2012 GREEN INFRASTRUCTURE TECHNICAL ASSISTANCE PROGRAM

City of Beaufort, Planning Department
Beaufort, South Carolina

Block-Scale Green Infrastructure Design for the Historic Northwest Quadrant, City of Beaufort

Photo: Morris Street, City of Beaufort

AUGUST 2013
EPA 830R13006

About Green Infrastructure Technical Assistance Program

Stormwater runoff is a major cause of water pollution in urban areas. When rain falls in undeveloped areas, the water is absorbed and filtered by soil and plants. 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 and discharged into nearby waterbodies. 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. These neighborhood or site-scale green infrastructure approaches are often referred to as low impact development.

EPA encourages the use of green infrastructure to help manage stormwater runoff. In April 2011, EPA renewed its commitment to green infrastructure with the release of the Strategic Agenda to Protect Waters and Build More Livable Communities through Green Infrastructure. The agenda identifies technical assistance as a key activity that EPA will pursue to accelerate the implementation of green infrastructure.

In February 2012, EPA announced the availability of $950,000 in technical assistance to communities working to overcome common barriers to green infrastructure. EPA received letters of interest from over 150 communities across the country, and selected 17 of these communities to receive technical assistance. Selected communities received assistance with a range of projects aimed at addressing common barriers to green infrastructure, including code review, green infrastructure design, and cost-benefit assessments.

Through the assistance provided to the City of Beaufort, South Carolina (City), EPA developed block-scale green infrastructure designs appropriate for the historic residential community located in the City's Northwest Quadrant. These designs respect the historic character of the neighborhood while enhancing the pedestrian environment, adding functional open space, and protecting the Beaufort River and marsh.

For more information, visit http://water.epa.gov/infrastructure/greeninfrastructure/gi_support.cfm

Acknowledgements

Principal EPA Staff

Anne Keller, USEPA Region 4
Katherine Snyder, USEPA Region 4
Tamara Mittman, USEPA
Christopher Kloss, USEPA

Community Team

Lauren Kelly, City of Beaufort
Isiah Smalls, City of Beaufort
Libby Anderson, City of Beaufort
Monica Holmes, The Lawrence Group

Consultant Team

Jason Wright, Tetra Tech
Merrill Taylor, Tetra Tech
Garrett Budd, Tetra Tech
Neil Weinstein, Low Impact Development Center
Doug Davies, Low Impact Development Center

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1. Introduction

In Beaufort, South Carolina, the pristine beauty of the Beaufort River and marsh are essential to the City's economy and livelihood. In order to ensure that future generations are able to appreciate and experience Beaufort's natural beauty, City staff and leadership consider the principles of preservation, growth, and sustainability in each development and infrastructure decision. This commitment to preserving Beaufort's natural resources for future generations has led the City to embrace the concept of green infrastructure for stormwater management. In developing their stormwater management program, the vision of Beaufort's Public Works and Planning Departments is to implement appropriate, low-cost green infrastructure practices to filter and clean stormwater.

To implement appropriate green infrastructure practices within Beaufort's Northwest Quadrant, the City has conceived of the Block by Block Green Infrastructure (3BGI) program. The Northwest Quadrant is a historic residential community with a rich history of planning that seeks to preserve the historic feel of the community, enhance community amenities, and provide sustainable stormwater management. The City articulated its vision for maintaining the historic feel of the Northwest Quadrant in the preservation guidelines adopted in 1999. The goals stated in the guidelines include:

- Maintaining the traditional character of the block;
- Maintaining the informal nature of the streets, lanes, and gardens where they exist;
- Maintaining the soft edges found along neighborhood streets; and
- Encouraging informal gardens throughout the neighborhood.

The Neighborhood Strategic Plan, adopted in 2008, includes goals related to stormwater management in the community. The plan highlights the goals of:

- Encouraging the use of rain barrels and greywater recycling;
- Supporting community gardens; and
- Identifying future pocket park locations.

Given the aesthetic, social, and environmental goals identified for the Northwest Quadrant, the City determined that block-scale green infrastructure practices would be most appropriate for this community, and developed the concept of the Block by Block Green Infrastructure (3BGI) program. The US EPA recognized the unique opportunity to address historic preservation, community open space, and water quality goals in the Northwest Quadrant and selected the City to receive technical assistance. Through this technical assistance, EPA developed conceptual designs for two block-scale green infrastructure interventions in the Northwest Quadrant. One design was developed for the redevelopment of Duke Street between Ribaut Road and Bladen Street, and a supplementary second design was developed for the underutilized open space at the southeast intersection of Hamar Street and Prince Street. The project area is illustrated in Figure 1-1 and will be referred to as the 3BGI Northwest Quadrant Project Site. The City's vision for the 3BGI Site is to develop a green street corridor along Duke Street as well as a supplemental vegetated infiltration basin within the open space parcel that preserve the historic feel of the neighborhood.

This project will provide community space that serves as a stormwater facility, an amenity, and an educational opportunity for the entire community. The project will serve as a model for other existing neighborhoods in Beaufort, as well as other historic communities, and will provide a range of appropriate green infrastructure tools that can be implemented citywide.

