National Stormwater Calculator was used to model the two drainage areas. The two drainage areas are shown in the figure on page 39 and includes the parameters outlined in the following table.

Both the proposed permeable pavers and the street planters underdrain to existing catch basins located at the intersection of Rainier Avenue and 32nd Street. The illustration above shows what the integration of permeable pavers and street planters may look like on 32nd Street.

Parameter	DA - 1	DA - 2
Hydrologic Soil Group	C	C
Hydraulic Conductivity (inch/hour)	0.093	0.093
Surface Slope (%)	10	10
Precipitation Data Source	National Arboretum	National Arboretum
Evaporation Data Source	National Arboretum	National Arboretum
% Forest	31	15
% Lawn	35	25
% Impervious	34	60
Years Analyzed	10	10
Ignore Consecutive Wet Days	False	False
Wet Day Threshold (inches)	0.10	0.10

Drainage Areas

DA - 1

Draining Area 1 (DA-1) is the larger of the two drainage areas at 1.02 acres. The drainage area encompasses half of 32nd Street and the majority of the residential lots on the western side of 32nd Street. Since the drainage area includes both residential properties and public ROW land, suitable LID practices included downspout disconnects, rainwater

LID Control	DA 1 - Baseline	DA 1 - Retrofits	DA 2 - Baseline	DA 2 - Retrofits
Disconnection	20/100	30/100	7/100	7/100
Rain Harvesting	0	10/1	0	0
Rain Gardens	0	15/9	0	0
Street Planters	0	20/5	0	35/5
Porous Pavement	0	0	0	40/13
Statistic				
Average Annual Rainfall (inches)	44.30	44.30	44.30	44.30
Average Annual Runoff (inches)	14.17	10.66	24.33	10.68
Percent of All Rainfall Retained	68.01	75.94	45.08	75.89
Days per Year w/ Rainfall	74.56	74.36	74.66	74.66
Days per Year w/ Runoff	33.78	21.09	51.67	19.29
Percent of Wet Days Retained	54.69	71.64	30.79	74.16
Smallest Rainfall w/ Runoff (inches)	0.30	0.30	0.16	0.30
Largest Rainfall w/o Runoff (inches)	0.49	0.95	0.29	1.08
Max Retention Volume (inches)	1.73	1.85	1.07	1.64

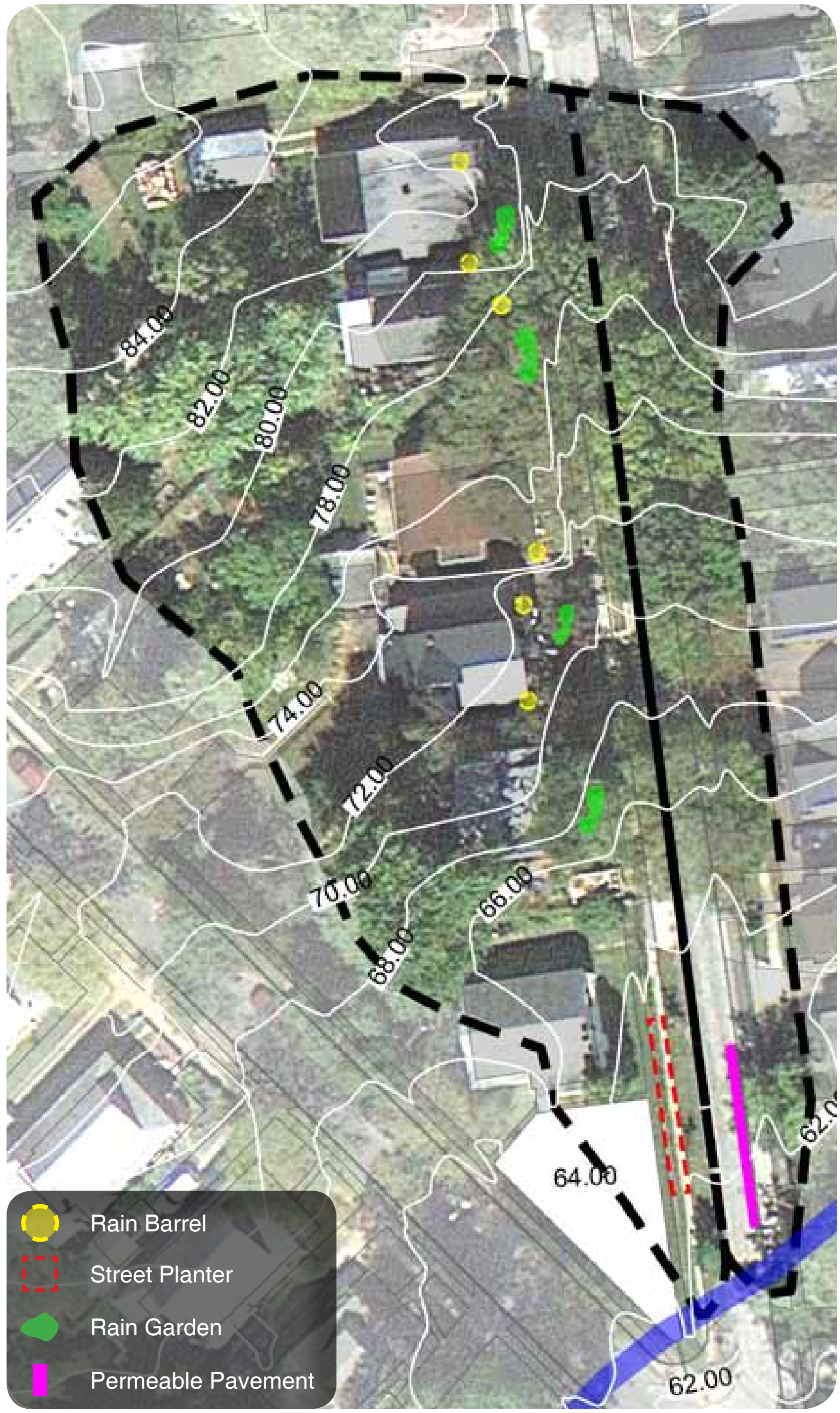
harvesting, rain gardens, and street planters. Porous pavements were not included amongst the potential LID practices because such pavement is typically not suitable for busy roads and because the parking lane of 32nd Street is located on the eastern side of the street. Sidewalks and private driveways could be appropriate for porous pavement retrofits.

However, ascertaining their suitability requires a higher level of investigation, and as such, they were precluded from consideration. While a significant portion of downspouts in DA-1 are disconnected, some rooftops drain to driveways and directly contribute to stormwater runoff. Since none of the disconnected downspouts are directed to landscaped areas, the baseline condition was modeled with 20% disconnected downspouts.

In addition to disconnecting or directing more downspouts to pervious areas, the following LID controls were used to capture the 1.0 inch storm:

- Three 50 gallon rain barrels per residential house to capture additional rain water from the downspout disconnects
- 200 square feet of rain gardens (split into four 50 square feet residential rain gardens) to treat 2,250 square feet of driveway and sidewalk
- 150 square feet of street planters to treat 3,000 square feet of roadway

Overall, 75% of the impervious surface area in DA-1 was required to be treated with some form of LID control to capture the 1.0 inch storm. The downspout disconnects, rain barrels, and rain gardens that are located on private property capture a significant amount of water. While they reduce the amount of stormwater entering the storm drain system, they also provide homeowners with water for irrigation and other water needs, and have the possibility to alleviate minor localized flooding.



The concept plan identifies locations for rain barrels, street planters, rain gardens, and permeable pavements along 32nd Street. The above graphic shows the approximate locations of the modeled LID Controls.

Rain gardens, such as the one being planted here at the Mount Rainier Nature Center, effectively manage stormwater while creating a visually appealing landscape.

The street planter, which is located at the base of the hill on 32nd Street (near the intersection with Rainier Avenue), helps capture a significant portion of the roadway and sidewalk runoff. While the LID facilities may help with minor flooding issues or localized standing water, flooding due to large, more extreme rainfall events would not be alleviated, as LID facilities, strictly speaking, are not flood control structures.

