EPA United States Environmental Protection Agency

2012 GREEN INFRASTRUCTURE COMMUNITY PARTNERS
3 Rivers Wet Weather
Pittsburgh, Pennsylvania

Conceptual Green Infrastructure Design in the Swisshelm Park Neighborhood, City of Pittsburgh

December 2015
EPA EP-C-11-009

About the Green Infrastructure Technical Assistance Program

Stormwater runoff is a major cause of water pollution in urban areas. When rain falls in undeveloped areas, soil and plants absorb and filter the water. When rain falls on our roofs, streets, and parking lots, however, the water cannot soak into the ground. In most urban areas, stormwater is drained through engineered collection systems (storm sewers) and discharged into nearby water bodies. The stormwater carries trash, bacteria, heavy metals, and other pollutants from the urban landscape, polluting the receiving waters. Higher flows also can cause erosion and flooding in urban streams, damaging habitat, property, and infrastructure.

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, *green infrastructure* refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems that mimic nature by soaking up and storing water. Green infrastructure can be a cost-effective approach for improving water quality and helping communities stretch their infrastructure investments further by providing multiple environmental, economic, and community benefits. This multi-benefit approach creates sustainable and resilient water infrastructure that supports and revitalizes urban communities.

The U.S. Environmental Protection Agency (EPA) encourages communities to use green infrastructure to help manage stormwater runoff, reduce sewer overflows, and improve water quality. EPA recognizes the value of working collaboratively with communities to support broader adoption of green infrastructure approaches. Technical assistance is a key component to accelerating the implementation of green infrastructure across the nation and aligns with EPA's commitment to provide community focused outreach and support in the President's *Priority Agenda Enhancing the Climate Resilience of America's Natural Resources*. Creating more resilient systems will become increasingly important in the face of climate change. As more intense weather events or dwindling water supplies stress the performance of the nation's water infrastructure, green infrastructure offers an approach to increase resiliency and adaptability.

For more information about Green Infrastructure, visit http://www.epa.gov/greeninfrastructure.

Acknowledgements

Principal EPA Team

Kenneth Hendrickson, USEPA Region 3
Dominique Lueckenhoff, USEPA Region 3
Christopher Kloss, USEPA
Tamara Mittman, USEPA

Community Team

Beth Dutton, 3 Rivers Wet Weather
John W. Schombert, 3 Rivers Wet Weather

Consultant Team

Dan Christian, Tetra Tech
Valerie Novaes, Tetra Tech
Anne Thomas, Tetra Tech

This report was developed under EPA Contract No. EP-C-11-009 as part of the 2012 EPA Green Infrastructure Community Partner Program.

Cover photo by John Altdorfer.

Contents

Tables

Figures

Executive Summary

The City of Pittsburgh, like many East Coast metropolitan areas, is served by a combined sewer system constructed in the 1800s. This type of system collects stormwater along with wastewater and carries it to a publically owned water treatment works. In 2008, the city entered into a consent decree to address combined sewer overflows (CSOs); part of this agreement required the development of a Long Term Control Plan (LTCP). The LTCP includes a variety of measures, including the use of green infrastructure practices to reduce stormwater runoff, promote infiltration, and provide other benefits.

The organization 3 Rivers Wet Weather (3RWW) was created to help address these issues. Recognizing the opportunity to achieve multiple environmental and livability goals by addressing green infrastructure early in the Wet Weather Plan planning process, 3RWW sought technical assistance from EPA. Using tools to guide site selection, 3RWW identified three sites in the Pittsburgh community for further analysis, including a model conceptual design for green infrastructure practices at each site.

One of these project sites is a historic residential street in Pittsburgh's Swisshelm Park neighborhood; Windermere Drive. The site is several blocks from the Monongahela River and just across the highway from Frick Park. Based on the project and design goals, an EPA team developed a conceptual stormwater management design that would complement and enhance the Wet Weather Plan to reduce CSOs in the Pittsburgh area.

The conceptual design was intended to achieve the project goals of reducing stormwater volume to the combined sewer system while improving drainage and water quality with a combination of bioretention and permeable pavement. The design also achieves aesthetic appeal by adding natural vegetative features. The conceptual design includes:

- Permeable pavement and traffic circle bioretention on the 1300 block of Windermere Drive.
- Curb-extension bioretention in three locations along the 1200 block of Windermere Drive.
- Permeable parking strips on the 1100 block of Windermere Drive.

The other two sites (Frick Museum in Point Breeze and Sussex Avenue in Brookline) are addressed in separate reports.

I. Introduction

The Greater Pittsburgh Area is located on the Allegheny Plateau, where the confluence of the Allegheny River from the northeast and the Monongahela River from the southeast form the Ohio River. The rivers and mountains form the backdrop for the area's economy and livelihood. In addition to being used for swimming, boating, and fishing, the three rivers provide drinking water for the community.

The City of Pittsburgh and surrounding municipalities were built with a combined sewer system serving its older urban core areas. Combined sewers convey sewage and stormwater flows in a single pipe sewer system, allowing combined sewer overflows (CSOs) to Pittsburgh waterways during wet weather. Addressing the sewage overflow problems is a priority for the region, including the Allegheny County Sanitary Authority (ALCOSAN), which provides wastewater treatment services to 83 municipalities in the county.

In January 2008, ALCOSAN entered into a consent decree with the United States Environmental Protection Agency (EPA), Pennsylvania Department of Environmental Protection (DEP), and the Allegheny County Health Department (ACHD). The consent decree is a legal, binding document that requires ALCOSAN to meet a series of requirements for planning, design and construction, operation and permitting with the purpose of improving water quality in receiving waters and protecting designated waterway uses that include drinking water, recreation, aquatic life, and others. The consent decree requires that ALCOSAN reduce CSO discharges into the Ohio, Allegheny, and Monongahela Rivers, and their tributary streams of Chartiers Creek, Saw Mill Run, and Turtle Creek.

This commitment to reduce CSOs and improve water quality and recreation has led the municipalities to consider the use of green infrastructure for stormwater management and CSO reduction.

The 3 Rivers Wet Weather (3RWW) nonprofit was created in 1998 to help Allegheny County municipalities address the region's wet weather overflow problem. As part of their mission, 3RWW created the RainWays® tool to aid residents and engineers in determining the effects of proposed green infrastructure projects on CSO discharges. This tool is available at http://www.3riverswetweather.org/green-infrastructure.

Using RainWays® and EPA's System for Urban Stormwater Treatment and Analysis IntegratioN (SUSTAIN) best management practice siting tool, 3RWW conducted a study assessing the feasibility of using green infrastructure within the City of Pittsburgh, Borough of West View, and Borough of Millvale. These areas are typical of the greater Pittsburgh area with moderate slopes and a constrained urban setting. Three sewersheds in the city (Nine Mile Run, McNeilly Run, and Girty's Run) were evaluated for potential green infrastructure projects on municipal, commercial and residential properties. 3RWW then developed a planning-level methodology to identify potential locations for green infrastructure projects within SUSTAIN, then used the RainWays® tool to analyze flow reduction and costs for implementation. From this study, 12 candidate sites were chosen for further analysis.

After investigating the 12 candidate sites in March of 2013, three of the sites (two in Nine Mile Run and one in McNeilly Run) were selected as green infrastructure conceptual design projects as part of the 2012 EPA Green Infrastructure Community Partners Program. The goal was to determine model sites with the highest likelihood of success in managing stormwater and contributing toward the reduction of CSOs within the ALCOSAN system. The selection process weighed the following long-term as well as near-term considerations:

Long-Term Considerations

- Probability of neighborhood acceptance
- Maintainability
- Visibility
- Contribution toward CSO reductions
- Potential for excessive/debilitating pollutant loads from tributary area (e.g. hot spots and unpaved driveways)
- Frequent flooding

Near-Term Considerations

- Constructability and functionality
- Relative cost compared to other green infrastructure practices
- Existing pavement conditions (pavement needing resurfacing gets priority)

One of the selected project sites was Windermere Drive and the surrounding area within the Nine Mile Run Sewershed (City of Pittsburgh, Swisshelm Park Neighborhood). Refer to Figure 1-1 for the project location.

This project will enhance the space in the Swisshelm Park Neighborhood by providing stormwater treatment facilities, a "green" amenity in a public space, and an educational opportunity for local residents. The project will serve as a model for other existing urban neighborhoods in the greater Pittsburgh area and will demonstrate a range of appropriate green infrastructure tools that can be implemented elsewhere within the region.