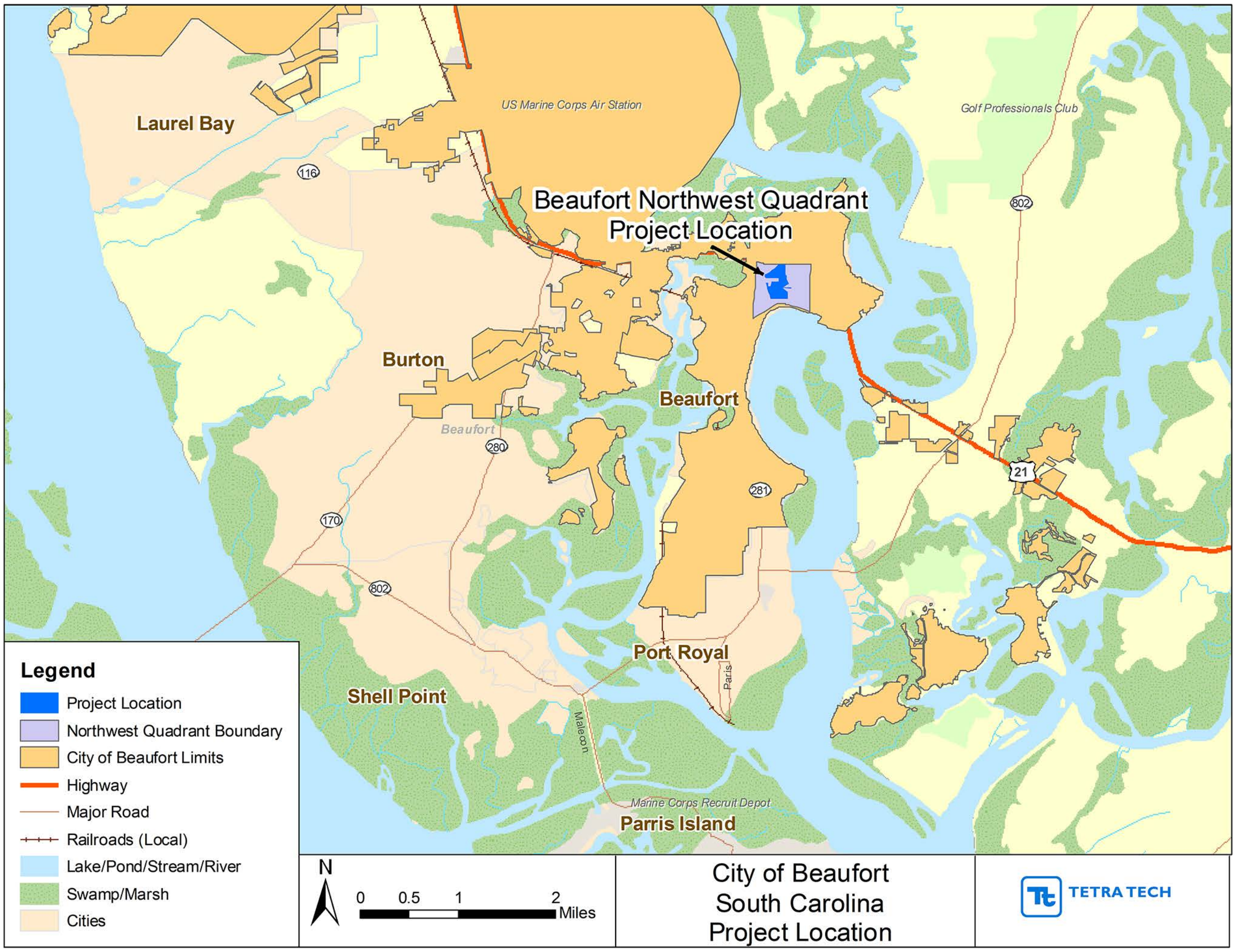


Figure 1-1. Site location map.

1.1. Benefits of Green Infrastructure

Green infrastructure restores the natural hydrologic processes of infiltration, percolation, and evapotranspiration to reduce the adverse effects of urban stormwater runoff on receiving water bodies. Green infrastructure practices have been shown to cost-effectively reduce the impacts of stormwater runoff; reduce maintenance requirements; and provide multiple environmental, social and economic benefits (Kloss 2006). The 3BGI program therefore has the potential to provide a cost savings to the City of Beaufort, while advancing many of the goals articulated in the Preservation Guidelines and Neighborhood Strategic Plan. Some of the additional environmental, social, and economic benefits of green infrastructure include:

Increased enjoyment of surroundings: A large study of inner-city Chicago found that one-third of the residents surveyed said they would use their courtyard more if trees were planted (Kuo 2003). Residents living in greener, high-rise apartment buildings reported significantly more use of the area just outside their building than did residents living in buildings with less vegetation (Hastie 2003; Kuo 2003). Research has found that people in greener neighborhoods judge distances to be shorter and make more walking trips (Wolf 2008). Implementing green infrastructure practices to enhance vegetation, preserve parking within the right-of-way, and add open or park space through the 3BGI project will help to create a more pedestrian friendly environment that encourages walking and physical activity. Green infrastructure practices can also be incorporated into future community gardens and pocket parks, enhancing and increasing the enjoyment of the neighborhood.

Increased safety and reduced crime: Researchers examined the relationship between vegetation and crime for 98 apartment buildings in an inner city neighborhood and found the greener a building's surroundings are, the fewer total crimes (including violent crimes and property crimes), and that levels of nearby vegetation explained 7 to 8 percent of the variance in crimes reported by building (Kuo 2001a). In investigating the link between green space and its effect on aggression and violence, 145 adult women were randomly assigned to architecturally identical apartment buildings but with differing degrees of green space. The levels of aggression and violence were significantly lower among the women who had some natural areas outside their apartments than those who lived with no green space (Kuo 2001b). The stress-reducing and traffic-calming effects of trees are also likely to reduce road rage and improve the attention of drivers. Green streets can also increase safety. Generally, if properly designed, narrower, green streets decrease vehicle speeds and make neighborhoods safer for pedestrians (Wolf 1998; Kuo 2001a).

Increased sense of well-being: There is a large body of literature indicating that green space makes places more inviting and attractive and enhances people's sense of well-being. People living and working with a view of natural landscapes appreciate the various textures, colors, and shapes of native plants, and the progression of hues throughout the seasons (Northeastern Illinois Planning Commission 2004). Birds, butterflies, and other wildlife attracted to the plants add to the aesthetic beauty and appeal of green spaces and natural landscaping. "Attention restorative theory" suggests that exposure to nature reduces mental fatigue, with the rejuvenating effects coming from a variety of natural settings, including community parks and views of nature through windows; in fact, desk workers who can see nature from their desks experience 23 percent less time off sick than those who cannot see any nature, and desk workers who can see nature also report a greater job satisfaction (Wolf 1998).

Increased property values: Many aspects of green infrastructure can increase property values by improving aesthetics, drainage, and recreation opportunities that can help restore, revitalize, and encourage growth in some of the economically distressed areas in the City of Beaufort. Table 1-1 summarizes the recent studies that have estimated the effect that green infrastructure or related practices have on property values. The majority of these studies addressed urban areas, although some suburban studies are also included. The studies used statistical methods for estimating property value trends from observed data.

Table 1-1. Studies estimating percent increase in property value from green infrastructure

Source	Percent increase in Property Value	Notes
Ward et al. (2008)	3.5 to 5%	Estimated effect of green infrastructure on adjacent properties relative to those farther away in King County (Seattle), WA.
Shultz and Schmitz (2008)	0.7 to 2.7%	Referred to effect of clustered open spaces, greenways and similar practices in Omaha, NE.
Wachter and Wong (2006)	2%	Estimated the effect of tree plantings on property values for select neighborhoods in Philadelphia.
Anderson and Cordell (1988)	3.5 to 4.5%	Estimated value of trees on residential property (differences between houses with five or more front yard trees and those that have fewer), Athens-Clarke County (GA).
Voicu and Been (2008)	9.4%	Refers to property within 1,000 feet of a park or garden and within 5 years of park opening; effect increases over time
Espey and Owasu-Edusei (2001)	11%	Refers to small, attractive parks with playgrounds within 600 feet of houses
Pincetl et al. (2003)	1.5%	Refers to the effect of an 11% increase in the amount of greenery (equivalent to a one-third acre garden or park) within a radius of 200 to 500 feet from the house
Hobden, Laughton and Morgan (2004)	6.9%	Refers to greenway adjacent to property
New Yorkers for Parks and Ernst & Young (2003)	8 to 30%	Refers to homes within a general proximity to parks

2. 3BGI Northwest Quadrant Project Site

The Northwest Quadrant is a historic neighborhood established following the Civil War by freed slaves looking for work and stability. Between downtown Beaufort and the Boundary Street Redevelopment District, the Northwest Quadrant is a diverse neighborhood that is part of the larger Beaufort National Historic Landmark District. The historically African American neighborhood consists of simple one- and two-story houses built from 1865 to 1950. In recent years the Northwest Quadrant has experienced a resurgence due to its location, culture, diversity, and character. Preserving this diversity and character is the impetus for appropriate new green infrastructure investments.