DA – 2

Drainage Area 2 (DA-2) is smaller at 0.31 acres and consists primarily of impervious ROW. Only a small portion of the single-family housing residential lots on the eastern side of 32nd Street contribute to the drainage area, since much of the land in the residential lots drains to the rear away from the street. Downspout disconnects were modeled at 10% for the baseline condition to account for this small amount of roof area. Since the majority of the drainage area is in the ROW, the primary LID controls utilized for DA-2 were porous pavements and street planters.

The following LID controls were used to capture the 1.0 inch storm:

- 300 square feet of porous pavement
- 150 square feet of street planters

Treating a similar 75% of impervious surface as DA-1, DA-2 is able to capture the 1.0 inch storm. The potential to install permeable pavements in DA-2 is high because the parking lane is located within the drainage area. Due to its placement at the foot of the hill near the intersection of Rainier Avenue and 32nd Street, the porous pavement could also help alleviate or reduce localized street ponding issues.

Designing a rain-friendly front yard not only helps to limit the amount of rainwater flowing into the street, but can also make for more aesthetically appealing properties and neighborhoods.

Conclusion

Capturing the first 1.0 inch of rainfall that drains along the 4200 block of 32nd Street to the storm drain inlets is possible by treating stormwater on both public and private land. Combinations of multiple LID practices across the block are able to treat portions of runoff and distribute the associated cost and maintenance across homeowners and the City. For homeowners, downspout disconnects, rainwater harvesting, and rain gardens provide the best opportunities for treatment of stormwater runoff, whereas for public ROW, street planters and porous pavements provide the best opportunities for treatment of stormwater runoff. This case study also reveals that even if not all the homeowners on a block are able to participate, it is still possible to achieve some level of stormwater neutrality.

The concept plan uses the EPA National Stormwater Calculator to estimate stormwater reductions. While the calculator is a quick and efficient tool for modeling and calculating stormwater retention amounts, more exacting methods may be required to precisely calculate actual stormwater reductions that reflect real ground conditions.

River Cleanup at the Bladensburg Waterfront Park. Brent Bolin (right) jumps in to help the cleanup effort.

Strategies and Recommendations

As described previously, the purpose of the Mount Rainier Urban Green Infrastructure Plan is to develop a comprehensive vision for implementing environmentally and financially sustainable stormwater management practices within the City which also enhance the community's social and economic well-being. The stated goal – to become a stormwater neutral City – is a challenging one.

In previous sections, various land uses were explored individually and as a whole to determine the level of effort that will be required for the City to become stormwater neutral. In the case of mixed-use sites, in particular, the analysis showed that attaining stormwater neutral status with on-site controls alone might not be practical. However, when looking at a drainage area as a whole, and by placing additional features within the right-of-way and on other available areas, the potential to become stormwater neutral returns. The policies and strategies outlined below provide some next steps for the City as it moves forward. The effectiveness of this plan ultimately depends on developing policies and strategies that are manageable, constructible, and measurable.

Providing retrofit opportunities, working with existing site constraints, and the lack of existing gray stormwater infrastructure will be the most significant challenges to implementation of the Plan. Since the City owns most of its streets, approval for right-of-way improvements will be more streamlined. The following six policies were identified to ensure plan implementation:

- Reduce impervious cover
- Increase the urban tree canopy
- Promote outreach and education
- Enhance and promote multi-modal transportation
- Implement pilot projects
- Identify funding sources

For each policy, this section provides specific strategies and recommendations to ensure plan implementation.

This parking lot in Easton, MD reduced its impervious cover and now helps infiltrate some stormwater after a section of asphalt was removed and replaced with vegetation.

Casey Trees organizes spring and fall tree planting projects within Washington, D.C.

A storm drain mural in Baltimore, MD, by street artist Adam Stab in partnership with Banner Neighborhoods and Blue Water Baltimore.

Reduce Impervious Cover

Communities in the developed tier must find innovative ways to save their small city character. While the majority of streets in Mount Rainier are appropriately scaled, many streets could be enhanced by utilizing green street and complete street techniques, such as curb extensions for pedestrian safety or bike lanes for increased mobility. Commercial corridors in Mount Rainier can create more inviting spaces for the community by providing wider sidewalks and pocket parks while also integrating stormwater management facilities.

Strategies

- Maximize potential landscape areas and minimize impervious surfaces.
- Convert excess sidewalk to street planters and/or street tree boxes to reduce and cover impervious surface with tree canopy.
- Design sites to drain stormwater runoff into landscaped surfaces and minimize underground piped infrastructure.
- Evaluate local planning and design codes to identify barriers and opportunities to limit impervious surfaces.
- Implement lane diets wherever possible to reduce impervious cover, calm traffic, increase pedestrian safety, and create room for stormwater facilities.
- Integrate permeable pavements wherever possible to reduce the stormwater impacts of impervious surfaces.

Increase the Urban Tree Canopy

Until recently, the urban tree canopy was undervalued as a green infrastructure and sustainable stormwater management technique. Previous mapping technologies were only able to measure forest hubs and corridors and were unable to accurately measure urban tree canopy. With advances in mapping technology, urban tree canopy can now be distinguished and measured as an indicator of overall watershed health. Generally, a watershed with 37% tree canopy can be categorized as “fair” in a stream health rating; watersheds with 45% or higher tree canopy can be categorized as “good” (Goetz et al, 2003).

Parking space estimates put the number of surface parking spaces at over 800 Million. That’s roughly 3 spaces for every car in America. *(Joseph, 2012)*

While the benefits from individual tree species vary, recent studies indicate that one tree can reduce stormwater runoff by upwards of 13,000 gallons per year. Increasing tree canopy within Mount Rainier can significantly reduce stormwater runoff, cool ambient temperatures reducing the urban heat island effect, and beautify the streetscape.

Strategies

- Work with the County to develop an urban forest master plan that identifies the best species to plant based on their environmental performance and establishes guidelines for the planting and care of urban trees and forests.
- Increase the urban tree canopy wherever possible and maintain and protect existing tree canopy.
- Use the Prince George’s County Urban Tree Canopy Assessment to help set initial tree planting goals for various land uses.
- Utilize local non-profits, volunteer efforts, and other community outreach tools to incentivize and encourage tree planting on private property.
- Develop a grassroots, community-based tree inventory program to help confirm and track urban tree canopy goals and prioritize planting locations.

The Mixed-Use Town Center Zoning Development Plan promotes pedestrian, bike, bus, and streetcar transportation.

- Provide educational materials on preferred tree species, planting techniques, and proper tree maintenance.

Promote Outreach and Education Initiatives

With more than 70% of Mount Rainier zoned for single- or multi-family housing, it is integral to the success of any of the implementation strategies in this plan that community residents and business owners participate. Local non-profits, community groups, and residents with municipal guidance, support, and education can significantly improve implementation success.

In addition, the City's Sustainability Plan emphasizes the necessity of environmental education through its watershed stewardship/pollution prevention outreach program as part of its efforts to create a more sustainable Mount Rainier. To build off this momentum, a list of several strategies can be integrated into current outreach efforts.

Strategies

- Engage local non-profits for outreach and volunteer program support.
- Engage local artists whenever possible to integrate art into green infrastructure installations.
- Develop web and print materials for homeowners, businesses, and other organizations on how they can implement retrofits on private property.
- Encourage environmental education for students, residents, and business owners.
- Engage stakeholders in a manner that builds enthusiasm and ownership in green infrastructure projects.
- Get information out to the public on programs such as Prince George's new Rain Check Rebates program which allows property owners to receive rebates for installing Rain Check approved stormwater management practices.

Enhance and Promote Multi-Modal Transportation

Multi-modal transportation refers to alternative transportation modes including walking, biking, and public transit. Providing safe and accessible walking and biking facilities can eliminate short distance vehicular travel and create connections to public transit while improving regional mobility. Reducing the use of the automobile is one of the best ways to reduce the amount of pollution to our waterways. Integrating pervious materials into this infrastructure can reduce stormwater outfalls and introduce visible surface change demarcating such areas from the rest of the roadway.

The permeable parking lot, near City Hall, has a storage capacity of over 40,000 gallons per rain event, resulting in zero discharge to municipal drains.