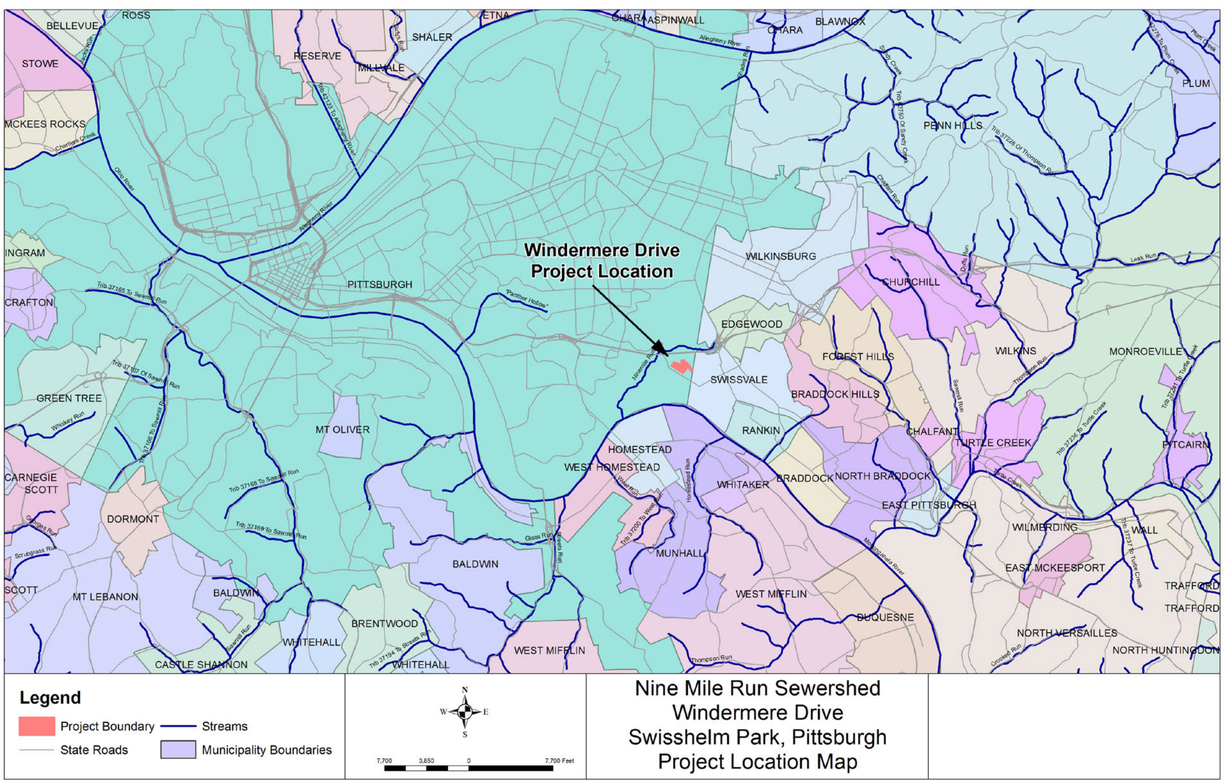


Figure 1-1. Site Location Map

2. Nine Mile Run Sewershed: Windermere Drive Project Site

The project site is located in the Swisshelm Park neighborhood within the Nine Mile Run Sewershed (see Figure 2-1 and Figure 2-2). The neighborhood is located in the southeast part of the City of Pittsburgh adjacent to the Monongahela River. The project site is located in a residential neighborhood that is adjacent to Frick Park, a 561-acre municipal park providing a network of recreational hiking trails and extensive wildlife habitat. Drainage from the project site would naturally flow to Nine Mile Run, but presently most stormwater is captured by the upstream combined sewer system.

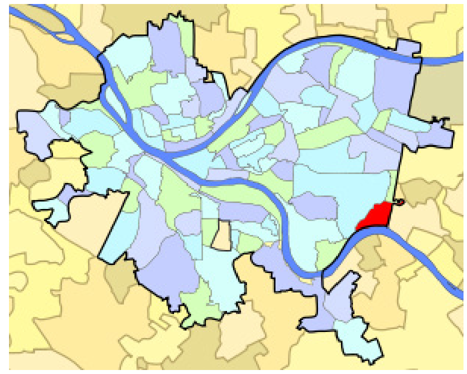


Figure 2-1. Swisshelm Park Neighborhood within the City of Pittsburgh

Using green infrastructure concepts at the block scale will help improve water quality, increase base flow to Nine Mile Run, and help decrease CSOs by decreasing the peak flow rate and stormwater volume to the combined sewer system. In addition, the community could experience several other benefits often associated with green infrastructure including increased property values, enhanced enjoyment of surroundings, a greater sense of well-being, and reduced crime. Information gained from this project will help promote similar projects throughout the greater Pittsburgh area.

Figure 2-2. Windermere Drive Project Boundary

2.1. Existing Site Conditions

The project site consists of single-family residences (~1/8-acre lots) with a forested area adjacent to the north of the site. The neighborhood is organized in a medium density configuration with houses that are situated close to the street. Lots are typically small such that minimal stormwater retention is expected. Refer to the Appendix for a copy of the completed site reconnaissance checklist and accompanying map for this area.

Most of the streets have curb and gutter facilities (see Figure 2-3 and Figure 2-4) and two traffic islands are present. Stormwater typically sheet flows off the ground surface into stormwater catch basins that tie directly into the combined sewer system. During small rain events, the stormwater is directed to the ALCOSAN wastewater treatment plant and treated before being released to the Ohio River. During larger rain events, the combined sewer system is overwhelmed and a mixture of sanitary sewage and stormwater is discharged untreated to the local waterways. Pollutants from the area are anticipated to include bacteria, nutrients, and heavy metals, typical of urban areas.

An analysis of the site topography indicates that surface water generally flows from the southeast to the northwest. The existing stormwater drainage network currently drains to Nine Mile Run, north of I-376. The site elevations range from approximately 900 to 930 feet with several steep roads and topographic depressions. The predominant soil type suggests poor-draining soil and marginal potential for removing stormwater from the combined sewer system (see below for a more detailed discussion). There are no known potential soil contamination issues within the project contributing area. The area is not designated as a groundwater recharge area, and there are no environmentally sensitive areas within the project limits.

The road surface of Windermere Drive is in fair condition and sediment sources are minimal. The sidewalk is directly adjacent to the road with no defined parkway. Windermere Drive is owned and maintained by the City of Pittsburgh.

The likelihood of neighborhood acceptance of green infrastructure practices is high. As a result of the education and outreach efforts of the local Nine Mile Run Watershed Association, many residents have some understanding of green infrastructure and are likely to accept proposed practices.

Figure 2-3. Windermere Drive southeast of Raymond Street

Figure 2-4. Windermere Drive

2.2. Proposed Site Design

The goals of the field reconnaissance conducted for all three Pittsburgh-area sites on March 4-5, 2013 were to 1) verify the feasibility of implementing the proposed green infrastructure practices from the 3RWW RainWays®, and SUSTAIN study, 2) generate ideas for incorporating practical green infrastructure practices, and 3) further assess the drainage area based on catch basin locations.

Many different types of green infrastructure practices were considered for the project site. Based on the project goals and the site constraints, bioretention and permeable pavement within the right-of-way were selected as the preferred practice types. Permeable pavement parking strips are proposed along both curblines of the 1300 and 1100 blocks of Windermere Drive. Bioretention is proposed in the traffic island at the end of the 1300 block and along the north and south sides of the 1200 block of Windermere Drive. A more detailed discussion of these practices is provided below.

Much of the potential area within the right-of-way has typical urban constraints, including buried utilities and narrow rights-of-way; therefore, it is important to choose green infrastructure practices that can demonstrate success within this environment. As this is a demonstration project, the selected practices need to translate easily to other locations within the Pittsburgh area, recognizing any lessons learned as well as special design techniques for constructing on moderate slopes (5 to 10 percent). See section 5 for a description of the placement and design of the proposed green infrastructure practices.

3. Goals

3RWW is providing direct assistance to 83 municipalities to coordinate the development of their consent order-required "feasibility studies," which analyze alternatives for the reduction, conveyance, or storage of wet weather flows within the communities. These feasibility studies specify the proposed actions (including both gray and green infrastructure) that municipalities served by ALCOSAN will implement to reduce CSOs. As these studies are integrated into the ALCOSAN Long-Term Control Plan (LTCP), the vision is to ensure that green infrastructure is evaluated and included in the municipal plans where cost-effective and appropriate. There is a sense of urgency in the timing of implementation of green infrastructure; the City's LTCP is already under development and will be the blueprint for the construction of a system that will be required to mitigate sewer overflows in the ALCOSAN service area by 2026. 3RWW will work directly with the municipalities through the existing Feasibility Study Working Group of about 25 municipal engineers who represent more than 70 of the 83 communities. Green infrastructure evaluation projects (such as the conceptual design presented in this report) are one of the mechanisms being used to emphasize the importance of green infrastructure and at the same time bring familiarity to those likely to plan for and design green infrastructure to mitigate sewer overflows.

3.1. Project Goals

Green infrastructure concepts and practices are intended to approximate the hydrologic conditions of the site prior to development through infiltration, evaporation, and detention of stormwater runoff. More specifically, the green infrastructure planned for this project is intended to assist in reducing CSOs while also improving drainage and water quality in the neighborhood. Secondary goals of the project are to improve the aesthetic appeal of the neighborhood while maintaining the historic character of the area. These goals will be accomplished through implementation of permeable pavement and bioretention within the project area on Windermere Drive.

3.2. Design Goals

In accordance with the consent decree, ALCOSAN is working toward a target of no more than four overflows per sewer system regulator per year. Regulator structures direct all the dry weather flow to the ALCOSAN system and control the quantity of flow diverted to the ALCOSAN treatment plant during wet weather conditions. Modeling efforts during a previous study of the ALCOSAN system calculated overflow volumes for each event and ranked them from largest to smallest.

The project site is upstream of regulator M-47-OF. The model information was analyzed at this overflow point, and it was found that the fifth largest overflow event had a rainfall depth of 1.41 inches. (CSO requirements in Pennsylvania allow for four CSO events per year, so designing to control the fifth largest precipitation event will meet the requirements.) The allowable peak flow rate from the regulator drainage area to comply with this overflow event is 0.0019 cubic feet per second (cfs) per acre of drainage area (i.e., 164 cubic feet per day per acre or 1,230 gallons per day per acre). This is essentially the capacity at the regulator, normalized over the drainage area, when the hydraulic grade line is at the crest of the overflow weir. For a green infrastructure practice to assist in meeting the overflow limit, the allowable release rate from the practice is 0.0019 cfs per acre. Since this is such a slow release rate, it is likely that the existing 72-hour facility dewatering requirement (to prevent mosquito infestations) will govern the release rate of the practice.

For purposes of the conceptual design, the green infrastructure practices are sized to store the runoff resulting from 1.41 inches of rainfall from the tributary drainage area discounting release rates. This is standard design practice and will result in a slightly over-sized system; the sizing of the project would be reviewed as part of the final design.

4. Green Infrastructure Toolbox

Green infrastructure utilizes the natural features of the site in conjunction with the goals of the site development. Multiple controls can be incorporated into the development of the site to complement and enhance the proposed layout while also providing water quality treatment and volume reduction. Green infrastructure practices are those methods that provide control and/or treatment of stormwater runoff on or near locations where the runoff initiates. Typical large-scale practices include approaches such as vegetated infiltration basins and stormwater wetlands. Smaller scale practices include approaches such as permeable pavement and bioretention facilities. The green infrastructure practices identified as appropriate for the project area include vegetated green infrastructure practices (i.e., bioretention) and permeable pavement. To assist planners and designers in going forward with these conceptual designs, the following discussion addresses constraints and opportunities associated with each applicable green infrastructure practice.

4.1. Vegetated Green Infrastructure Practices

Vegetated green infrastructure practices are vegetated, depressed areas with a fill soil (often engineered soil media) that infiltrate stormwater and remove pollutants through a variety of physical, biological, and chemical treatment processes. Vegetated green infrastructure practices can be large-scale controls treating several acres or small-scale controls placed in parking medians, rights-of-way, and other locations within impervious areas. The following section discusses bioretention as a small-scale control for this project.