The Northwest Quadrant Neighborhood is adjacent to the pristine marsh of the Beaufort peninsula in the Low country of South Carolina (Figure 2-1). The elevation ranges from approximately 10 to 25 feet, with several gradual topographic depressions throughout. These topographic depressions result in several places in the neighborhood that collect water instead of conveying runoff to the marsh. The standing water results in safety issues and can cause building damage. Pollutants from urban land uses, including bacteria, nutrients, and heavy metals, also create a hazard for the Beaufort River ecosystem.

Using green infrastructure concepts at the block scale in the Northwest Quadrant will preserve the small single family lots and provide opportunities for additional urban housing, while also improving water quality and drainage in a manner appropriate for the historic neighborhood. 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. Following this project, the City hopes to apply block-scale green infrastructure interventions to other urban neighborhoods. The City may be able to leverage private investment in the neighborhood to build these green infrastructure interventions.

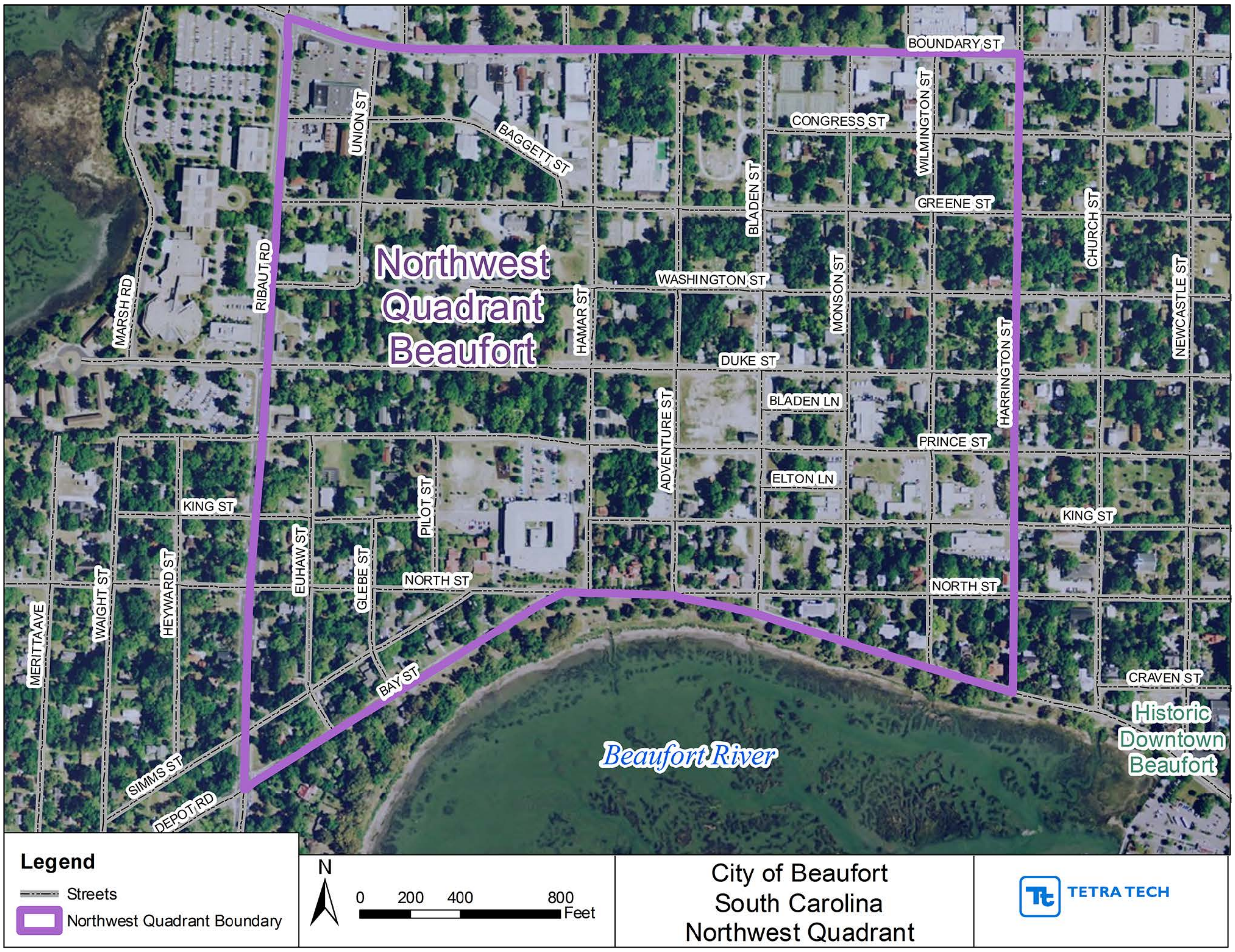


Figure 2-1. Northwest Quadrant boundary.

2.1. Existing Site Conditions

The Northwest Quadrant is primarily residential and traditionally has very few streets with curb and gutter. Stormwater typically surface-drains directly into the sandy/loamy soils through a system of state-owned, poorly maintained swales and roadsides. During small rain events, the soil quality of the Northwest Quadrant typically allows for rainwater to filter into the sandy soils. In larger rain events (typical of spring and summer), however, standing water tends to collect in numerous locations. The neighborhood has a low to medium density configuration with small houses on small- to medium-sized lots that are close to the street and often lack yard space for conventional stormwater treatment. The inadequate space and urban setting requires a more comprehensive strategy that evaluates the drainage on a "block-by-block" approach. To address these issues, the City recently implemented multiple pilot projects incorporating permeable pavement within the parking lanes along Bladen Street and is interested in implementing additional pilot projects in the neighborhood. The 3BGI Northwest Quadrant Project Site (the area of interest for this project) spans Boundary Street to King Street and Union Street to Bladen Street and encompasses approximately 36 acres as shown in Figure 2-2.

An analysis of the existing utilities and site topography indicated that surface water generally flows north to south on the site. The Department of Social Services is located within the 3BGI site area and manages its own stormwater runoff by providing treatment with a dry extended detention basin. Because of the onsite stormwater treatment at the Department of Social Services, it was excluded in the delineation of the contributing areas to the proposed green infrastructure practices, as indicated in Figure 2-2. The existing stormwater drainage network currently outfalls to the Beaufort River which was listed with an approved total maximum daily load (TMDL) for dissolved oxygen in April 2006.

The predominant soil type in the City is sandy with a hydrologic soil group classification of Type A, indicating the potential for high infiltration rates. There are no known potential soil contamination issues (including leaking underground storage tanks) within the project contributing area. The area is not designated as a groundwater recharge area. There are no environmentally sensitive areas within the project limits and project efforts will improve the stormwater impact to the downstream receiving waters and wetlands.