Construction of the permeable alley adjacent to the Perry Street Parking Lot. The original plan called for digging down and removing 12 inches of soil to allow for clean drain stone to be placed underneath the pavers. The presence of unstable soils and four disconnected storm drains required the construction crew to excavate down 36 inches.

Strategies

- Implement the Green Team's bicycle master plan, and investigate additional bike infrastructure opportunities including bike storage and bike service stations.
- Complete sidewalk gaps, making sure to improve width, landscape area, and signage where possible.
- Develop innovative wayfinding signage to encourage and showcase the multiple bus lines available along Rhode Island Avenue and elsewhere in the City.
- Where sidewalks are complete, improve the landscape condition and implement sidewalk strategies highlighted in the City of Mount Rainier Mixed-Use Town Center Zone Development Plan.

Install Pilot Projects

The most effective way to showcase the multiple benefits of green infrastructure is through pilot projects. Efforts such as the upcoming Buchanan Green Street and the recently constructed municipal permeable parking lot and alley are examples of pilot projects that serve to promote and showcase the benefits of green infrastructure in Mount Rainier. A description of potential future projects and initiatives is outlined in the Concept Plan section.

Not only will projects in Mount Rainier protect the environment by reducing urban heat island effects and improving air quality, projects in the ROW or in high visibility areas also improve community aesthetics, bringing in new residents and businesses. Investing in demonstration projects such as

A closer look at the pavers installed in the alleyway. The interlocking pavers are placed over a stone reservoir that temporarily stores surface runoff.

streetscape improvements will help spur new investment from current home and business owners, tying into other community priorities such as beautification and livability.

Strategies

- Review existing pilot projects within the City to determine how close they have come to achieving stormwater neutrality. Where possible, use the sites for additional demonstrations until the stormwater neutral status has been achieved.
- Identify 1-2 stormwater neutral pilot projects where the City teams with a homeowner(s) to demonstrate how a stormwater neutral project can be implemented on single family homes.
- Consider establishing an annual landscape designers challenge where – similar to the Better Block Project – designers are paired-up with homeowners to transform the landscaping of a block through the installation of rain gardens and other green infrastructure techniques.
- Develop a public communication and outreach plan to solicit additional input from neighborhood residents, business owners, and other community members.

Identify Funding Sources

Because of the large amount of residential properties within the City of Mount Rainier, many of the recommendations identified in this plan involve improvements to residential properties. In those cases, the City should work with the County to identify potential funding sources – such as Prince George's County's new Rain Checks Rebates program – that are available to incentivize residents to install green infrastructure practices on-site.

A considerable number of the identified recommendations also focus on improvements within the ROW. However, designing and constructing green and complete streets will most likely require new sources of municipal capital funding and dedicated maintenance funding. Where green street and green infrastructure elements can be implemented with on-going public works projects, costs can be reduced.

Strategies

- Combine regular street improvements with green street and green infrastructure retrofits in order to reduce costs.
- Look for opportunities to incorporate green infrastructure elements such as the addition of trees, lane striping (for bike lanes, etc.), and any necessary utility upgrades when on-going public works capital and maintenance projects are being conducted.
- Develop a communication and planning procedure to involve the multiple agencies that control related capital improvement projects with the City to ensure green infrastructure priorities are included in ongoing and future system plans.
- Work with the State Highway Administration to identify possible projects that could be considered in its stormwater mitigation bank.
- Identify financing tools such as grants, special districts, community development tools, tax-sharing agreements, bonds, and grants to fund longer-term projects, such as the de-channelization of Arundel Branch stream.
- Identify private funding partnerships and organizational structures to ensure future implementation of green infrastructure improvements.


In Spring of 2013, several Mount Rainier storm drains got a face-lift, thanks to an Art Lives Here grant awarded to the Anacostia Watershed Society. This storm drain art project was designed by artists and painted by students from Mount Rainier Elementary School.

Stormwater Design Toolbox

Overview

The City of Mount Rainier has long been a gateway community to Washington, D.C. Situated at the District's northeastern boundary, the area grew as a residential community with a rural appeal, standing in contrast to Washington, D.C.'s largely urban character. Today, Mount Rainier is still more than 70% residential, with approximately 20% of the remaining area within the City's right-of-way. As highlighted in the previous sections, these areas provide some of the greatest opportunities to implement green infrastructure and LID controls to allow the City to become stormwater neutral.

Several green infrastructure and LID controls were previously identified when evaluating options for establishing stormwater neutral sites within the City. This section – the Stormwater Toolbox – showcases specific green stormwater management and green infrastructure techniques available within the development and redevelopment process. Starting from the rooftop and ending with the street, basic information is included about green roofs, street trees, permeable pavements, and other green infrastructure features fit for urban environments. While all of the toolbox items are applicable within Mount Rainier, not all features are applicable in every location.

Bioretention Systems

Bioretention systems are green infrastructure practices that use a combination of vegetation, such as trees, shrubs, and grasses, planted in a specialized soil bed to slow down, collect, and filter stormwater runoff. Runoff is directed into bioretention systems either as overland flow or through a stormwater drainage system.

When configured as a basin, bioretention systems are most commonly referred to as rain gardens. Bioretention basins are designed to collect water and give it time to infiltrate into the ground or evapotranspirate into the air. Alternatively, a bioretention system can be constructed directly in a drainage channel or swale. Bioretention swales differ from basins in that they are designed more as conveyance treatment devices, not storage devices.

Because of their relatively small footprint and flexible design features, bioretention systems can easily fit into an urban landscape or other areas where space is limited. Bioretention basins are just as applicable in residential settings as they are in commercial, industrial, and street settings. Bioretention swales are less likely to be found in residential settings unless used in the design of large, multi-family dwellings. Instead, they are more likely to be found in parking lots or along streets or sidewalks.

Bioretention systems can remove a wide range of pollutants from stormwater runoff, including suspended solids, nutrients, metals, hydrocarbons, and bacteria. They can also be used to slow water down to reduce peak runoff rates (NJDEP, 2009). In areas where infiltration is not desired due to a high water table or the presence of contaminated soils, an underdrain can be installed to move excess water into a conventional storm sewer pipe.

Bioretention basins (i.e., rain gardens) allow rain and snowmelt to seep naturally into the ground while also providing visually appealing landscaping.

In addition to the numerous stormwater management benefits, other benefits of bioretention include a reduced urban heat island effect, reduced downstream erosion and sedimentation, and improved community aesthetics. Many other green infrastructure techniques such as vegetated curb extensions and tree planters are based off of this structural best management practice.

Installation and maintenance costs for bioretention systems vary depending on the site preparation needs and the types and density plants selected. Residential systems generally average $3 to $4 per square foot. Commercial, industrial, and institutional site costs can range between $10 to $40 per square foot, based on the need for control structures, curbing, storm drains, and underdrains. Those landscaping expenses that would be required regardless of the bioretention installation should be subtracted when determining the net cost. Additionally, the use of bioretention systems can decrease the costs required for constructing traditional stormwater conveyance systems at a site and reduce the public burden to maintain large centralized facilities.

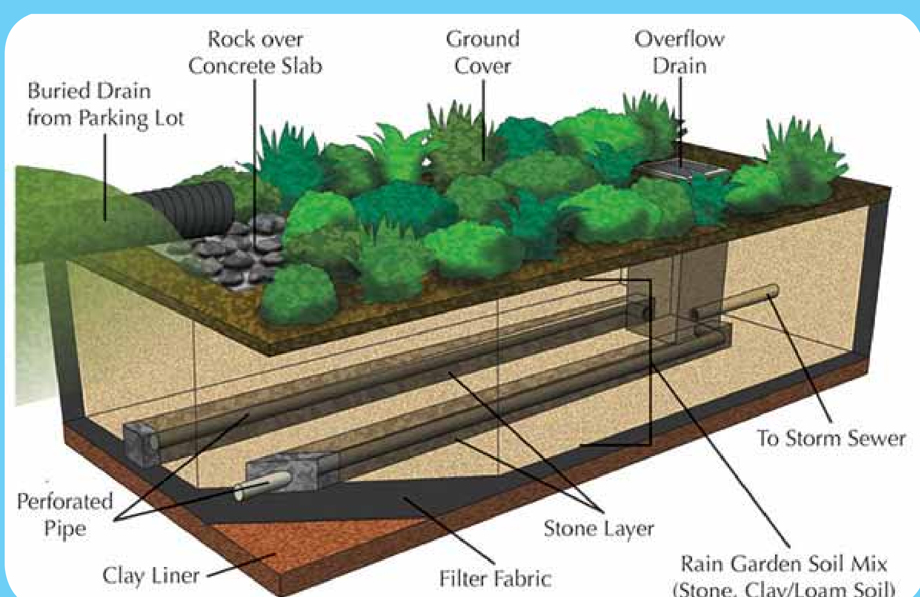


Diagram of a bioretention system connected to a storm drain.