Bioretention: Bioretention typically consists of vegetation, a ponding area, mulch layer, and soil media. The depressed area is planted with small- to medium-sized vegetation including trees, shrubs, grasses and perennials and may incorporate a vegetated groundcover or mulch that can withstand urban environments and tolerate periodic inundation and dry periods. Runoff intercepted by the practice is temporarily captured in the depression and then filtered through the soil (often engineered soil) media. Pollutants are removed through a variety of physical, biological, and chemical treatment processes. Pretreatment of stormwater flowing into the bioretention area is recommended to remove large debris, trash, and larger particulates. Pretreatment may include a grass filter strip, sediment forebay, or grass swale. Ponding areas can be designed to increase flow retention and provide flood control.

Bioretention is well suited for removing stormwater pollutants from runoff, particularly for smaller wet weather events. Bioretention can be used to partially or completely meet stormwater management requirements on smaller sites. Bioretention areas are best suited for areas that would typically be dedicated to landscaping and can be designed to capture roof runoff, parking lot runoff, or sidewalk and street runoff (as shown in Figure 4-1 and Figure 4-2). Bioretention is especially useful in this project area to encourage walkability and green space within the right-of-way.

Figure 4-1. Bioretention in Median

Source: Aaron Volkening

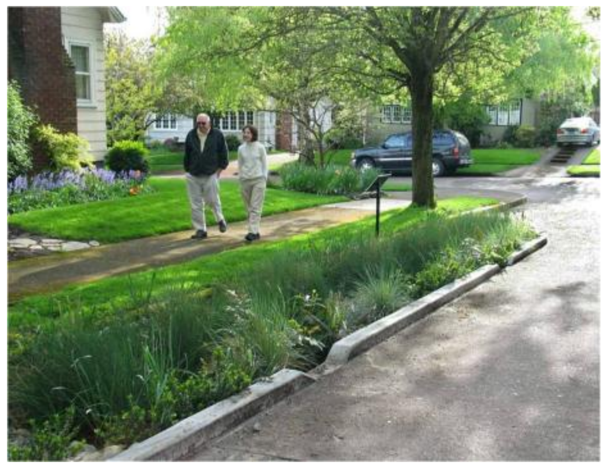


Figure 4-2. Curb-extension Bioretention

Source: Environmental Services, City of Portland, OR

4.2. Permeable Pavement

Conventional pavement results in increased surface runoff rates and volumes relative to pre-developed conditions. Permeable pavement, in contrast, works by allowing streets, parking lots, sidewalks, and other impervious surfaces to utilize the underlying soil’s natural infiltration capacity while maintaining the structural and functional features of the materials they replace. Permeable pavement contains small voids that allow water to drain through the pavement to a layer of aggregate and then infiltrate into the soil. If the native soils below the permeable pavement do not have enough percolation capacity, underdrains can be included to direct the stormwater to other downstream control systems. Permeable pavement can be developed using modular paving systems (e.g., concrete pavers, grid pavers, grass-pave, or gravel-pave) or poured-in-place solutions (e.g., pervious concrete or pervious asphalt).

Permeable pavement reduces the volume of stormwater runoff by converting an impervious area to a treatment unit. The aggregate sub-base can provide water quality improvements through filtering and enhance additional chemical and biological processes. The volume reduction and water treatment capabilities of permeable pavement are effective at reducing stormwater pollutant loads.

Permeable pavement can be used to replace traditional impervious pavement for most pedestrian and vehicular applications. Composite designs that use conventional asphalt or concrete in high-traffic areas adjacent to permeable pavement along shoulders or in parking areas can be implemented to provide a cost-effective solution to meet both transportation and stormwater management requirements. Permeable pavement is most often used in constructing pedestrian walkways, sidewalks, driveways, low-volume roadways, and parking areas of office buildings, recreational facilities, and shopping centers (Figure 4-3 and Figure 4-4). Permeable pavement is a suitable green infrastructure choice within the project area because it can be used without decreasing street parking or pedestrian walkways in narrow rights-of-way, such as alleys. It is also a convenient choice for parking lot pavement as it does not cause a reduction in parking capacity.

Figure 4-3. Permeable Interlocking Concrete Paver Parking Lane

Figure 4-4. Permeable Interlocking Concrete Paver Parking Stalls

5. Green Infrastructure Conceptual Design

This section addresses the selection, layout, and design of the green infrastructure practices for the project site. The selection and proposed layout of the controls within the project area are based on the 3RWW RainWays® and SUSTAIN study, determining the effects of green infrastructure on CSO volume reduction, and a field reconnaissance to verify feasibility and identify additional opportunities. The design method is described in section 5.1 and the conceptual layout and sizing practices are discussed in section 5.2. Detailed design information is summarized and presented in section 6.

5.1. Analytical Methods

Since a primary goal of this project is to alleviate CSO issues, the design of the green infrastructure practices is intended to retain a runoff volume resulting from 1.41 inches of rainfall from the tributary drainage area, disregarding release rates. The runoff curve number method was used to calculate runoff. Required storage volumes from the tributary drainage areas to the green infrastructure practices are presented in Table 5-1.

The subcatchment areas for the proposed green infrastructure practices were derived from topographic data (provided by 3RWW) and field visits. Note that these data will need to be validated as part of the final design. The soil was represented as poor-infiltrating soil (Hydrologic Soil Group D) per the Natural

Resources Conservation Service Soil Survey data provided by 3RWW. Actual soil infiltration rates will need to be determined as part of the final design (see section 6).

The final conceptual sizing of the green infrastructure practices was based on available surface area and a projected design cross-section to ensure that the practice, at a minimum, could capture the required storage volume for the regulator capacity. Storage within the practice took into account void space within the soil media and aggregate storage layer but not the required 72-hour dewatering time, infiltration, and evapotranspiration. Therefore, during final design, these parameters should be taken into account which would help decrease the practice sizes. It was also assumed that bioretention systems would include underdrains with a downstream valve at the outlet; the valve may be used to meet the dewatering requirements. With Type D soils, an underdrain is recommended and is also useful for future flow monitoring.

Table 5-1. Subcatchment Delineations and Required Storage Volume

Subcatchment	Subcatchment Drainage Area (acres)	Required Storage Volume for Regulator Capacity (cubic feet)
Windermere Drive, 1300 block - permeable parking strips	1.09	624
Windermere Drive, 1300 block - traffic island bioretention	0.06	35
Windermere Drive, 1200 block - curb extension bioretention #1	0.25	140
Windermere Drive, 1200 block - curb extension bioretention #2	0.42	240
Windermere Drive, 1200 block - curb extension bioretention #3	0.38	219
Windermere Drive, 1100 block - permeable parking strips	2.82	1,613

5.2. Recommended Sizing and Layout

The conceptual layout and sizing of the green infrastructure practices within the project area are discussed in this section. The cross-section designs used for the sizing of the practices are in section 6.

Within the discussion below, note that the water storage volume is the product of the surface area of the practice and the equivalent storage depth. Equivalent storage depth is the sum of the surface ponding depth and the product of the void space and applicable underlying layers. The soil layer, cube storage, and aggregate storage layer void space are 20 percent, 100 percent, and 40 percent, respectively. The void space is the difference between the porosity and the field capacity of the material. The cross-section of the final design can vary from the conceptual design cross-section as long as the water storage volume capacity is maintained.

5.2.1. Windermere Drive – 1300 Block

Proposed green infrastructure practices along the 1300 block of Windermere Drive include a combination of permeable pavement and bioretention within the traffic circle. (See Figure 5-1 and Figure 5-2.) Permeable pavement parking strips are proposed adjacent to the curb in the parking lane on both sides of the street. This configuration of permeable pavement would capture the sheet flow from the center line of Windermere Drive to the outside curb line. Permeable interlocking concrete pavers, pervious asphalt, or pervious concrete would be the best option for this application. Based on the available area of 5,100 square feet within the parking lane and an equivalent water storage depth of 0.8 feet, the available storage volume is 4,080 cubic feet. This cross-section meets the required volume for the design criteria. The equivalent water storage depth assumes 6 inches of bedding layer and 18 inches of aggregate storage.

The traffic circle bioretention will be able to accommodate the design criteria for the regulator with a capture and treatment runoff depth of 4 inches in a cross-section including 6 inches of surface storage and 18 inches of engineered soil. This green infrastructure practice stores such a large runoff depth because the drainage area is small relative to the available surface area. The bioretention surface area could be smaller but for aesthetic purposes the entire available area is used. The 6 inches of surface storage and 18 inches of engineered soil are recommended minimum depths. The proposed bioretention surface area avoids the mature tree located on the north side of the traffic island.

The permeable pavement parking strips and bioretention could be installed together or each practice could be installed individually. If both projects are installed, a greater reduction in CSOs will be realized. If only one project is selected, bioretention provides similar benefits in terms of storage capacity but includes more “green” in the design.

Figure 5-1. Windermere Drive (west side) looking south

Figure 5-2. Windermere Drive traffic circle

5.2.2. Windermere Drive – 1200 Block

Green infrastructure practices proposed for the 1200 block of Windermere Drive include three curb-extension bioretention practices in front of 1260, 1239, and 1230 Windermere Drive (see Figure 5-3 and Figure 5-4). Refer to Figure 4-2 for an example curb-extension bioretention. The curb-extension bioretention practices are designed to collect runoff from the front yards and road on the 1200 block of Windermere Drive. The bioretention practices are 120 square feet (4 feet wide by 30 feet long) and will not impede the flow of traffic. Roadside parking is not prevalent in this area making curb-extension bioretention a viable option.

The bioretention practice in front of 1260 Windermere Drive can capture and treat 0.92 inches of runoff from the fifth largest storm event (1.41 inches) over the drainage area, while the bioretention practices in front of 1239 and 1230 Windermere Drive can capture and treat 0.87 and 0.74 inches of runoff from the fifth largest storm event, respectively. The cross-section for all three practices includes 6 inches of surface storage, 12 inches of engineered soil, 12 inches of aggregate storage, and 48 inches of subsurface storage based on the a cube storage system under the adjacent sidewalk. The cube storage system is a modular plastic cube that provides essentially 100% void space (see Figure 5-5 for an example). They provide more storage volume than can be provided with aggregate alone and save costs for aggregate. The cube storage is included to provide sufficient storage for the regulator volume requirement. This cross-section is fairly deep due to the large tributary drainage area relative to the available surface area of the practice.