The Duke Street location right of way, shown in Figure 2-3, is owned and maintained by the South Carolina Department of Transportation, but the City of Beaufort could assume ownership in the future. The proposed vegetated infiltration basin site, shown in Figure 2-4, is comprised of multiple privately-owned parcels with an area maintained as open space (open space parcel). Rights to the parcels must be secured prior to project design.

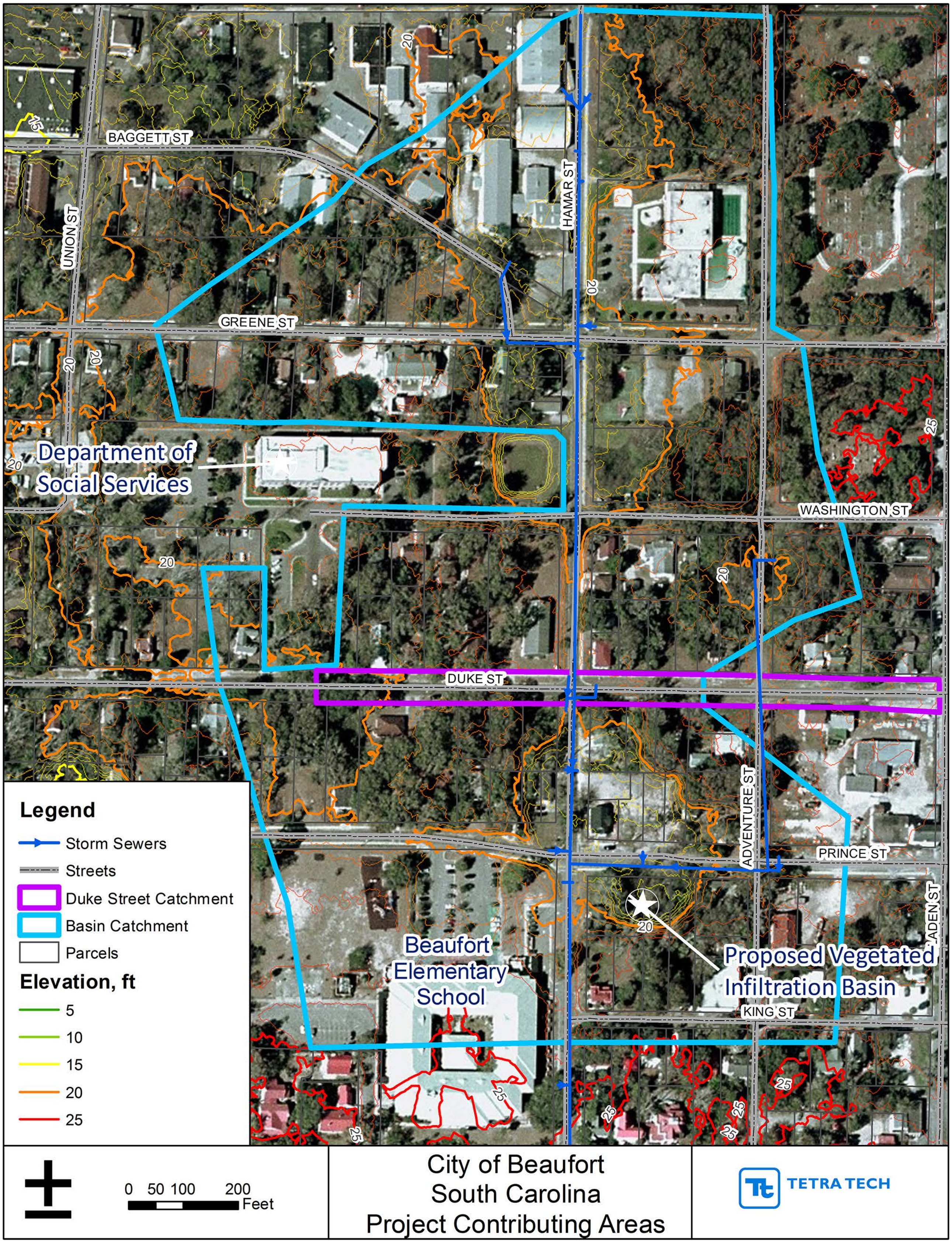


Figure 2-2. Contributing drainage areas and existing conditions.

Figure 2-3. 3BGI green street site, east side.

Figure 2-4. 3BGI vegetated infiltration basin site.

2.2. Proposed Site Design

In November 2012, a team consisting of City Staff, EPA Region 4, and multiple consultants participated in the Northwest Quadrant Stormwater Charrette for the 3BGI project. The goal of the design charrette was to evaluate the neighborhood to identify potential implementation sites and types of green infrastructure practices that could be incorporated into these sites. Through the course of the charrette, participants identified two locations for green infrastructure conceptual designs: a two-block segment of Duke Street, and an open space parcel at the southeast corner of Hamar and Price Streets. Participants identified green street design elements as appropriate practices for the Duke Street location, and a vegetated infiltration basin as an appropriate practice for the open space parcel.

The overall vision for stormwater management discussed at the design charrette was to incorporate a variety of green infrastructure techniques into the conceptual designs at different spatial scales, from a lot level to a neighborhood level. These techniques would be transect-specific, relating to their surrounding context. A memo describing the charrette process was delivered on December 12, 2012 and is included in Appendix C. See Section 5 for more detail regarding the conceptual design of the stormwater control measures.

3. Goals

Beaufort County has been at the forefront of adopting green infrastructure standards for new development. However, the toolset is lacking for existing urban development. The Northwest Quadrant project will be the first in the county to explore an urban toolset applying green infrastructure concepts to an existing historic neighborhood on a block-by-block scale. This block scale application could also create opportunities for the addition of dense infill development that drains to a series of block- and neighborhood-scale green infrastructure practices. The proposed framework will provide flexible treatment solutions that can be adapted to the goals and standards of a range of existing development types, including historic residential areas, while maintaining the character of the neighborhood.

3.1. Project Goals

While allowing for full development of the 3BGI site, 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. Matching natural hydrologic conditions will improve drainage, reduce local flooding, and improve water quality. Secondary goals of the project are to improve the aesthetic appeal of the neighborhood while maintaining the historic character of the area and to reinforce the right-of-way to prevent vehicles from negatively impacting the vegetation on the edge of the road. These goals will be accomplished through implementation of permeable pavement and bioretention along Duke Street and a vegetated infiltration basin at the southeast corner of Hamar and Prince Street. It is feasible that a stormwater wetland could be effective at this location; however, a vegetated infiltration basin will provide greater volume reduction due to the infiltration capacity of the native soils and is recommended for the site. Use of these practices will allow the existing community to achieve the desired additional on-street parking and landscaping while still protecting and improving water quality.

3.2. Design Goals

Stormwater management design criteria for the City of Beaufort are provided in the Beaufort County Manual for Stormwater Best Management and Design Practices (2012). According to the Design Criteria Manual, stormwater measures must be designed to capture the 1.95 inch, 24-hour Type III storm event. To simplify the design process, the manual requires that the volume sizing of the green infrastructure practice be the greater of 0.5 inch of runoff over the entire contributing area or 1.5 inches of runoff over the impervious area. Additional design criteria as identified in the Beaufort County Best Management Practices Manual are summarized as specifications in Section 6 of this report.