Green Roofs

Green roofs -- also commonly referred to as living roofs or eco roofs -- use soil and plants in place of traditional roof materials. Green roofs provide multiple economic, environmental, and social benefits. In addition to water quality benefits, green roofs reduce the life cycle costs of roofs, provide energy savings and greater fire protection, remove airborne particulate matter, create wildlife habitat, provide space for food production, and can create usable green space in urban environments.

Details from a common extensive green roof installation consist of a vegetative layer that grows in a specially-designed soil which sits on top of a drainage layer.

Green roofs come in two general types: extensive and intensive. Extensive green roofs typically have a growing medium of 3-4 inches, are usually planted with sedum, require less irrigation, and are low maintenance. Intensive green roofs have up to 12 inches of growing medium and can support shrubs and trees. The ability to maintain larger plant material also introduces a need for constant irrigation and a more regular maintenance schedule.

Research conducted on green roof installations in the northeast indicates that they retain 50% or more of annual rainfall (EPA, 2009), and can add 3 hours to the time it takes runoff to leave a roof (GSA, 2011). An intensive 7,000 square-foot green roof on top of Hackensack UMC's John Theurer Cancer Center in Hackensack, NJ, retains up to 90% of summertime precipitation and 40% of wintertime precipitation (EPA, 2012). Recent research has also shown that green roofs have the capability to sequester large amounts of carbon. Replacing traditional roofing materials in an urban area of about one million people, for example, would capture more than 55,000 tons of carbon -- the same effect as removing more than 10,000 mid-sized SUVs or trucks off the road a year (Getter et al., 2009).

Several factors can influence the costs of green roofs. These include whether the project involves a retrofit or is new construction, the type of green roof (extensive versus intensive), accessibility, maintenance requirements, and market maturity. The installation cost for extensive green roofs range from $10.30 to $12.50 more per square foot than a conventional black roof, while intensive green roof costs range from $16.20 to $19.70 more per square foot than a conventional black roof. Annual maintenance costs are generally $0.21 to $0.31 more than a conventional black roof. However, the average life expectancy is more than twice that of a black roof. And, when adding in the monetary benefits derived from stormwater runoff reductions, energy savings, improved real estate values, and community improvements, a recent report by the General Services Administration determined that a green roof of 3-6 inches in depth provides a payback of about 6.4 years for a 5,000 square feet installation, and 6.2 years for a 10,000 square feet installation (GSA, 2011).

The 31st Street Harbor green roof rests atop of the harbor services building in Chicago. The development, which includes a 1,000-slip marina and a park with newly configured bike and walking paths, totally transformed an under-used portion of Lake Michigan's shoreline into a public amenity. The consideration of social and economic components were critical to its development. The area serves as one of the Chicago Park District's largest revenue generators, and has helped to revitalize surrounding neighborhoods.

Green Walls

Green infrastructure technology is continuously evolving as engineers, designers, and landscape architects find new, creative ways to integrate the concepts of 'green' into urban landscapes. Green walls, also know as biowalls, living walls, and vertical gardens, are one such example.

While the idea of having greenery growing up a building or retaining wall is not new, coupling it with ways to ensure improved stormwater uptake, improve air quality, and provide additional community benefits is new. Researchers are currently experimenting with ways to improve their utility and ease of maintenance.

Green walls can be designed to help slow down and absorb stormwater, clean the air, modify micro-climates, and add beauty to a garden or living space. When designed without soil, cisterns placed higher than the top of the growing medium can help provide a constant supply of water.

Just as green roofs can reduce the strains on combined sewer systems by slowly releasing stormwater over time, this delay in runoff is also considered a benefit of green wall technology. It is commonly cited that green walls can absorb 45 to 75% of rainfall; however, there is limited data as of yet on the stormwater retention benefits various green wall technologies provide (Loh, 2008).

Recently published research on the air quality benefits of green walls in urbanized areas, however, is very compelling. In high-density areas, it is not uncommon for the height of buildings on either side of a street to be twice the width of a road or more. When this happens, air flow is restricted, and air pollution can become trapped in the "street canyon." The strategic placement of green walls with street trees and other greenery can reduce air pollution (e.g., nitrogen oxide and particulate matter) by up to 30%, proving to be a more cost-efficient measure than other strategies that are currently employed (Pugh et al., 2012).

In Philadelphia, a temporary green wall was installed by the popular Shake Shack as their recently-opened location in the Rittenhouse Square neighborhood was undergoing construction.

In general, the cost to design and install a green wall can range from $100 to $175 per square foot, depending on the complexity of the system and plant materials chosen. Maintenance requirements and costs also vary by system. These costs must be weighed against the monetary benefits associated with improved air quality, reduced energy consumption (green walls can reduce surface energy use by 23% in the summer), reduced noise pollution, and reduced stormwater runoff (ASLA, 2011).

These systems are equally viable for use in interior settings in combination with a rainwater capture and filtration system, and can serve to add greenery without taking up valuable floor space. In the U.S., where retail and office space average $25.50 per square foot, dedicating 35 square feet of wall space is much cheaper on an annual basis than dedicating the same amount of floor space to indoor plants (Irwin, 2009), while also providing a more stunning backdrop and allowing for the integration of stormwater reuse systems that further their appeal.

Green wall systems differ based on size, height, and types of plants used. Here, three different systems are shown. The left image illustrates a tray system, where soil is bound in burlap and plants are inserted through a hole in the fabric. The center image illustrates a plug system. These systems can also be used in interior settings, combined with a rainwater capture and filtration system, to add greenery and improve interior air quality without taking up valuable floor space. The right image depicts an interior system.

Downspout Disconnects

A downspout is a pipe that carries rainwater off of rooftops. Some downspouts drain into yards or other vegetated surfaces. Other downspouts drain directly onto paved surfaces or are piped into stormwater inlets. Even during very short rains, downspouts that flow onto pavement and/or directly into stormwater inlets contribute to sewer overflows. When the sewer system fills up with rainwater, sewage overflows into the nearest local waterway.

Downspout disconnection is the process of disconnecting the downspout from the pipe or the paved area. Discouraging or eliminating direct connections of impervious areas to stormdrains is a simple yet effective green infrastructure practice that is widely applicable. By directing downspouts into rain barrels, water can be stored and used later for irrigation. When directed to rain gardens or other pervious areas, increased infiltration will result. To ensure effectiveness and to minimize possible problems such as building or street flooding, close attention must be paid to site drainage patterns. This practice is not well-suited to properties when cracks exist in basement walls and/or lawn area is not available or properly graded. In these instances, other toolbox practices, such as rain barrels and cisterns, could be an alternative.

Typically costing less than $15 per downspout, downspout disconnections are very inexpensive and can be implemented on a large-scale relatively easily. In Portland, OR, the city disconnected downspouts on more than 26,000 properties, removing more than 1.2 billion gallons of stormwater from its combined sewer annually (Garrison et al., 2011). In Detroit, MI, modeling extrapolated from a pilot project indicated that a city-wide downspout disconnection program would result in reducing annual combined sewer volumes by 2 billion gallons (Salim et al., 2001).

Urban downspouts can be disconnected into stormwater planters when there is insufficient space to dissipate stormwater over land.

Rain Barrels & Cisterns

Rain barrels are cost efficient, easy to maintain features that have applications in residential, commercial, and industrial buildings. Rain Barrels capture stormwater from the roofs of buildings and store it on site. These systems help reduce runoff volumes and velocity, and protect delicate watersheds and aquatic life. To be most effective, they should be completely dewatered between rain events.