Figure 5-3. Bioretention Proposed as Curb-Extension on Windermere Drive

Figure 5-4. Bioretention Proposed as Curb-Extension at 1239 Windermere Drive

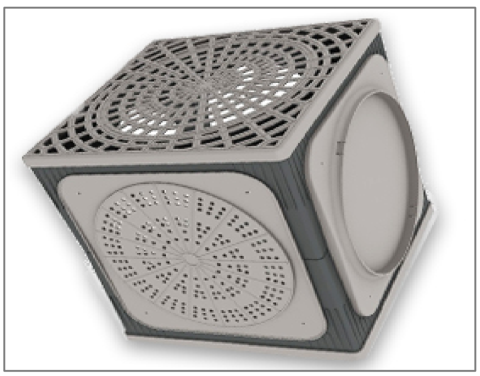


Figure 5-5. CUDO Water Storage System

Source: www.kristar.com

5.2.3. Windermere Drive – 1100 Block

Permeable pavement parking strips are proposed for the 1100 block of Windermere Drive along the outside curb, adjacent to the sidewalk in the parking lane (see Figure 5-6 and Figure 5-7). This configuration of permeable pavement would capture some front yard runoff and the sheet flow from the center line of Windermere Drive to the outside curb line on both sides of the road. Permeable interlocking concrete pavers, pervious asphalt, or pervious concrete would be the best options for this application. Based on the available area of 6,840 square feet within the parking lane and an equivalent water storage depth of 1 foot, the available storage volume is 6,840 cubic feet. This is enough storage to capture and treat 0.77 inches over the drainage area, above the depth required by the design criteria. The equivalent water storage depth assumes 6 inches of bedding layer and 24 inches of aggregate storage.

Figure 5-6. Permeable Parking Strips Proposed on Windermere Drive, 1100 Block

Figure 5-7. Permeable Parking Strips Proposed on Windermere Drive, 1100 Block

5.2.4. Summary of Project Sites

Table 5-2 and Table 5-3 provide a detailed description of available storage capacity and cross-section depths for each of the green infrastructure practice sites described above. Figure 5-8 shows the placement of the practices.

Table 5-2. Green Infrastructure Practice Sizing and Storage

Green Infrastructure Practice	Location Description	Location	Width (ft)	Length (ft)	Surface Area (sq ft)	Equivalent Water Storage Depth (ft)[2]	Available Water Storage Volume (cu ft)[3]	Runoff Depth Stored (in)[4]
Permeable Pavement - parking stalls	Windermere Dr. – 1300 block	Right-of-way	12	425	5,100	0.8	4,080	0.90
Bioretention	Windermere Dr. – 1300 block	Traffic Island	45	25	1,125	0.8	900	4.1
Curb-Extension Bioretention	Windermere Dr. -1200 block	Right-of-way	4	30	120	7.0[1]	834	0.92
Curb-Extension Bioretention	Windermere Dr. -1200 block	Right-of-way	4	30	120	7.0[1]	834	0.87
Curb-Extension Bioretention	Windermere Dr. -1200 block	Right-of-way	4	30	120	7.0[1]	834	0.74
Permeable Pavement – Parking Strips	Windermere Dr. – 1100 block	Right-of-way	6	1,140	6,840	1.0	6,840	0.77

[1]Equivalent water storage depth for the curb-extension bioretention takes into account the cube storage under the sidewalk that is not included in the surface area square footage.
[2]Equivalent Water Storage Depth: Ponding Depth x void space + Engineered Soil Depth x void space + Bedding Depth x void space + Aggregate Storage Depth x void space [Example Calculation: (0.5' x 1.0) + (1.5' x 0.2) + (0 x 0.4) + (0 x 0.3) = 0.8 feet equivalent depth]
[3]Available Water Storage Volume: Surface Area x Equivalent Water Storage Depth
[4]Runoff Depth Stored: Available Water Storage Volume/Surface Area and converted to inches.

Table 5-3. Green Infrastructure Practice Cross-Sections

Green Infrastructure Practice	Location Description	Location	Ponding Depth (in)	Engineered Soil Depth (in)	Bedding Depth (in)	Aggregate Storage Depth (in)
Permeable Pavement - parking stalls	Windermere Dr. – 1300 block	Right-of-way	0	0	6	18
Bioretention	Windermere Dr. – 1300 block	Traffic Island	6	18	NA	0
Curb-Extension Bioretention	Windermere Dr. -1200 block	Right-of-way	6	12	NA	12 plus 48 in. cube storage under sidewalk
Curb-Extension Bioretention	Windermere Dr. -1200 block	Right-of-way	6	12	NA	12 plus 48 in. cube storage under sidewalk
Curb-Extension Bioretention	Windermere Dr. -1200 block	Right-of-way	6	12	NA	12 plus 48 in. cube storage under sidewalk
Permeable Pavement – Parking Strips	Windermere Dr. – 1100 block	Right-of-way	0	0	6	24

Figure 5-8. Proposed Green Infrastructure Practice Placement

6. Green Infrastructure Practice Technical Specifications

This section describes the conceptual design of the green infrastructure practices as proposed in section 5. The Pennsylvania Stormwater Best Management Practices Manual includes design guidance for many green infrastructure practices and should be referenced in any final design steps. The following is additional information, which may be helpful in the design of bioretention and permeable pavement applications.

6.1. Common Design Elements

The following sections describe design elements that are common to both bioretention and permeable pavement projects. Specific design elements for each practice are described separately below.

6.1.1. Site Evaluation and Soil Infiltration Testing

Site evaluation and soil infiltration testing is necessary to determine the suitability of a site for infiltration and gather data for the design of the infiltration practice. The Pennsylvania Stormwater Best Management Practices Manual, Appendix C – Site Evaluation and Soil Testing, should be referenced for evaluation and testing methods.

Expansive soils with a high shrink-swell potential are not prevalent in the Pittsburgh area, but if these soils are found at the site, the green infrastructure practice design should include underdrains and impermeable barriers where the controls are adjacent to infrastructure such as roads and buildings. Drainage should always be directed away from building foundations and road subgrades.

6.1.2. Underdrain

If the native soils underneath a green infrastructure practice are low-permeability soils, an underdrain may be required and should meet the following criteria:

- The type of perforated pipe is not critical to the function of the green infrastructure practice as long as the total opening area of the perforations exceeds the expected flow capacity of the underdrain and does not limit infiltration through the soil media. The perforations can be placed closest to the invert of the pipe to achieve maximum potential for draining the facility. If an anaerobic zone is intended, the perforation can be placed at the top of the pipe.
- Place the underdrain within a pocket of drainage stone a minimum of 4 inches thick on all sides.
- The underdrain should drain freely and discharge to the existing sewer infrastructure. Alternatively, the underdrain outlet can be upturned to provide an internal sump (internal water storage) to improve infiltration and water quality. The optimal elevation of the underdrain invert should be no less than 1.5 feet from the surface of the basin to provide an aerobic root zone for plants and to prevent previously-sorbed pollutants from mobilizing.
- Install a valve at the downstream end of the underdrain, where the system connects back to the sewer system. The valve may be used as a passive device to adjust the allowable release rate.

6.2. Design Elements

The green infrastructure siting was based on multiple factors including 1) effectiveness as a demonstration site, 2) multi-use asset for the surrounding neighborhood, 3) potential for volume reduction for CSO issues, and 4) ancillary benefits such as aesthetic improvement. The potential for green infrastructure practice demonstration was evaluated based on the proximity to parks, schools, museums, or other features that would attract the public and acceptability in the neighborhood. The design also considered the potential for applying the green infrastructure design similarly throughout the greater Pittsburgh area.

The conceptual design of the practices takes into account the approximate soil infiltration rate, drainage area, runoff coefficient, and allowable peak flow rates based on the downstream combined sewer regulator. Additional design parameters for bioretention include the surface storage depth, planting soil depth, aggregate storage depth, and void space ratios of the soil and aggregate. Permeable pavement design parameters include pavement thickness, aggregate storage depth, and the applicable void space ratios. As this project moves into final design other considerations will include buried utilities, connection to the combined sewer system, and topography based on a survey.

6.3. Bioretention

Bioretention areas should have the following design features:

- For unlined systems, maintain a minimum of 5 feet between the green infrastructure practice and any adjacent buildings and at least 10-15 feet between the green infrastructure practice and any adjacent basement.
- The design of the practice should consider the allowable release rate back to the combined sewer. This rate is dicated by the regulator capacity (refer to section 3) and also the recommended maximum facility dewater time of 72 hours. Both flow rates should be calculated and the rate that meets both design criteria will ultimately dictate the design of the practice. Dewatering mechanisms include infiltration through underlying soils as well as flow through an underdrain system. Use of an underdrain system is very effective in areas with low infiltration capacity soils.
- Utilize native and noninvasive plant species tolerant of urban environments, salt, and frequent inundation, and place a maximum of 3 inches of mulch on the surface of the soil.
- For the aggregate storage layer, use clean coarse aggregate AASHTO #4, #5, or equivalent.
- The filter layer placed between the soil media and the storage layer is recommended to be 2 to 4 inches of clean medium sand (ASTM c-33) over 2 to 3 inches of #8 or #78 washed stone.
- Include an overflow structure with a non-erosive overflow channel to safely pass flows that exceed the capacity of the facility; or design the facility as an off-line system where only the design volume enters the bioretention area.
- Inclusion of a pretreatment mechanism such as a grass filter strip, sediment forebay, or grass swale upstream of the practice to enhance the treatment capacity of the unit.

6.3.1. Soil Media

A minimum of 12-18 inches of engineered soil mixture is recommended in most cases for bioretention practices. This may be either an engineered soil mixture to replace the existing soil or a compost amendment to the existing soil. The soil media is typically specified to meet the growth requirements of the selected vegetation while still meeting the hydraulic requirements of the system.

Engineered Soil Mixture: Recognizing that there are many possible variations in soil media, the following is one example:

The engineered soil mixture is a blend of loamy soil, sand, and compost that is 30-40 percent compost (by volume). The expected infiltration rate should range from 1 to 2 inches per hour.