In addition to sizing practices to manage the specified design storms, modeling was performed to estimate the maximum storm size that could be captured if all of the available space for green infrastructure were utilized.

4. Green Infrastructure Toolbox

Green infrastructure typically incorporates multiple practices utilizing the natural features of the site in conjunction with the goal 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, thus providing water quality improvement and volume reduction. Typical large scale practices include approaches such as vegetated infiltration basins and stormwater wetlands. Smaller scale practices typically include approaches such as permeable pavement and bioretention facilities. The green infrastructure practices identified as appropriate for the Beaufort region included vegetated green infrastructure practices, permeable pavement, and stormwater wetlands. To assist the City in incorporating green infrastructure practices into the project locations, the following discussion addresses constraints and opportunities associated with each 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 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, right of ways, and other locations within impervious areas. The following sections discuss two types of vegetated green infrastructure practices; bioretention areas and vegetated infiltration basins. Each provides a similar water treatment mechanism but provides different scales of treatment. Bioretention areas are typically designed to treat watersheds of less than 5 acres, whereas vegetated infiltration basins are designed to provide treatment for much larger areas.

Bioretention: Bioretention typically consists of vegetation, a ponding area, mulch layer, and planting or engineered 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 (water quality) storm 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).

Figure 4-1. Bioretention incorporated into a parking lot.

Figure 4-2. Bioretention incorporated into a right-of-way.

Vegetated Infiltration Basin: A vegetated infiltration basin is a constructed depression designed to provide temporary storage of stormwater for subsequent infiltration into the underlying soil. Vegetated surfaces along the bottom and sides of the infiltration basin allow for pollutant removal and treatment of stormwater within the basin through a variety of physical, biological, and chemical treatment processes before it infiltrates into the groundwater. Amended or engineered soils and plant selection differentiate the vegetated infiltration basin from other County infiltration measures including trenches and wells. A vegetated infiltration basin consists of a ponding area and vegetated surface. Infiltration basins, in general, are commonly used as water quality controls with additional benefits such as storage and groundwater recharge. Large scale vegetated infiltration basins typically require large open parcels and can be configured to provide multi-use benefits including use as parks between rain events, such as the one shown in Figure 4-3, or outdoor classrooms.

Figure 4-3. Vegetated infiltration basin incorporated into an open space park.

4.2. Permeable Pavement

Conventional pavement results in increased surface runoff rates and volumes relative to pre-developed conditions. Permeable pavements, in contrast, work by allowing streets, parking lots, sidewalks, and other impervious surfaces to retain the underlying soil's natural infiltration capacity while maintaining the structural and functional features of the materials they replace. Permeable pavements contain small voids that allow water to drain through the pavement to an aggregate reservoir and then infiltrate into the soil. If the native soils below the permeable pavements do not have enough percolation capacity, underdrains can be included to direct the stormwater to other downstream stormwater control systems. Permeable pavement can be developed using modular paving systems (e.g., concrete pavers, grass-pave, or gravel-pave) or poured-in-place solutions (e.g., pervious concrete or permeable 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 pavements 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 pavements along shoulders or in parking areas can be implemented to provide a cost effective solution to meet both transportation and stormwater management requirements. Permeable pavements are most often used in constructing pedestrian walkways, sidewalks, driveways, low-volume roadways, and parking areas of office buildings, recreational facilities, and shopping centers (Figure 4-4 and Figure 4-5).

Figure 4-4. Grass paver parking stalls.

Figure 4-5. Permeable Interlocking Concrete Paver parking stalls.

4.3. Stormwater Wetland

A stormwater or constructed wetland is a constructed basin designed to treat stormwater by temporarily storing runoff to allow for pollutant removal and water quality improvement. Stormwater wetlands employ a combination of physical, chemical, and biological processes to remove multiple pollutants carried by stormwater runoff including sediment, metals, motor oil, pathogens and nutrients. Wetland plants help to slow incoming runoff, allowing sediment and other particles to fall out of suspension and settle in the wetland. Stormwater wetlands consist of varying ponding depths, or zones, including deep pools, shallow water, and areas of temporary inundation. The variable depths allow for ample and diverse vegetation that remove nitrogen and phosphorus through direct uptake to fuel their own growth. Bacteria living with wetland plants and sediment are especially important in providing water treatment services by breaking down hydrocarbons, such as oil, and removing excess nitrogen from the water through a process called denitrification. The distinction should be made that a stormwater wetland does not divert runoff into a natural, existing wetland but rather creates a new, distinct engineered wetland designed with the intent of controlling and treating stormwater. Stormwater wetlands are most effective in conditions where infiltration is not feasible. Infiltration provides the greatest water quality benefit; however, pending the results of a full geotechnical investigation, if infiltration is proven to be infeasible at the open space parcel at Hamar Street and Prince Street, then a stormwater wetland will be an appropriate green infrastructure practice.

In addition to pollutant reduction, stormwater wetlands can provide important habitat for plants, insects, amphibians, birds, and other animals that is otherwise lacking in most urban landscapes, contributing to greater biologic diversity in urban and suburban areas. Biodiversity is an important part of most ecosystems as it underpins the provision of many other ecosystem services. For instance, diverse plant and benthic macroinvertebrate communities may improve nutrient cycling and removal in stormwater wetlands and have increased resilience against disturbances such as drought or disease. Stormwater wetlands can support a diverse community of aquatic insects and fish that prey upon mosquito larvae, providing control of mosquitoes. Stormwater wetlands can provide a place for community members to participate in recreational activities and be incorporated as an amenity in community parks and open space like the stormwater wetland shown in Figure 4-6. Many wetland plants produce colorful flowers that attract dragonflies, butterflies, and birds, making stormwater wetlands an ideal place to observe wildlife within urban and suburban areas. Walking trails and boardwalks can be installed in stormwater wetlands treating runoff from neighborhoods to provide community members a place to stroll and enjoy the aesthetic component of these constructed ecosystems. Stormwater wetlands are complex ecological systems that can also be utilized as an educational amenity providing a site for hands-on learning. Educational signs can be placed at any stormwater wetland to inform the public about the beneficial suite of services these ecosystems provide.

Figure 4-6. Stormwater wetland.

5. Green Infrastructure Design

This section addresses the selection, layout, and design of the green infrastructure practices for the 3BGI site in Beaufort. The selection and proposed layout of the controls are based on discussions during the charrette as detailed in Section 2.2. The conceptual layout and sizing of green infrastructure practices to meet the water quality objectives are discussed in Section 5.3. Details on design information are summarized and presented in Section 6 to assist with final design of the green infrastructure practices.