Rain barrels and cisterns hold water that is free of most sediment and dissolved salts, making it perfect for landscape irrigation. These systems help reduce a building's overall potable water usage while capturing rain water for reuse. Covers and screens are placed at the entrance to keep out mosquitoes.

Cisterns are typically used in more commercial applications, can hold as much as 10,000 gallons of rainwater, and can be stored either above or below grade. Cisterns can help reduce pollution runoff by capturing water and storing potentially contaminated water and filtering it before further use. As their use has increased, some residential builders have begun offering them as well.

A rain barrel installed at Community Forklift in nearby Edmonston, MD.

Stormwater Planters

Stormwater planters intercepts and infiltrates stormwater from curb cuts reducing the flow to catch basins.

Stormwater planters, also known as infiltration or flow-through planters, are similar in function to regular bioretention practices except they are adapted to fit into “containers” within urban landscapes. Integrated into tree boxes or urban landscaping planters, stormwater planters collect stormwater from pavement (mostly sidewalk and roads) and filter it through a bioretention system to treat pollutants such as excess nutrients, heavy metals, oil, and grease. Treated stormwater is then either infiltrated into the ground as groundwater (infiltration planters) or discharged into a conventional storm sewer pipe (flow-through planters), where infiltration is not appropriate.

Stormwater planters have a small footprint, are normally rectangular, feature hard edges and concrete sides, and can easily be incorporated into street retrofits or be built to fit between driveways, utilities, trees, and other existing constraints. Such systems can be used in conjunction with permeable pavement and curb extensions to fully develop a green street and reduce overall stormwater outfall. Stormwater planters also help to provide greenery, improve air quality, and reduce the urban heat island effect.

A stormwater planter can be expected to last about 25 years. Depending on the size, materials, and plants used, and whether or not an underdrain is required, installation costs can be highly variable. For a 500 square feet planter, a simple estimate would be $4,000, or $8 per square foot, with annual maintenance costs of $400 (LIDC, 2005). For new development and redevelopment, stormwater planters are often less expensive than more conventional stormwater management facilities (PES, 2006).

Stormwater Curb Extensions

The Indianapolis Cultural Trail incorporates vegetated curb extensions to serve as a buffer between the auto traffic and the foot and bike path.

Curb extensions are a traffic calming device that narrow roadway widths. When modified to incorporate stormwater treatment into their design, they are capable of filtering and infiltrating all of the stormwater from the street on which they are located. Stormwater flowing down the street is directed towards the curb extension, where it is filtered and infiltrated in a vegetated area that resembles that of a biortetention cell. Vegetated curb extensions are ideal retrofits for low to medium density residential or commercial areas where some loss of on-street parking is tolerable.

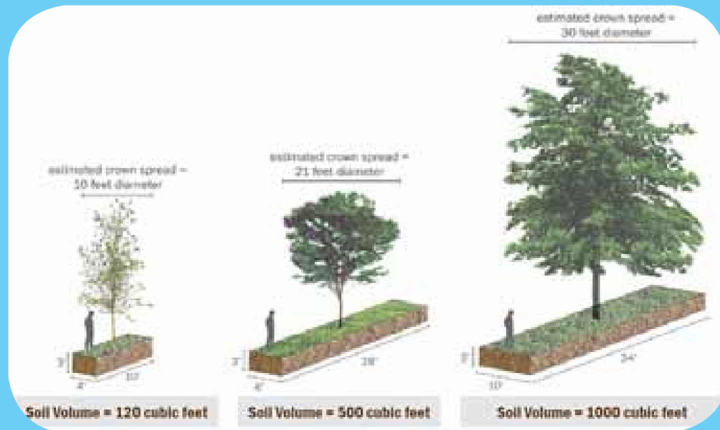
In addition to providing stormwater treatment and traffic calming, vegetated curb extensions also help to reduce the urban heat island effect, improve air quality, and improve community aesthetics. They can also be combined with mid-block crossings to further increase pedestrian safety when crossing streets.

In areas where on-street parking is at a premium, smaller vegetated curb extensions that are spaced more frequently can minimize parking loss to any individual property.

Curb extensions are appropriate where on-street parking lanes already exist, unless used in conjunction with a lane diet. The cost of a curb extension, which can range from $2,000 to $20,000, depends largely on the design and existing site condition, with drainage usually being the most significant determinant (US DOT, no date).

Street Trees

Street trees are one of the most economical green infrastructure practices available. In a study of urban street trees in Minneapolis, MN, it was estimated that the average street tree intercepts 1,685 gallons of stormwater (McPherson et al., 2005). Urban trees intercept stormwater in their canopies, improve air quality, reduce the urban heat island effect, and improve neighborhood aesthetic. In addition, a study of street trees in Philadelphia found that they can raise a house's value up to 9% and increase the time shoppers spend in stores by 12% (Wachter and Gillen, 2006).



Bioretention basins (i.e., rain gardens) allow rain and snowmelt to seep naturally into the ground while also providing visually appealing landscaping.

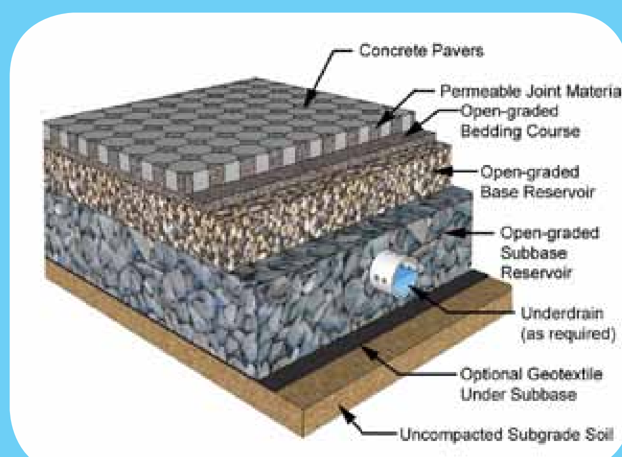
More important than the number of street trees is the size and composition of the soil area which allows for proper tree growth. In urban areas, the size potential and stormwater benefit of trees are often limited by densely compacted soils and confined growing areas.

For urban trees to reach their full maturity, trees need 1 to 2 cubic feet of soil volume for every square foot of crown area spread. However, a typical street tree only has about 120 cubic feet of available soil, restricting its tree canopy spread to 10 ft. before it begins to decline. By expanding tree spaces to allow for 500 cubic feet of soil, the same tree canopy can grow more than 20 feet. Even larger soil volumes will yield larger trees (Casey Trees, 2008).

While costs vary, an average street tree in Philadelphia costs approximately $360 to plant. However, cities such as Los Angeles, CA, have determined that one tree can produce a $2.80 return on investment in energy savings, pollution reduction, stormwater management, and increased property values (NGC, 2007).

Permeable Pavements

Permeable pavement comes in many varieties, but the most common include open grid and interlocking pavers, porous concrete, and asphalt. Permeable pavement provides the same load-bearing support that conventional pavement does and is good for walking, biking, and parking areas, and for driving on low- to moderately-trafficked streets. Unlike traditional pavements, its design allows stormwater to infiltrate through the pavement to an underground storage basin or filter into the ground and recharge the water table.



This diagram shows the system components of permeable interlocking concrete pavement. The base layer is similar to those for permeable pavers, porous asphalt, and pervious concrete.

Permeable pavement is ideal for planting trees in a paved environment while still permitting full use of the pavement. Their porous nature allows adjacent trees to receive ample air and water. High albedo permeable pavements reflect sunlight away from the pavement helping to reduce the urban heat-island effect, reduce cooling costs, improve the health of urban vegetation, and can improve air quality. From a health perspective, improved air quality can reduce the symptoms of respiratory disease.

Costs may vary based on the site conditions, design requirements, and type of paving that is selected. The cost per installed square foot can vary from $0.50 to $10.00. When comparing systems, the full cost of the stormwater management paving system should be considered. For example, when impervious paving costs for drains, reinforced concrete pipes, catch basins, outfalls, and stormwater connects are included, an asphalt or conventional concrete stormwater management paving system can cost two times more (LIDC, 2007).

Pocket Parks

Pocket parks are small public spaces created in the existing public right-of-way located in wide sidewalks or curb extensions and often contain landscaping as well as seating areas, play areas, community garden areas, or other features to encourage use.