A particle gradation analysis of the blended material, including compost, should be conducted in conformance with ASTM C117/C136 (AASHTO T11/T27). The gradation of the blended material should meet the following gradation criteria:

Sieve Size	Percent Passing
1 inch	100
#4	75-100
#10	40-100
#40	15-50
#100	5-25
#200	5-15

Other design criteria that should be considered:

- Soil media must have an appropriate amount of organic material to support plant growth. Organic matter is considered an additive to help vegetation establish and contributes to sorption of pollutants and should be between 5-10 percent. Additional organic matter can be added to the soil to increase the water holding capacity. Organic materials will oxidize over time, causing an increase in ponding that could adversely affect the performance of the bioretention area. Organic material should consist of aged bark fines, or similar organic material. Organic material should not consist of manure or animal compost. Newspaper mulch has been shown to be an acceptable additive.
- pH should be between 5–8, cation exchange capacity should be greater than 5 milliequivalent/100 g soil.
- High phosphorus concentrations are common in compost and when applied to a bioretention area, can result in leaching of phosphorus. When an overabundance of phosphorus enters waterways, it can cause unhealthy balances of aquatic life. All bioretention media should be analyzed for background levels of nutrients. Total phosphorus should not exceed the industry standard of 15 ppm.

Compost Amendment: It may be possible to restore the surface soils by adding approximately 2.5 inches of compost over the surface of the site (King County 2005) and breaking up the soil with a subsoiler or ripper attached to a tow vehicle (Kees 2008). It may also be beneficial to amend the existing subsurface soil with compost to enhance the infiltration rate. This practice increases infiltration rates and also helps reduce cations and toxicants in the water. The disadvantage is that nutrient leaching occurs for a period of time (Pitt et al. 1999). Establishing native plants with extensive root systems will also help provide channels to promote infiltration in the subsurface soil.

6.3.2. Grading

Bioretention systems function best when the top soil layer is flat. A flat surface allows for even infiltration throughout the system and reduces runoff velocities, thereby minimizing the potential for erosion. Design and construction of long, linear bioretention systems with a flat surface can be problematic when the surrounding terrain is sloped due to the required grading. Terracing the system is one approach to maintaining a flat soil layer while minimizing the required earthwork. Clay check dams and existing driveway approaches are two possible approaches to terracing. The system may be designed with a longitudinal slope similar to a swale, however special attention is required. Storage volume calculations should assume a flat water surface profile if the soil layer is sloped. Care is needed to ensure sufficient infiltration capacity through the engineered soil layer and to guard against surface erosion.

6.3.3. Plant Selection

For the green infrastructure practice to function properly and be attractive, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

- Plant materials must be tolerant of drought, ponding fluctuations, salt, and saturated soil conditions for 10 to 48 hours.
- Native plant species or hardy cultivars that are not invasive and do not require chemical inputs are recommended to be used to the maximum extent practicable.
- For native plant species, refer to the Pennsylvania Stormwater Best Management Practices Manual; Appendix B (http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-76385/363-0300-002%20Appendix%20B.pdf).
- Turf grass systems may also be used. The advantage of turf grass systems is the reduced maintenance requirements. Figure 6-1 shows an example of a bioretention system planted with turf grass and street trees. Figure 6-2 shows a typical design for a curb extension.

Figure 6-1. Bioretention Planted with Turf Grass

Source: Tetra Tech

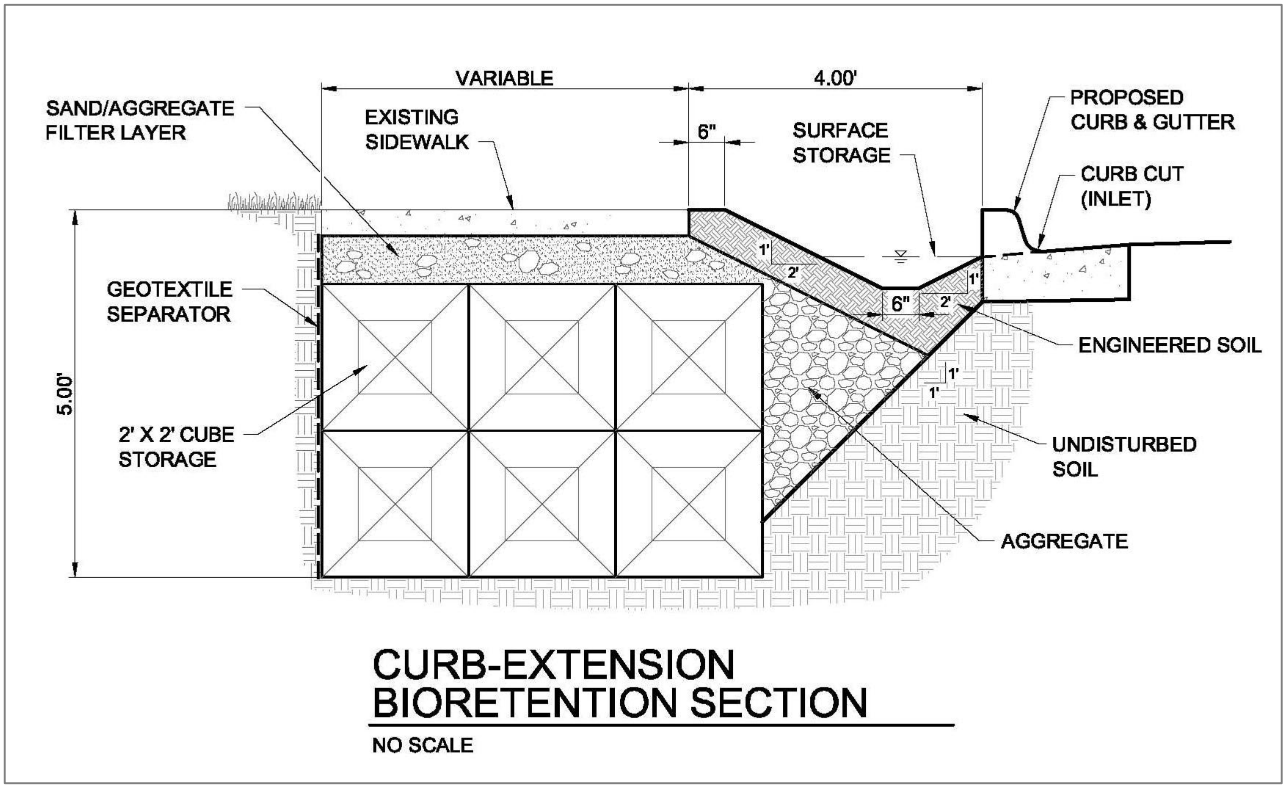


Figure 6-2. Curb-Extension Bioretention Cross-Section

6.4. Permeable Pavement

Figure 6-3 shows a typical design for permeable pavement practices. General guidelines for applying permeable pavement are as follows:

- Permeable pavement can be developed using modular systems (e.g., concrete pavers, grid pavers, grass-pave, or gravel-pave) or poured-in-place solutions (e.g., pervious concrete or pervious asphalt).
- Permeable pavement can be substituted for conventional pavement in parking areas, low-volume/low-speed roadways, pedestrian areas, and driveways if the grades, native soils, drainage characteristics, and groundwater conditions of the paved areas are suitable.
- Permeable pavement is not appropriate for stormwater hotspots where hazardous materials are loaded, unloaded, or stored, unless the sub-base layers are completely enclosed by an impermeable liner.
- The bedding layer and sub-base structural layers should provide an adequate construction platform and base for the overlying pavement layers.
- If permeable pavement is installed over low-permeability soils or temporary surface flooding is a concern, an underdrain should be installed to ensure water removal from the sub-base reservoir and pavement.
- The infiltration rate of the soils or an installed underdrain should drain the sub-base within 72 hours.

- An impermeable liner can be installed between the sub-base and the native soil to prevent water infiltration when clay soils have a high shrink-swell potential or if a high water table or bedrock layer exists.
- Measures should be taken to protect permeable pavement from high sediment loads, particularly fine sediment, to reduce maintenance. Typical maintenance includes removing sediment with a vacuum truck.
- A reinforced concrete transition (width of 12-18 inches) is required where permeable pavement meets adjacent non-concrete pavement or soil.
- For interlocking or grid-type pavers use fine aggregate, coarse sand, or top soil and grass in openings
- Bedding layer immediately beneath the permeable pavement:
  - Permeable Interlocking Concrete Pavers: 1.5 to 3 inches of AASHTO #8 or #78 washed stone
  - Concrete and Plastic Grid Pavers: 1 to 1.5 inches of bedding sand
  - Pervious Concrete and Asphalt: None
- Structural layer or aggregate layer beneath the bedding layer:
  - 12 to 30 inches of clean aggregate AASHTO #56 or equivalent; thickness depends on strength/storage needed; install 30 millimeter geotextile liner or filter layer where aggregate meets soil
- Design for projected traffic loads using AASHTO methods.
- When evaluating the potential placement of permeable pavement, avoid areas adjacent to mature trees as their root systems may be impacted when excavating for the structural/aggregate and sub-base layers (minimum 12 inches)