5.1. Design Elements

The selection and proposed layout of the stormwater control measures are based on discussions during the charrette where improving water quality on the site; incorporating and preserving vegetated areas; and preserving the historic character of the neighborhood were emphasized as high priorities. The sites were selected based on multiple factors including the potential to improve drainage or reduce flooding, potential water quality improvement based on treatment volume, potential for green infrastructure practice demonstration, multi-use benefit for the surrounding neighborhood, and ancillary benefits such as aesthetic improvement. The potential for green infrastructure practice demonstration was evaluated based on the proximity to parks, schools, or other BMPs that would attract the public.

Duke Street is in close proximity to permeable pavement implemented along Bladen Street and Duke Street east of Bladen Street. While the right-of-way between the curb and sidewalk is not designated or delineated for parking, current residents are parking in the space impacting the grass and destabilizing the area causing a potential for erosion. Permeable pavement implemented in the right-of-way on Duke Street west of Bladen Street would stabilize the right-of-way and bioretention could add additional opportunities for landscaping enhancing the current efforts by providing additional treatment and opportunity for demonstration in the Northwest Quadrant.

A stormwater diversion structure implemented in the right of way at Prince Street and Hamar Street would divert flow from the stormwater drainage network to the undeveloped, open space parcel at the intersection of Hamar Street and Prince Street prior to discharging to the Beaufort River, thus providing water quality treatment and protecting the quality of the river. The parcel is directly adjacent to the Beaufort Elementary School, providing educational opportunities for the students and teachers. A green infrastructure practice installed at the site could also provide multi-benefit uses to the surrounding residents, serving as an open space park in addition to providing water quality treatment. All of these benefits were emphasized and expressed as critical elements of the goals of the City of Beaufort during the charrette process. For additional details on the charrette process and the selection of the green infrastructure practices, see Appendix C.

5.2. Analytical Methods

The Beaufort Design Manual allows stormwater controls to be sized to capture the greater of 1.5 inches over the impervious area or 0.5 inches over the entire drainage area. The greatest amount of runoff was produced by 1.5 inches of rainfall over the entire impervious area in the drainage areas of interest, and was therefore selected as the design target for this analysis.

EPA's Storm Water Management Model (SWMM) was used to assess the existing runoff conditions and evaluate green infrastructure opportunities in the project area (USEPA 2004). SWMM is a dynamic precipitation-runoff simulation model designed for discrete event or continuous representation of hydraulics, hydrology, and water quality in urbanized catchments. SWMM represents land areas as a series of *subcatchments*, with properties that define retention and runoff of precipitation, infiltration, percolation to a shallow aquifer, and discharge from the aquifer. Subcatchments are connected to the drainage network, which may include natural watercourses, open channels, culverts and storm drainage pipes, storage and treatment units, outlets, diversions, and many other elements of an urban drainage system.

The subcatchment areas for the proposed green infrastructure practices were derived from LIDAR topographic data and field visits (Figure 2-2). Note that these data will need to be validated as part of the final design. The drainage areas were represented as a residential land use per the land use map generated by the City. The imperviousness was calculated at 50% for Duke Street and 32% for the vegetated infiltration basin catchment using the building footprint and road area data made available. The soil was represented as a high-infiltrating sandy soil (Hydrologic Soil Group A) per the Natural Resources Conservation Service Soil Survey and field observations.

Green infrastructure practice improvements were represented using the low impact development (LID) components recently introduced in SWMM 5. LID is modeled in SWMM using a layered configuration that allows a great deal of flexibility in representing various types of practices, including bioretention, swales, infiltration devices, permeable pavement, rain barrels, and cisterns. Horton or Green-Ampt infiltration parameters can be defined for filtering media, and the model tracks evaporation and soil moisture, allowing infiltration rates during runoff events to be dynamic. Green infrastructure practices are sized by assuming an equivalent depth and calculating the surface area required to treat the design storm.

To size the design elements in the project area, bioretention and permeable pavement were incorporated into the Duke Street sub-catchment, while a storage basin model was incorporated into the basin sub-catchment to represent the vegetated infiltration basin. Table 5-1 shows the volume of runoff produced by the 1.5 inch design target that must be treated by the green infrastructure practices. All of the detailed SWMM modeling assumptions used in this study can be found in Appendix B.

Table 5-1. Subcatchment delineations and runoff volumes.

Subcatchment	Subcatchment drainage (acres)	Volume of water 1.95 inch, 24-hour Type III (cu ft)	Volume of water 25-year, 24-hour Type III (cu ft)
Duke Street - Green Street	1.5	4,140	26,790
Vegetated Infiltration Basin	36.3	82,200	553,210

5.3. Recommended Sizing and Layout

The conceptual layout and sizing of the green infrastructure practices with in the right-of-way along Duke Street and at the corner of Prince and Hamar Streets are discussed in this section.

Green Street: Green infrastructure BMPs could be implemented in the right-of-way in the eight feet of pervious area between the edge of the curb and the sidewalk for the length of Duke Street to treat the runoff from the adjacent parcel and one driving lane of Duke Street. The available area and green infrastructure practice dimensions of bioretention and permeable pavement along Duke Street are shown in Table 5-2 and Figure 5-1. A bioretention area of 1,453 square feet with an equivalent depth of approximately 1.4 feet (providing a storage volume of 2,034 cubic feet) and a permeable pavement area of 2,906 square feet with an equivalent depth of approximately 0.3 feet (providing a storage volume of 872 cubic feet) will be required to treat the design storm. The primary design parameters for bioretention conceptual sizing included the surface storage depth, planting soil depth and void space ratio, and native soil infiltration rate. The primary design parameters for permeable pavement conceptual sizing included the surface storage depth, pavement thickness, aggregate base depth, void space ratio, and native soil infiltration rate. The water storage volume is the product of the area and equivalent storage depth. Equivalent storage depth is the sum of the surface ponding depth and the product of the soil depth and porosity. Storage volume indicates the green infrastructure practice volume required to treat the design storm. Because infiltration is accounted for in the design, the water storage volume will be less than the required treatment volume allowing for smaller green infrastructure practices to treat equivalent volumes. Each of the primary design parameters can vary in the final design and the design goals will be met as long as the water storage volume capacity is maintained. Utilizing all of the area available for implementation (6,717 square feet of bioretention and 13,434 square feet of permeable pavement) will provide treatment for the runoff generated by the 5.97 inch event (approximately a 5 year event), substantially more than is required by the current design storm. The analysis indicates that approximately one-quarter of the available area would be required to treat the runoff generated from the 1.95 inch event, as shown in Table 5-3 and Figure 5-2. Additional analysis, including the cost estimate, will focus on treating the design storm.

Table 5-2. Available area for green infrastructure practices.

Green Infrastructure Practice	Green Infrastructure Practice Location	Width (ft)	Length (ft)	Surface Area (sq ft)	Water Storage Volume (cu ft)
Bioretention	Right-of-way	8	840	6,717	9,404
Permeable Pavement	Right-of-way	8	1,680	13,434	4,030

Figure 5-1. Available green infrastructure practice area on Duke Street.