Pocket parks take advantage of small and/or irregular pieces of land that would otherwise not be suitable for development, and are an excellent way to provide public open space in high-density urban areas. When installed as part of a green street, they can also be designed to provide on-site stormwater management as well as bird or other urban wildlife habitat. Additionally, pocket parks can be designed to incorporate educational components.

Banner Street Sidewalk Park in San Francisco, CA.

Pavement Reductions

Removing pavement can be a low-cost alternative to other stormwater toolbox items. Not only does removing pavement decrease the total amount of impervious surfaces within Mount Rainier, but such areas can then begin to infiltrate stormwater on-site. Underutilized parking lots and vacant lots are two examples of where pavement reduction could be implemented. On residential lots, excess concrete or pavement that is not used for parking or for recreation could be removed and replaced with a permeable system or a LID landscape control.

In the above parking lot in Easton, MD, the asphalt once extended all the way to the sidewalk. In 2012, a portion of the asphalt was removed and replaced with vegetation that helps capture rainwater on-site.

Medians / Refuge Islands

Medians and refuge islands are raised spaces in the middle of the roadway that allow cyclists and pedestrians to pause and wait for a safe opportunity to cross one direction of traffic at a time. In addition, medians and refuge islands provide a means for bioretention areas to be integrated into the street design in a manner that beautifies the street. Pedestrian friendliness through better walkability/connectivity and an improved look of the streetscape were listed as the top two community concerns through the community survey process.

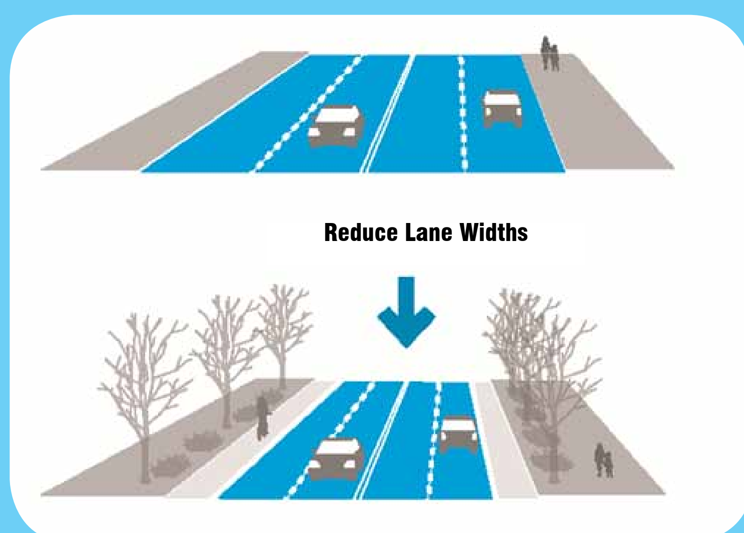
With the exceptoin of Rhode Island Avenue and Queens Chapel Road, the use of medians and refuge islands are limited in the City of Mount Rainier due to the relatively narrow right-of-way of most of the City's streets. The existing refuge islands and medians on Rhode Island Avenue and Queens Chapel Road, however, could be redesigned to increase the amount of area utilized for on-site stormwater management.

This refuge island in Brainbridge, MA is offset to encourage pedestrians to look both ways before continuing across.

Lane Diets

Whereas in a road diet the number of travel lanes is reduced in order to achieve systemic improvements, a lane diet merely reduces the width of each lane to reduce vehicle speeds and yield space for other use, such as bike lanes and wider sidewalks. It can also be used to help local businesses attract shoppers.

In a green street design, the stormwater management capabilities of such areas are further enhanced by incorporating permeable pavement, stormwater planters, pocket parks, or other features intended to increase on-site stormwater management. In the City of Mount Rainier, many of the roads in the residential core are narrow but major roads, such as 34th street, and Chillum Road could connect downtown Mount Rainier with the West Hyattsville Metro Station.



Where existing streets are wider than necessary, lane diets help reduce impervious surface and provide space for medians, bike lanes, and parking.

For example, a four lane road in Fairfax, VA, averaged 15 crashes in a 4 year period prior to a lane diet that added two bike lanes and removed two traffic lanes. Since the lane diet, Lawyers Road has averaged 3 crashes a year over a two year period – an 80% drop. In addition to the drop in crashes, speeders over 50 mph have dropped from 13% the year before construction to 1% after construction. Residents who previously had mixed opinions a year earlier now indicate an approval rate of over 74% for the lane diet.

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Location	Source
vi	City of Mount Rainier
1	City of Mount Rainier
2	Maryland-National Capital Park and Planning Commission
4	LID Center, Inc., with background aerial from Bing
5	United States Army Corps of Engineers
6	Krista Schlyer
8	Unknown
10	City of Mount Rainier
12	Krista Schlyer
13 - 15	GIS data from the Maryland-National Capital Park and Planning Commission and Prince George's County; background aerial from Bing
16	Unknown
19	Krista Schlyer
22	Tom Cardarella, www.PelicanArts.com
25	Unknown
32	LID Center, with GIS data from the Maryland-National Capital Park and Planning Commission
33-35	LID Center
36	Krista Schlyer
38	LID Center
39	LID Center, with GIS data from the Maryland-National Capital Park and Planning Commission
40	Brent C. Bolin
41	Unknown
42	Krista Schlyer
43	LID Center

Location	Source
44, left	Casey Trees
44, right	Blue Water Baltimore
45, left	Maryland-National Capital Park and Planning Commission
45, right	Ernest Maier
46	Ernest Maier
48	Anacostia Watershed Society
50, top	LID Center
50, bottom	Center for Watershed Studies, Bilogical Systems Engineering, VT
51, top	Progressive Times WordPress Blog
51, bottom	AECOM
52, top	Mickey Pascarella
52, bottom left	Manuguf
52, bottom middle	Bonnie Alter
52, bottom right	Geraldine R. Dodge Foundation
53, top	United States Environmental Protection Agency
53, bottom	Community Forklift
54, top	LID Center
54, bottom	Lucy Wang
55, top	Casey Trees
55, bottom	Interlocking Concrete Pavement Institute
56, top	San Francisco Planning Department
56, bottom	LID Center
57, top	Carl Sundstrom
57, bottom	Boston Transportation Department
A2-A18	United States Army Corps of Engineers

Appendix A

18 projects within the Mount Rainier city boundary are identified through the Anacostia River Restoration Plan. The table below includes project costs and potential pollutant reductions.