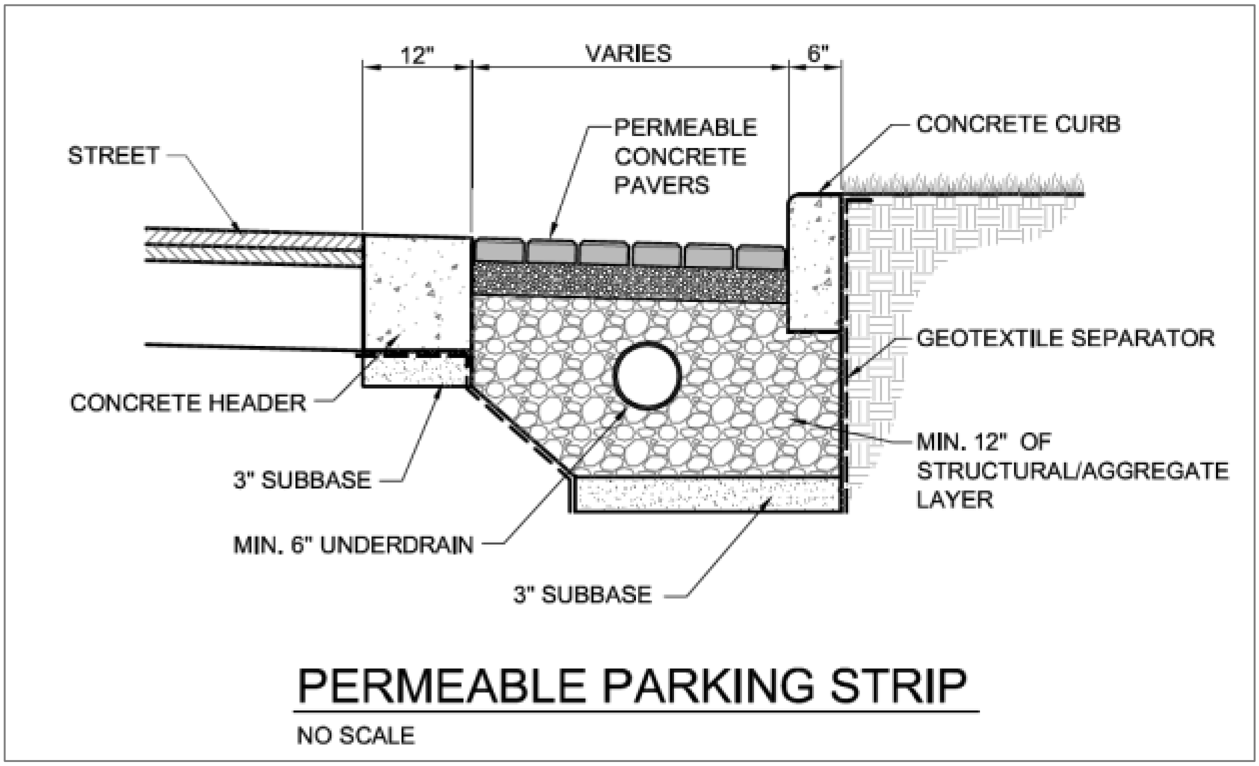


Figure 6-3. Permeable Parking Strip Cross-Section.

7. Operations and Maintenance

Maintenance activities for landscaped practices such as bioretention are generally similar to maintenance activities for any garden. The focus is to remove trash and monitor the health of the plants, replacing or thinning plants as needed. Over time, a natural soil horizon should develop which will assist in plant and root growth. An established plant and soil system will help in improving water quality and keeping the practice drained. The biological and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance.

The primary maintenance requirement for permeable pavement consists of regular inspection for clogging and vacuuming with a vacuum sweeper or equivalent.

Table 7-1 and Table 7-2 outline the recommended maintenance tasks, their associated frequencies, and other notes.

Table 7-1. Bioretention Operations and Maintenance Considerations.

Task	Frequency	Maintenance notes
Monitor infiltration and drainage	1 time/year	Measure infiltration rate after construction to establish a baseline for future comparison. Inspect drainage time (< 72 hours). Recalculate infiltration rate every 2–3 years. Turning over or replacing the media (top 2–3 inches) might be necessary to improve infiltration (at least 0.5 inch/hour).
Pruning	1–2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	As needed	Frequency depends on the location, plant selection, and desired aesthetic appeal.
Mulching	1–2 times/year	Recommend maintaining 1–3 inches uniform mulch layer by replacement or redistributing in plant bed.
Mulch removal	1 time/2–3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2–3 days for first 1–2 months; as needed after establishment	If drought conditions exist, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for first year vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 30 percent of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment. May need to clean out the underdrain to remove any accumulated sediment and debris.
Miscellaneous upkeep	12 times/year	Tasks include spot weeding, trash collection, plant health, and removing mulch from the overflow device.

Table 7-2. Permeable Pavement Operations and Maintenance Considerations.

Task	Frequency	Maintenance notes
Impervious to Pervious interface	Once after first rain of the season, then monthly during the rainy season	Check for sediment and debris accumulation to ensure that sediment loads are not flowing onto permeable pavement. Remove any accumulated sediment, vegetative debris, or trash. Stabilize any exposed soil.
Vacuum-assisted sweeping	2 times/year as needed or as needed to maintain infiltration rates.	Recommended times of the year include shortly after the last snowmelt to clean up debris left from snow piles and in the late fall after most leaves have fallen. Perform ASTM 1701 Standard Test Method for Infiltration Rate of In-Place Pervious Concrete as needed. *Equipment Costs:* *Vacuum truck attachment (Bunyan Infiltration Restoration Device [BIRD]* *$7,300 - $11,200* *Walk-behind vacuum sweeper* *$5,000 to $12,000* *Vacuum-assisted street sweeper vehicle* *$170,000 to $220,000*
Replace fill materials (applies to pervious pavers only)	1-2 times/year (and after any vacuum truck sweeping)	Fill materials will need to be replaced after each sweeping and as needed to keep voids with the paver surface.
Miscellaneous upkeep	4 times/year or as needed for aesthetics	Tasks include trash collection, sweeping, and spot weeding.

8. Green Infrastructure Practice Cost Estimates

The cost estimates for constructing the green infrastructure practices at each of the sites are found in Table 8-1 through Table 8-6 below. Cost information was derived from bid tabulation data published by various public agencies and compared against projects constructed in the Pittsburgh area. All cost estimates assume retrofit of the green infrastructure practices and are based on the sizing information from section 6. Retrofit costs take into account pavement removal and subsequent pavement replacement or patching. A 30 percent contingency has been added to all costs. Costs do not include engineering fees, legal fees, soil erosion control, or construction management.

Annual maintenance costs are also included in Table 8-7.

Table 8-1. Windermere Drive 1300 Block – Permeable Concrete Paver Block Parking Stalls

Item	Unit	Unit Cost	Quantity	Cost
Sidewalk Removal	Sq yd	$5.00	472	$2,360
Curb and Gutter Removal	LF	$4.50	850	$3,825
Pavement Removal	Sq yd	$5.00	944	$4,720
Machine Grading Modified	Sta	$1,200.00	4.25	$5,100
Concrete Header, Reinforced 9"	LF	$11.00	850	$ 9,350
Concrete Header, Reinforced 12"x12"	LF	$17.00	870	$14,790
Earth Excavation	Cu yd	$10.00	190	$1,900
3" Subbase, compacted in place	Cu yd	$12.00	40	$480
Permeable Paver Blocks	Sq ft	$20.00	5100	$102,000
18" Aggregate Storage Layer	Cu yd	$25.00	283	$7,075
Geotextile Separator	Sq yd	$8.00	378	$3,024
6" Perforated Underdrain	LF	$3.25	850	$2,763
Aggregate Base, 8"	Sq yd	$7.50	283	$2,123
13A Hot Mix Asphalt Pavement	Ton	$55.00	55	$3,025
4" Concrete Sidewalk	Sq ft	$3.00	3200	$9,600
6" Concrete Sidewalk	Sq ft	$5.00	1050	$5,250
6" Storm Sewer Tap	Ea	$400.00	4	$1,600
Parkway Restoration	Sq yd	$8.00	190	$1,520
Drainage Structure Cover Adjust	Ea	$250.00	4	$1,000
Adjust Water valve	Ea	$200.00	2	$400
Notes: Existing sidewalk adjacent to existing curb and gutter will be removed during construction. Remove and replace hot mix asphalt pavement in between the two permeable paver strips. 6 inch sidewalk is assumed across driveways, all other locations to be restored with 4-inch sidewalk. A 9 inch concrete header is assumed for the curb, and a roadside header of 12" x 12"		Sub-Total		$181,904.00
		30% Contingency		$54,600.00
		Total		$236,504.00
				$46/Sq Ft

Table 8-2. Windermere Drive 1300 Block – Traffic Island Bioretention

Item	Unit	Unit Cost	Quantity	Cost
Protect Trees	Ea	$500.00	2	$1000
Curb and Gutter, Remove	LF	$4.50	10.0	$45
Pavement, Remove	Sq yd	$5.00	22.0	$110
Earth Excavation	Cu yd	$10.00	105.0	$1050
Aggregate Base, 3”	Sq yd	$3.00	1.0	$3
Aggregate Base, 8”	Sq yd	$7.00	22.0	$154
Hot Mix Asphalt, Hand Patching	Ton	$150.00	4.5	$675
Curb and Gutter	LF	$12.00	10.0	$120
Concrete Encased CMP Slotted Trench Drain, 15"	LF	$100.00	30.0	$3,000
Concrete Spillway	Ea	$75.00	2.0	$150
Stone Drainage Course 6" deep	Cu yd	$25.00	21.0	$525
Engineered Soil Mixture 18" deep	Cu yd	$38.00	63.0	$2,394
Plantings	Sq ft	$5.00	1125.0	$5,625
6" Perforated Underdrain	LF	$3.25	145.0	$508
6" PVC Drain Pipe	LF	$45.00	45.0	$2,025
6" Storm Sewer Tap	Ea	$400.00	2.0	$800
Notes: Assume two outlets. No curb removal except for underdrain outlets/spillway construction. All excavation within island.		Sub-Total		$18,184
		30% Contingency		$5,450
		Total		$23,650
				$21/Sq Ft

Table 8-3. Windermere Drive 1200 Block – Curb-Extension Bioretention at 1260 Windermere

Item	Unit	Unit Cost	Quantity	Cost
Curb and Gutter, Remove	LF	$4.50	40.0	$180
Sidewalk Remove	Sq yd	$5.00	23.0	$115
Pavement, Remove	Sq yd	$5.00	27.0	$135
Earth Excavation	Cu yd	$10.00	50.0	$500
Aggregate Base, 3"	Sq yd	$3.00	33.0	$99
Aggregate Base, 8"	Sq yd	$7.00	20.0	$140
Hot Mix Asphalt Hand Patching	Ton	$150.00	4.0	$600
Curb and Gutter	LF	$12.00	48.0	$576
Concrete Spillway	Ea	$75.00	2.0	$150
4" Concrete Sidewalk	Sq ft	$3.00	200.0	$600
Aggregate Storage Layer	Cu yd	$25.00	3.3	$83
Engineered Soil Mixture	Cu yd	$38.00	6.0	$228
2' x 2' Cube Storage (Cudo)	Cu ft	$15.00	720.0	$10,800
Plantings	Sq ft	$5.00	120.0	$600
Parkway Restoration	Sq yd	$8.00	13.0	$104
6" Perforated Underdrain	LF	$3.25	30.0	$98
6" PVC Drain Pipe	LF	$45.00	25.0	$1,125
6" Storm Sewer Tap	Ea	$400.00	1.0	$400
Notes: Assume 3' existing parkway behind sidewalk and replacement of existing sidewalk for installation. Includes underdrain with one outlet. Perforated underdrain to be installed under green infrastructure practice; drain pipe to be installed under road.		Sub-Total		$16,533
		30% Contingency		$4,960
		Total		$21,500
				$179/Sq Ft