Table 5-3. Green infrastructure practices proposed for redevelopment of Duke Street to treat the 1.95 inch event

Green Infrastructure Practice	Green Infrastructure Practice Location	Width (ft)	Length (ft)	Surface Area (sq ft)	Water Storage Volume (cu ft)
Bioretention	Right-of-way	8	182	1,453	2,034
Permeable Pavement	Right-of-way	8	363	2,906	872

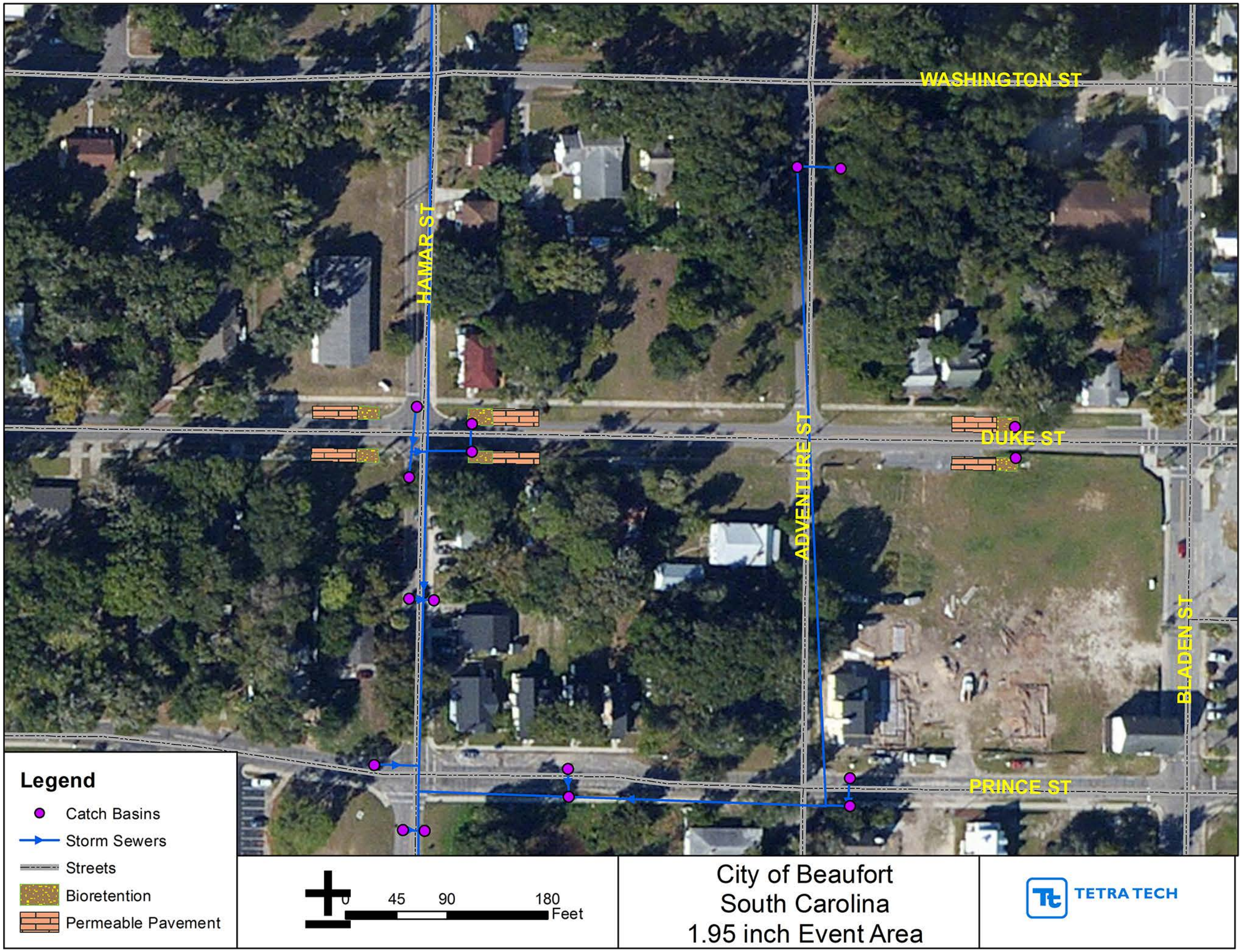


Figure 5-2. Recommended green infrastructure practice area on Duke Street to treat the 1.95 inch event.

Vegetated Infiltration Basin: The dimensions of the vegetated infiltration basin proposed for the southeast corner of Prince and Hamar Streets are presented in Table 5-4 and Figure 5-3. The width and length are limited by the available area and current grading of the parcel. A vegetated infiltration basin with a surface area of 15,700 square feet and storage volume of 20,880 cubic feet would provide treatment for the runoff generated by the 1.22 inch event. While this is less than the design storm, an infiltration basin at this site will provide significant volume reduction and water quality treatment for the watershed. The primary design parameters for the vegetated infiltration basin conceptual design included contributing volume, available surface area, and native soil infiltration rates. Side slopes are also accounted for where applicable. A stormwater wetland could be an appropriate control for the site if the benefits of a stormwater wetland are preferred. Performance specifications for a stormwater wetland are provided in section 6.1.5. In order to maintain a permanent pool within the stormwater wetland, infiltration must be limited or prevented. It was determined, due to the lack of infiltration, that a stormwater wetland can only treat the runoff from the 0.45 inch event, providing significantly less treatment than a vegetated basin that utilizes the infiltration capacity of the native soils. Because of the significantly greater treatment capacity, the vegetated infiltration basin is recommended and will be the focus of the remaining analysis including the cost estimate.

Table 5-4. Green infrastructure practice proposed for the southeast corner of Hamar and Prince Street

Green Infrastructure Practice	Green Infrastructure Practice Location	Width (ft)	Length (ft)	Ponding Depth (ft)	Surface Area (sq ft)	Water Storage Volume (cu ft)
Vegetated infiltration Basin	Open Space Parcel	125	125	2.0	15,700	20,880

Additional design details for each green infrastructure practice are included in Appendix A.