Project ID	Ownership	Description	Project Description	Cost	N/lbs yr	P/lbs yr	TSS/ tons	Bacteria
NW-L-01-S-118	*Private*	*LID Bioretention, LID Green Roof*	*Green Roof = 1, Bioretention = 0.8*	*$915,000.00*	*35.75*	*3.02*	*0.62*	*573.91*
NW-L-01-S-117	*Private*	*Underground Pipe Storage, Sand Filter, LID Downspout Disconnection*	*Filter = 0.3, DD = 0.2, Pipe Storage*	*$32,000.00*	*5.20*	*0.78*	*0.17*	*88.48*
NW-L-01-S-116	*Private*	*Underground Pipe Storage, Sand Filter*	*Filter = 0.6, Pipe Storage*	*$32,000.00*	*6.69*	*1.22*	*0.20*	*176.96*
NW-L-01-S-40	*Private*	*LID Bioretention*	*Bioretention = 2.2*	*$220,000.00*	*52.32*	*4.11*	*0.78*	*1578.25*
NW-L-01-S-33	*Private*	*LID Bioretention*	*Bioretention = 1.4*	*$140,000.00*	*33.29*	*2.62*	*0.50*	*1004.34*
NW-L-01-S-34	*Private*	*LID Bioretention, LID Bioswale*	*Bioretention = 7.93, Bioswale = 3.97*	*$1,189,000.00*	*269.71*	*21.84*	*4.19*	*5688.87*
NW-L-01-S-37	*Private*	*LID Bioretention*	*Bioretention = 12.4*	*$1,240,000.00*	*294.88*	*23.18*	*4.40*	*8895.59*
NW-L-01-S-38	*Public*	*Permeable Pavement*	*PP = 0.5*	*$51,000.00*	*10.96*	*1.00*	*0.16*	*0.00*
NW-L-01-S-63	*Public*	*Sand Filter, LID Downspout Disconnection, LID Green Roof, LID Bioretention*	*Green Roof =1, Filter = 1.38, Bioretention = 0.46, DD = 0.46*	*$2,155,000.00*	*47.32*	*5.59*	*1.12*	*736.99*
NW-L-01-S-285	*Private*	*LID Bioswale, Existing Stormwater Management Facility Retrofit*	*Bioswale = 1.1, Wetland = 1.1*	*$224,000.00*	*32.70*	*3.81*	*0.72*	*683.91*
NW-L-02-SR-1	*Public*	*Soft Bottom Channel Creation, In-stream Habitat Enhancement*	*SR = 4130*	*$4,130,000.00*	*0.00*	*0.00*	*0.00*	*0.00*
NW-L-01-S-284	*Private*	*LID Downspout Disconnection, LID Rain Gardens, LID Bioretention*	*Rain Garden = 7.67, Bioretention = 7.67, DD = 7.66*	*$2,525,000.00*	*435.95*	*35.18*	*8.15*	*11004.71*
NW-L-01-S-274	*Public*	*LID Bioretention*	*Bioretention = 1.8*	*$180,000.00*	*42.81*	*3.36*	*0.64*	*1291.30*
NW-L-01-S-287	*Private*	*LID Bioretention*	*Bioretention = 3.3*	*$332,000.00*	*78.48*	*6.17*	*1.17*	*2367.38*
NW-L-01-S-283	*Private*	*LID Downspout Disconnection, LID Bioretention, LID Storm Filters*	*Filter = 0.5, DD = 0.5, Bioretention = 0.5*	*$135,000.00*	*22.11*	*2.38*	*0.52*	*506.16*
NW-L-01-S-275	*Private*	*LID Storm Filter, LID Curbside Planter*	*Filter = 0.42, Bioretention = 0.28*	*$63,000.00*	*10.40*	*1.35*	*0.24*	*123.87*
NW-L-01-S-271	*Private*	*LID Bioretention, LID Storm Filter*	*Filter = 0.36, Bioretention = 0.24*	*$54,000.00*	*9.72*	*1.18*	*0.21*	*278.35*
NW-L-05-R-5	*Public*	*Riparian Reforestation*	*Riparian Buffer = 0.2*	*$2,000.00*	*0.00*	*0.00*	*0.00*	*0.00*

Figure 40a – Candidate Stream Restoration Project		
Site Location:	Channelized stream reach between Arundel Road and 37th Street, Hyattsville, MD	
Project No.:	NW-L-02-SR-1	
ADC Map Book Location:	12 A 5	Map ID: 688
Approximate Length (feet):	4,130	
Description of Existing Conditions:	Concrete channelized stream located in a residential/industrial area. There is little to no riparian buffer present. Water depth in the channel is less than one inch.	
Project Description:	**Soft Bottom Channel Creation, In-stream Habitat Enhancement** - Remove concrete streambed and install in-stream structures for habitat enhancement.	

Figure 38ag – Candidate Stormwater Retrofit Project		
Site Location:	The corner of Varnum Street and Eastern Avenue, Brentwood, MD	
Project No.:	NW-L-01-S-33	
ADC Map Book Location:	11 J 6	Map ID: 619
Approximate Associated Drainage Area (acres):	1.6	
Approximate Imperviousness:	85%	1.4 acres
Description of Existing Conditions:	This site consists of a gas station and a curbed parking lot with green islands in the eastern and southern portions of the site. Downspouts are connected to the stormwater system. Stormwater runoff drains to the street.	
Project Description:	**LID Bioretention** – Construct a bioretention system in the grassy area at the southern corner of the site.	

Figure 38ah – Candidate Stormwater Retrofit Project		
Site Location:	Kaywood Garden Apartments, corner of Russell Avenue and Kaywood Drive, Brentwood, MD	
Project No.:	NW-L-01-S-34	
ADC Map Book Location:	11 J 5	Map ID: 621
Approximate Associated Drainage Area (acres):	19.8	
Approximate Imperviousness:	60%	11.9 acres
Description of Existing Conditions:	The site consists of an apartment complex with multiple green strips and grassy areas. The slope varies from steep to flat. Parking is on the street with curb and gutters present. Stormwater runoff drains to curb inlet drains. Downspouts are disconnected from the stormwater system.	
Project Description:	**LID Bioretention, LID Bioswale** - Construct bioretention systems in grassy areas adjacent to curb inlet drains. Convert grass swales to bioswales.	

Figure 38ak – Candidate Stormwater Retrofit Project		
Site Location:	Queens Manor Garden Apartment, corner of Queens Chapel Road and 25th Street, Mt. Rainier, MD	
Project No.:	NW-L-01-S-37	
ADC Map Book Location:	11 J 5	Map ID: 626
Approximate Associated Drainage Area (acres):	20.6	
Approximate Imperviousness:	60%	12.4 acres
Description of Existing Conditions:	The site consists of an apartment complex with green space around the buildings and parking areas. Stormwater runoff drains to curb inlet drains. Most downspouts are disconnected from the stormwater system.	
Project Description:	**LID Bioretention** - Construct bioretention systems at the green areas. Create curb cuts to direct flow into bioretention systems.	

Figure 38al – Candidate Stormwater Retrofit Project		
Site Location:	Corner of Arundel Road and 30th Street, Mt. Rainier, MD	
Project No.:	NW-L-01-S-38	
ADC Map Book Location:	11 K 5	Map ID: 627
Approximate Associated Drainage Area (acres):	2.0	
Approximate Imperviousness:	25%	0.5 acre
Description of Existing Conditions:	The site consists of a community park with a basketball court and small parking lot. Stormwater runoff drains south to the concrete-lined channel.	
Project Description:	**Permeable Pavement** – Install permeable pavement on the basketball court and parking lot.	

Figure 38an – Candidate Stormwater Retrofit Project		
Site Location:	2311 Varnum Street, Mt. Rainier, MD	
Project No.:	NW-L-01-S-40	
ADC Map Book Location:	11 J 6	Map ID: 629
Approximate Associated Drainage Area (acres):	3.2	
Approximate Imperviousness:	70%	2.2 acres
Description of Existing Conditions:	The site consists of a strip mall with parking lot to the south and the northeast. Downspouts are disconnected from the stormwater system and drain to theparking lot and eventually to curb inlet drains on Varnum Street.	
Project Description:	**LID Bioretention, LID Storm Filter -** Construct a bioretention systtem in the grassy area to the north of the site and in the grassy area adjacent to Eastern Avenue.	

Figure 38aak – Candidate Stormwater Retrofit Project		
Site Location:	Thomas Stone Elementary School, 4500 34th Street, Mt. Rainier, MD	
Project No.:	NW-L-01-S-63	
ADC Map Book Location:	12 A 5	Map ID: 684
Approximate Associated Drainage Area (acres):	5.1	
Approximate Imperviousness:	65%	3.3 acres
Description of Existing Conditions:	The site consists of a large elementary school, parking lot, and a field to the north. Downspouts are connected to the stormwater system. Stormwater runoff drains to drop inlet drains. A drop inlet drain in the gravel area by the playing field is clogged with sediment.	
Project Description:	**Sand Filter, LID Downspout Disconnection, LID Green Roof, LID Bioretention** – Disconnect the downspouts from the stormwater system. Install a green roof at next maintenance cycle. Relocate the gravel parking area and construct a bioretention system at the northeastern portion of the site adjacent to 34th Street.	

Figure 38aaaal – Candidate Stormwater Retrofit Project		
Site Location:	St Johns Episcopal/Anglican Church, 4112 34th Street, Mount Rainier, MD	
Project No.:	NW-L-01-S-116	
ADC Map Book Location:	12 A 6	Map ID: 784
Approximate Associated Drainage Area (acres):	0.6	
Approximate Imperviousness:	95%	0.6 acre
Description of Existing Conditions:	The site consists of a church building surrounded by paved parking lots. Stormwater runoff drains east towards 34th Street. Downspouts are internal.	
Project Description:	**Underground Pipe Storage, Sand Filter** – Install underground pipe storage with a sand filter feature.	