Table 8-4. Windermere Drive 1200 Block – Curb-Extension Bioretention at 1239 Windermere

Item	Unit	Unit Cost	Quantity	Cost
Curb and Gutter, Remove	LF	$4.50	40.0	$180
Sidewalk Remove	Sq yd	$5.00	23.0	$115
Pavement, Remove	Sq yd	$5.00	27.0	$135
Earth Excavation	Cu yd	$10.00	50.0	$500
Aggregate Base, 3”	Sq yd	$3.00	33.0	$99
Aggregate Base, 8”	Sq yd	$7.00	20.0	$140
Hot Mix Asphalt Hand Patching	Ton	$150.00	4.0	$600
Curb and Gutter	LF	$12.00	48.0	$576
Concrete Spillway	Ea	$75.00	2.0	$150
4" Concrete Sidewalk	Sq ft	$3.00	200.0	$600
Aggregate Storage Layer	Cu yd	$25.00	3.3	$83
Engineered Soil Mixture	Cu yd	$38.00	6.0	$228
2’ x 2’ Cube Storage (Cudo)	Cu ft	$15.00	720.0	$10,800
Plantings	Sq ft	$5.00	120.0	$600
Parkway Restoration	Sq yd	$8.00	13.0	$104
6" Perforated Underdrain	LF	$3.25	30.0	$98
6" PVC Drain Pipe	LF	$45.00	25.0	$1,125
6" Storm Sewer Tap	Ea	$400.00	1.0	$400
Notes: Assume 3' existing parkway behind sidewalk and replacement of existing sidewalk for installation. Includes underdrain with one outlet. Perforated underdrain to be installed under green infrastructure practice; drain pipe to be installed under road.		Sub-Total		$16,533
		30% Contingency		$4,960
		Total		$21,500
				$179/Sq Ft

Table 8-5. Windermere Drive 1200 Block – Curb-Extension Bioretention at 1224 Windermere

Item	Unit	Unit Cost	Quantity	Cost
Curb and Gutter, Remove	LF	$4.50	40.0	$180
Sidewalk, Remove	Sq yd	$5.00	23.0	$115
Pavement, Remove	Sq yd	$5.00	27.0	$135
Earth Excavation	Cu yd	$10.00	50.0	$500
Aggregate Base, 3”	Sq yd	$3.00	33.0	$99
Aggregate Base, 8”	Sq yd	$7.00	20.0	$140
Hot Mix Asphalt Hand Patching	Ton	$150.00	4.0	$600
Curb and Gutter	LF	$12.00	48.0	$576
Concrete Spillway	Ea	$75.00	2.0	$150
4" Concrete Sidewalk	Sq ft	$3.00	200.0	$600
Aggregate Storage Layer	Cu yd	$25.00	3.3	$83
Engineered Soil Mixture	Cu yd	$38.00	6.0	$228
2’ x 2’ Cube Storage (Cudo)	Cu ft	$15.00	720.0	$10,800
Plantings	Sq ft	$5.00	120.0	$600
Parkway Restoration	Sq yd	$8.00	13.0	$104
6" Perforated Underdrain	LF	$3.25	30.0	$98
6" PVC Drain Pipe	LF	$45.00	25.0	$1,125
6" Storm Sewer Tap	Ea	$400.00	1.0	$400
Notes: Assume 3' existing parkway behind sidewalk and replacement of existing sidewalk for installation. Includes underdrain with one outlet. Perforated underdrain to be installed under green infrastructure practice; drain pipe to be installed under road.		Sub-Total		$16,533
		30% Contingency		$4,960
		Total		$21,500
				$179/Sq Ft

Table 8-6. Windermere Drive 1100 Block – Permeable Pavement Parking Strips

Item	Unit	Unit Cost	Quantity	Cost
Sidewalk, Remove	Sq yd	$5.00	1267.0	$6,335
Curb and Gutter, Remove	LF	$4.50	2280.0	$10,260
Pavement Removal	Sq yd	$5.00	2533	$12,665
Machine Grading	Sta	$1,200.00	11.4	$13,680
Concrete Header, Reinforced 9"	LF	$11.00	1140	$12,540
Concrete Header, Reinforced 12"x12"	LF	$17.00	1152	$19,584
Earth Excavation	Cu yd	$10.00	250	$2,500
3" Subbase	Cu yd	$12.00	84	$1,008
Permeable Paver Blocks	Sq ft	$20.00	6840	$136,800
12" Aggregate Storage Layer	Cu yd	$25.00	253	$6,325
Geotextile Separator	Sq yd	$8.00	1013	$8,104
6" Perforated Underdrain	LF	$3.25	2280	$7,410
Aggregate Base, 8 inch	Sq yd	$7.50	1520	$11,400
Hot Mix Asphalt Pavement	Ton	$55.00	293	$16,115
4" Concrete Sidewalk	Sq ft	$3.00	9150.0	$27,450
6" Concrete Sidewalk	Sq ft	$5.00	2250.0	$11,250
6" Storm Sewer Tap	Ea	$400.00	12	$4,800
Drainage Structure Cover Adjust	Ea	$250.00	10	$2,500
Adjust Water valve	Ea	$200.00	4	$800
Notes: Existing sidewalk adjacent to existing curb and gutter to be removed during construction. Remove and replace HMA pavement between permeable pavement parking strips.			Sub-Total	$311,526
			30% Contingency	$93,500
			Total	$405,025
				$59/Sq Ft

Annual routine maintenance costs were adapted from Water Environment Research Foundation (WERF) estimates to account for the scale of the green infrastructure practice (WERF 2009). Typical routine maintenance is similar to maintenance for landscaped areas, parks, or standard asphalt streets. Maintenance activities for the proposed green infrastructure practices may already be accounted for in existing budgets for current maintenance and upkeep activities.

Table 8-7. Annual Maintenance Cost Estimate

Green Infrastructure Practice	Location Description	Surface Area (square feet)	Average Annual Unit Cost (per Sq Ft/year)	Average Annual Routine Maintenance Cost
Permeable Pavement - parking strips	Windermere Dr. – 1300 block	5,100	$0.67	$3,400
Bioretention	Windermere Dr. – 1300 block	1,125	$2.28	$2,550
Curb-Extension Bioretention	Windermere Dr. -1200 block	120	$2.28	$275
Curb-Extension Bioretention	Windermere Dr. -1200 block	120	$2.28	$275
Curb-Extension Bioretention	Windermere Dr. -1200 block	120	$2.28	$275
Permeable Pavement – Parking Strips	Windermere Dr. – 1100 block	6,840	$0.67	$4,550

9. Conclusion

Like many older communities with a combined sewer system, Pittsburgh has historically faced problems with CSOs. As part of implementing its LTCP, 3RWW sought model conceptual designs for green infrastructure practices at three typical sites within the community. These site designs would serve multiple purposes; first, as a preliminary design for a site-level project that will help reduce CSOs at the project site and second, as a template or pilot project for integrating green infrastructure practices at other sites throughout the community. The Windermere Drive site is one of three selected by 3RWW for a model design and the analysis demonstrates that green infrastructure approaches such as bioretention and permeable pavement can be retrofitted into urban neighborhoods to assist in reducing CSOs.

Green infrastructure can be incorporated into stormwater strategies (particularly in retrofits) as municipalities seek to reduce CSOs by reducing stormwater inflow to combined sewer systems. In addition to meeting stormwater management goals, this conceptual design illustrates how green infrastructure can help create a more attractive and livable landscape that weaves functional natural elements into the built environment.

10. References

Kees, Gary. 2008. Using subsoiling to reduce soil compaction. Tech. Rep. 0834–2828–MTDC. Missoula, MT: U.S.

King County Department of Development & Environmental Services. 2005. Achieving the Post-Construction Soil Standard.

Pitt, R., Lantrip, J., Harrison, R. 1999. *Infiltration through Disturbed Urban Soils and Compost-Amended Soil Effects on Runoff Quality and Quantity.* EPA/600/X-99/XXX. National Risk Management Research Laboratory, Office of Research and Development, U. S. EPA.

Water Environment Research Foundation (WERF). 2009. *User's Guide to the BMP and LID Whole Life Cost Models*. SW2R08. Version 2.0. Alexandrian, VA.

APPENDIX

Site Reconnaissance Checklist and Map

Retrofit Reconnaissance Investigation **RRI**

WATERSHED: 9-MILE RUN	**SUBWATERSHED:** WINDERMERE	**UNIQUE SITE ID:** 9MILE - 01

DATE: 03-04-13	**ASSESSED BY:** AMT/VMN	**CAMERA ID:**	**PICTURES:** 83 photos
GPS ID:	**LMK ID:**	**LAT:** 40°25'20.58" N	**LONG:** 79°54'03.35" W

SITE DESCRIPTION

Name: Windermere Drive, Pittsburgh (Swissholm Park)
Address:

Ownership: ☒ Public ☐ Private ☐ Unknown
If Public, Government Jurisdiction: ☒ Local ☐ State ☐ DOT ☐ Other:

Corresponding USSR/USA Field Sheet? ☐ Yes ☒ No If yes, Unique Site ID:

Proposed Retrofit Location:

Storage NA
- ☐ Existing Pond
- ☐ Below Outfall
- ☐ In Road ROW
- ☐ Other:
- ☐ Above Roadway Culvert
- ☐ In Conveyance System
- ☐ Near Large Parking Lot

On-Site
- ☐ Hotspot Operation
- ☐ Small Parking Lot
- ☒ Individual Street
- ☐ Underground
- ☐ Individual Rooftop
- ☐ Small Impervious Area
- ☐ Landscape / Hardscape
- ☐ Other:

DRAINAGE AREA TO PROPOSED RETROFIT

Drainage Area ≈ 11 ac
Imperviousness ≈ 50 %
Impervious Area ≈ 5.5 ac

Notes:

Drainage Area Land Use:
- ☒ Residential
  - ☒ SFH (< 1 ac lots)
  - ☐ SFH (> 1 ac lots)
  - ☐ Townhouses
  - ☐ Multi-Family
- ☐ Commercial
- ☐ Institutional
- ☐ Industrial
- ☐ Transport-Related
- ☐ Park
- ☐ Undeveloped
- ☐ Other:

EXISTING STORMWATER MANAGEMENT

Existing Stormwater Practice: ☒ Yes ☐ No ☐ Possible
If Yes, Describe:

Combined sewer in road right-of-way
Curb & gutter with catch basins (every ~ 200 feet)

Describe Existing Site Conditions, Including Existing Site Drainage and Conveyance:

- 24' wide road newly resurfaced
- snow dusting
- well-maintained neighborhood, grass lawns, sidewalks - 4'
- no parkway
- no observed sediment sources
- curb & gutter
- Some mature trees within 10 feet of road (mainly one side of street)
- utility poles in sidewalk - catch basins every ~200 ft. to combined sewer

Existing Head Available and Points Where Measured:

not measured

PROPOSED RETROFIT

Purpose of Retrofit:
- [x] Water Quality
- [ ] Recharge
- [x] Channel Protection
- [x] Flood Control
- [x] Demonstration / Education
- [ ] Repair
- [ ] Other: ______

Retrofit Volume Computations - Target Storage:
For 1-inch rainfall: ~ 0.6" runoff
11 Ac x 1/43560 x 0.6"/12 ≈ 24,000 CF

Retrofit Volume Computations - Available Storage:
24' road x 1' equivalent water depth of storage under road
x 2200 ft of road
≈ 53,000 CF

Proposed Treatment Option:
- [ ] Extended Detention
- [ ] Wet Pond
- [ ] Created Wetland
- [x] Bioretention
- [ ] Filtering Practice
- [ ] Infiltration
- [ ] Swale
- [x] Other: Pervious Pavers

Describe Elements of Proposed Retrofit, Including Surface Area, Maximum Depth of Treatment, and Conveyance:

(1) Pervious Pavers on a portion of road - 1300 Block
(2) Bioretention Curb Extensions, 2 or 3 - 1200 Block
(3) Pervious Pavers on a portion of road - 1100 Block
Combined sewer to remain in place - may need to move catch basins

SITE CONSTRAINTS

Adjacent Land Use:
- [x] Residential
- [ ] Commercial
- [ ] Institutional
- [ ] Industrial
- [ ] Transport-Related
- [ ] Park
- [ ] Undeveloped
- [ ] Other: ______

Possible Conflicts Due to Adjacent Land Use? [ ] Yes [x] No
If Yes, Describe:

Access:
- [ ] No Constraints

Constrained due to
- [ ] Slope
- [ ] Space
- [x] Utilities ?
- [x] Tree Impacts
- [ ] Structures
- [ ] Property Ownership
- [ ] Other: ______

Conflicts with Existing Utilities:
- [ ] None
- [x] Unknown

Yes	Possible	
[ ]	[ ]	Sewer
[ ]	[ ]	Water
[ ]	[ ]	Gas
[ ]	[ ]	Cable
[ ]	[ ]	Electric
[ ]	[ ]	Electric to Streetlights
[ ]		Overhead Wires
[ ]	[ ]	Other: ______

Potential Permitting Factors:

Dam Safety Permits Necessary	[ ] Probable	[x] Not Probable
Impacts to Wetlands	[ ] Probable	[x] Not Probable
Impacts to a Stream	[ ] Probable	[x] Not Probable
Floodplain Fill	[ ] Probable	[x] Not Probable
Impacts to Forests	[ ] Probable	[x] Not Probable
Impacts to Specimen Trees	[ ] Probable	[x] Not Probable

How many? ______
Approx. DBH ______

Other factors: ______

Soils:

Soil auger test holes:	[ ] Yes	[x] No
Evidence of poor infiltration (clays, fines):	[x] Yes	[ ] No – soil records
Evidence of shallow bedrock:	[ ] Yes	[ ] No ?
Evidence of high water table (gleying, saturation):	[ ] Yes	[ ] No ?

SKETCH

See map of site.

DESIGN OR DELIVERY NOTES

This site would work well with pervious pavers in parking lanes, especially on the 1300 and 1100 blocks. Roadside parking does not seem to be depended upon, so bioretention curb extensions would work especially on the 1200 Block. Stagger curb extensions to allow 2-way traffic. Pervious pavement storage could be increased by extending subsurface storage across entire road width and/or under sidewalks.

It looked like road was newly resurfaced.

FOLLOW-UP NEEDED TO COMPLETE FIELD CONCEPT

- ☐ Confirm property ownership
- ☒ Confirm drainage area
- ☐ Confirm drainage area impervious cover
- ☐ Confirm volume computations
- ☐ Complete concept sketch
- ☐ Obtain existing stormwater practice as-builts
- ☐ Obtain site as-builts
- ☒ Obtain detailed topography
- ☒ Obtain utility mapping
- ☐ Confirm storm drain invert elevations
- ☐ Confirm soil types

☐ Other:____________________

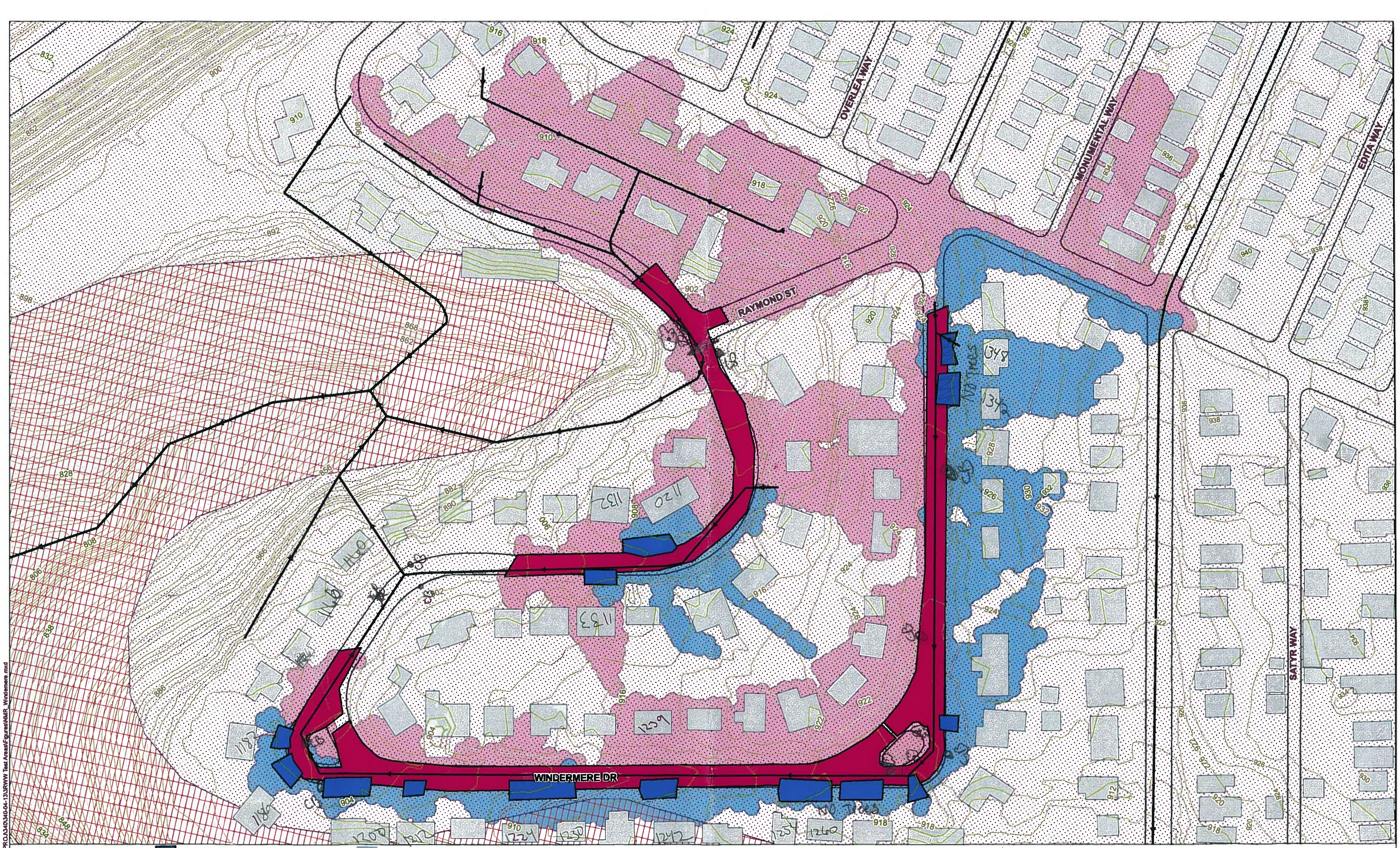
INITIAL FEASIBILITY AND CONSTRUCTION CONSIDERATIONS

Neighborhood acceptance of pervious pavers and curb extension.
Utility locations

SITE CANDIDATE FOR FURTHER INVESTIGATION:	☒ YES	☐ NO	☐ MAYBE
IS SITE CANDIDATE FOR EARLY ACTION PROJECT(S):	☐ YES	☐ NO	☐ MAYBE
IF NO, SITE CANDIDATE FOR OTHER RESTORATION PROJECT(S):	☐ YES	☐ NO	☐ MAYBE

IF YES, TYPE(S):____________________

Unique Site ID: 9MILE-01



3 Rivers Wet Weather
Improving our region's water quality

Municipal Bioretention Candidate Project	Municipal Bioretention Candidate Project Drainage Area
Municipal Infiltration Candidate Project	Municipal Infiltration Candidate Project Drainage Area
Municipal Permeable Pavement Candidate Project	Municipal Permeable Pavement Candidate Project Drainage Area
Commercial Permeable Pavement Candidate Project	Commercial Permeable Pavement Candidate Project Drainage Area

Sewerline	Index Contours
Type B Soil	Index Depression Contours
Type C Soil	Intermediate Contours
Type D Soil	Intermediate Depression Contours

0 50 100 200 300
1 inch = 100 Feet

PM-Ze-1

Nine Mile Run
Windemere Drive

Document Path: N:\PROJ\340\340-04-13\3RWW Test Areas\Figures\NMR_Windemere.mxd