Figure 38aaaam – Candidate Stormwater Retrofit Project		
Site Location:	3102 Shepherd Street, Mount Rainier, MD	
Project No.:	NW-L-01-S-117	
ADC Map Book Location:	11 K 6	Map ID: 785
Approximate Associated Drainage Area (acres):	0.6	
Approximate Imperviousness:	90%	0.5 acre
Description of Existing Conditions:	The site consists of a church building surrounded by paved parking lots. Stormwater runoff drains north towards Shepherd Street. Downspouts are connected to the stormwater system.	
Project Description:	**Underground Pipe Storage, Sand Filter, LID Downspout Disconnection** - Install underground pipe storage with a sand filter feature. Disconnect downspouts from the stormwater system and redirect to the underground pipe storage.	

Figure 38aaaan – Candidate Stormwater Retrofit Project		
Site Location:	4065 32nd Street, Mount Rainier, MD	
Project No.:	NW-L-01-S-118	
ADC Map Book Location:	11 K 7	Map ID: 786
Approximate Associated Drainage Area (acres):	1.8	
Approximate Imperviousness:	98%	1.8 acres
Description of Existing Conditions:	This site consists of an elementary school surrounded by paved parking lots. Stormwater runoff drains west towards 32nd Street. Downspouts are internal.	
Project Description:	**LID Bioretention, LID Green Roof** – Install a green roof. Construct a bioretention system in the faculty parking lot and at the northeastern portion of the site.	

Figure 38aaaaaaaaaal – Candidate Stormwater Retrofit Project		
Site Location:	3310 Chillum Road, Hyattsville, MD	
Project No.:	NW-L-01-S-271	
ADC Map Book Location:	11 K 4	Map ID: 549
Approximate Associated Drainage Area (acres):	0.6	
Approximate Imperviousness:	98%	0.6 acre
Description of Existing Conditions:	The site consists of a commercial property and parking lot. Stormwater runoff drains from the southern parking lot drains to Chillum Road. The northern area behind the store drains northwest and is ponding with vegetation present.	
Project Description:	**LID Bioretention, LID Storm Filter** – Remove the asphalt and construct a bioretention system in the northern parking lot. Install a storm filter in the drop inlet drain at the front of the property.	

Figure 38aaaaaaaaaaao – Candidate Stormwater Retrofit Project		
Site Location:	3301 Buchanan Street, Mt. Rainier, MD	
Project No.:	NW-L-01-S-274	
ADC Map Book Location:	12 A 5	Map ID: 552
Approximate Associated Drainage Area (acres):	5.0	
Approximate Imperviousness:	35%	1.8 acres
Description of Existing Conditions:	The site consists of a park with a community pool and large field with mature woody vegetation. The south side of park is separated from channelized creek by a vegetated berm. Stormwater runoff from the parking lot drains to a channel in the northeast corner of the site and into an inlet drain. The parking lot has broken asphalt curbs and is not well graded.	
Project Description:	**LID Bioretention** – Construct bioretention systems in the grassy areas adjacent to the parking lot in the northeastern portion of the property.	

Figure 38aaaaaaaaaap – Candidate Stormwater Retrofit Project		
Site Location:	3201 Queens Chapel Road, Hyattsville, MD	
Project No.:	NW-L-01-S-275	
ADC Map Book Location:	11 K 4	Map ID: 553
Approximate Associated Drainage Area (acres):	0.7	
Approximate Imperviousness:	95%	0.7 acre
Description of Existing Conditions:	The site consists of a commercial property and gas station. Stormwater runoff drains to Queens Chapel Road and Chillum Road. There is no evidence of stormwater management controls. There is a curb inlet on Chillum Road.	
Project Description:	**LID Storm Filter, LID Curbside Planter** - Install storm filters or equivalent in the inlet drain on Chillum Road. Add vegetated area at wide part of sidewalk at Caribbean Market, and the curbside planter below the market sign.	

Figure 38aaaaaaaaaax – Candidate Stormwater Retrofit Project		
Site Location:	3171 Queens Chapel Road, Hyattsville, MD	
Project No.:	NW-L-01-S-283	
ADC Map Book Location:	11 K 4	Map ID: 566
Approximate Associated Drainage Area (acres):	1.5	
Approximate Imperviousness:	98%	1.5 acres
Description of Existing Conditions:	The site consists of a strip mall and parking area. Stormwater runoff drains north to Chillum Road. There is no apparent drainage in the parking lot, but curb inlet drains on Chillum Road. The sidewalk widens close to Chillum Road. The south end drains to the southeast to Queens Chapel Road.. Drop inlet drains are on the east side of the parking lot. Downspouts are connected to the stormwater system.	
Project Description:	**LID Downspout Disconnection, LID Bioretention, LID Storm Filters –** Install storm filters at drop inlet drains. Disconnect downspouts form the stormwater system. Construct a bioretention system in the sidewalk at Chillum Road.	

Figure 38aaaaaaaaaay – Candidate Stormwater Retrofit Project		
Site Location:	3318 Buchanan Street, Hyattsville, MD	
Project No.:	NW-L-01-S-284	
ADC Map Book Location:	11 K 5	Map ID: 567
Approximate Associated Drainage Area (acres):	32.9	
Approximate Imperviousness:	70%	23.0 acres
Description of Existing Conditions:	The site consists of a community of garden apartments with internal green spaces and some mature vegetation. Stormwater runoff from the parking lots drains mainly toward the streets and to drop inlet drains.	
Project Description:	**LID Storm Filters, LID Rain Gardens, LID Bioretention –** Install storm filters in drop inlet drains. Install a rain garden at downspout locations. Construct bioretention systems in the grassy areas adjacent to the parking areas.	

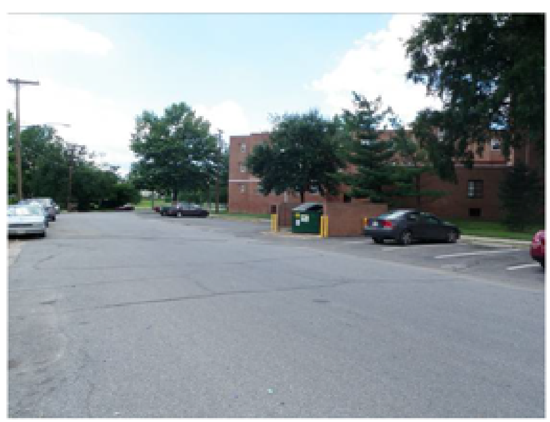

Figure 38aaaaaaaaaaz – Candidate Stormwater Retrofit Project		
Site Location:	Mt. Rainier Nature and Recreation Center, 4701 31st Place, Mt. Rainier, MD	
Project No.:	NW-L-01-S-285	
ADC Map Book Location:	11 K 5	Map ID: 568
Approximate Associated Drainage Area (acres):	6.2	
Approximate Imperviousness:	35%	2.2 acres
Description of Existing Conditions:	The site consists of a community center with a park building, fields, and small parking area. There are existing swales draining portions of the site from tennis courts directed under driveway to an extended detention pond. Evidence of channelized flow from driveway at the north end of the culvert. Pond is overgrown with invasive vegetation including vines. There was an outfall draining into a small, deep hole with standing water.	
Project Description:	**LID Bioswale, Existing Stormwater Management Facility Retrofit -** Replace swale around tennis courts with bioswale. Address erosion at driveway culvert. Retrofit existing stormwater management facility to stormwater wetland. Improve vegetation for better function.	

Figure 38aaaaaaaaaaab – Candidate Stormwater Retrofit Project		
Site Location:	5529 30th Street, Hyattsville, MD	
Project No.:	NW-L-01-S-287	
ADC Map Book Location:	11 K 5	Map ID: 571
Approximate Associated Drainage Area (acres):	3.9	
Approximate Imperviousness:	85%	3.3 acres
Description of Existing Conditions:	The site consists of an apartment complex with curb parking lot to the west. Most downspouts are disconnected from the stormwater system. Stormwater runoff from the east parking lot drains to a curb inlet; the west parking lot drains to Buchanan Street.	
Project Description:	**LID Bioretention -** Construct a bioretention system at the grassy area adjacent to the parking lots.