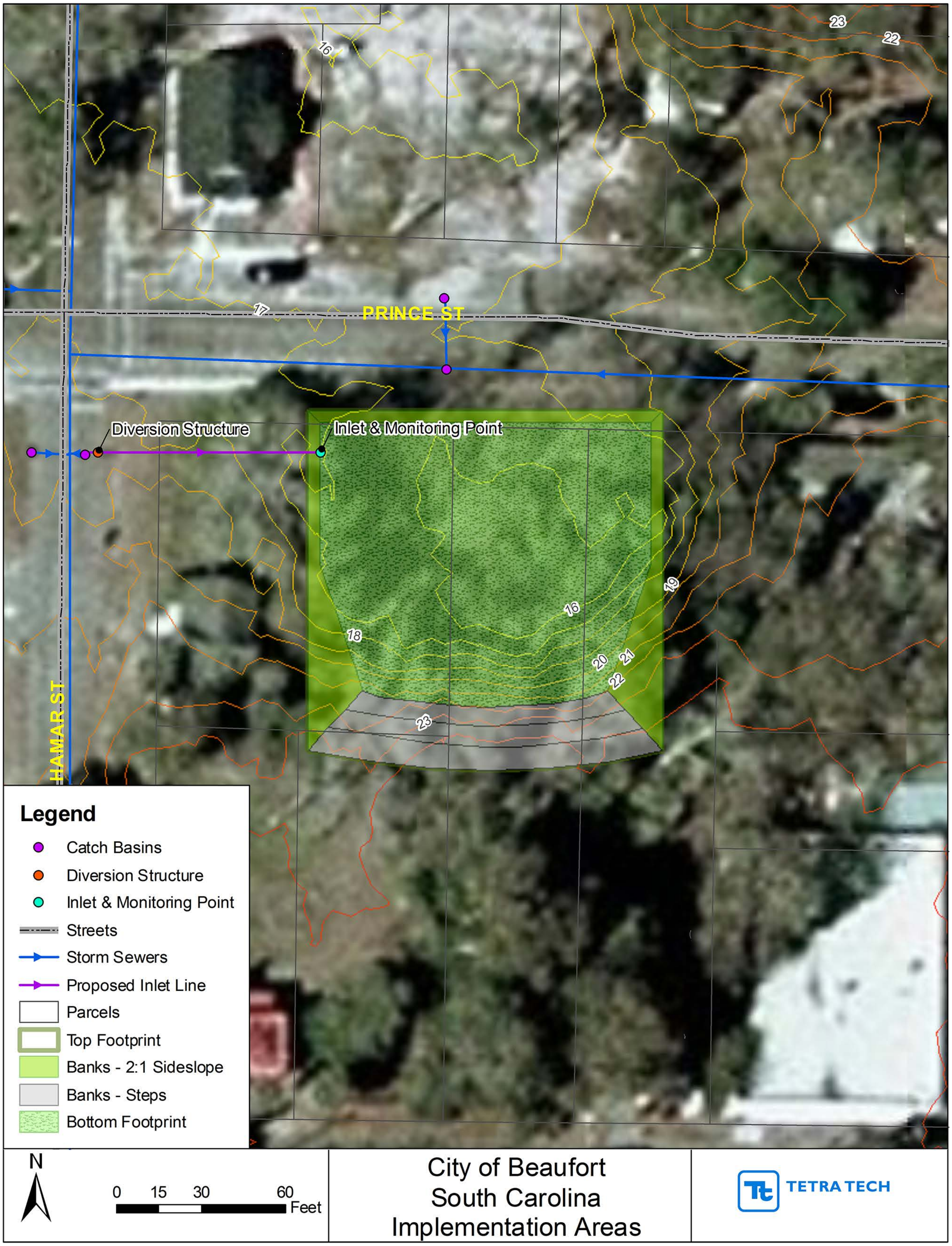


Figure 5-3. Hamar and Prince Street vegetated infiltration basin layout.

6. Green Infrastructure Practice Technical Specifications

The purpose of this section is to provide guidance for designing the green infrastructure practices during final design. Design guidance for each applicable green infrastructure practice is presented in a table with an accompanying figure showing a cross-section of a typical design.

6.1. Common Elements

Soil Media

Based on the soil type of the native soils, it is anticipated that infiltration capacity of each site is appropriate for infiltration. However, if the results of the geotechnical investigation (described below) show that the infiltration rate is less than 0.5 in/hr or reveal that infiltration is not feasible for the native soil at either site, an engineered soil media will be necessary. The soil media is typically specified to meet the growth requirements of the selected vegetation while still meeting the hydraulic requirements of the system. 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 20-30 percent compost (by volume). The expected infiltration rate should range from 1 to 2 in/hr.

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

- 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 but generally should be minimized (5 percent). 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 6–8, cation exchange capacity (CEC) should be greater than 5 milliequivalent (meq)/100 g soil.
- High levels of phosphorus in the media have been identified as the main cause of bioretention areas exporting nutrients. All bioretention media should be analyzed for background levels of nutrients. Total phosphorus should not exceed 15 ppm.

Underdrain

If the infiltration rates require an engineered soil media, an underdrain will 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 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 on a minimum 3-foot-wide bed of drainage stone 6 inches deep and cover with the same drainage stone to provide a 16-inch minimum depth around the bottom, sides, and top of the slotted pipe.
- The underdrain should drain freely and discharge to the existing stormwater infrastructure. Alternatively, the underdrain outlet can be upturned to provide an internal sump (internal water storage) to improve infiltration and water quality. The 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.

Plant Selection

For the green infrastructure practice to function properly as stormwater treatment and blend into the landscape, vegetation selection is crucial. Appropriate vegetation will have the following characteristics:

1. Plant materials must be tolerant of drought, ponding fluctuations, and saturated soil conditions for 10 to 48 hours.
2. It is recommended that a minimum of three tree, three shrubs, and/or three herbaceous groundcover species be incorporated to protect against facility failure from disease and insect infestations of a single species.
3. 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.
4. The following site provides assistance in choosing appropriate native species:
   - Beaufort County Manual for Stormwater Best Management and Design Practices (BMP) (http://www.bcgov.net/departments/Engineering-and-Infrastructure/stormwater-management/documents/beaufort_manual_mar2012.pdf)

Geotechnical Investigation

A full geotechnical investigation is necessary to characterize the soils prior to final design. Pertinent information includes permeability at each site, hydrologic soil group type, depth to water table, and the presence of expansive soils. If expansive soils are present, 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.

6.2. Bioretention

Generally, bioretention areas should have the following design features:

- For unlined systems, maintain a minimum of 5 feet between the green infrastructre practice and any adjacent buildings and at least 10 feet between the green infrastructure practice and any adjacent basement.

- Dewater surface in a time of no greater than 24 hours and subsurface within 72 hours either through infiltration with soils of sufficient percolation capacity or with an underdrain system and outlet to a drainage system. Use of an underdrain system is very effective in areas with low infiltration capacity soils.
- Planted with native and noninvasive plant species tolerant of urban environments, frequent inundation, and Beaufort's humid subtropical climate (per Koppen Climate Classification).
- Inclusion of 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.

If the infiltration rates are greater than 0.5 in/hr and infiltration is feasible, the growing layer, filter layer, and drainage layer will not be necessary. Native material will be appropriate for the entire Vertical Component.

1. Siting Setbacks	
Pavement	No requirement
Building	No requirement with lined bottom; otherwise, Basement: ≥ 10 feet No Basement: ≥ 5 feet
Property lines/ROW	≥ 2 feet / ≥0 feet
2. Volume	
Bottom slope	Flat
Side slopes	2H:1V or flatter
Freeboard	6 inches
3. Vertical Component	
Ponding Area	6 inches
Soil Media Layer	≥ 24 inches soil media; 3 inches of mulch, min
Filter Layer	2 to 4 inches of clean medium sand (ASTM c-33) over 2 to 3 inches of #8 or #78 washed stone when drainage layer is used
Drainage Layer	Recommended 12 to 30 in. of clean coarse aggregate AASHTO #4, #5, or equivalent
Native Material	Test infiltration; ≥0.5 in/hr if designing with infiltration

4. Drainage	
Inlet	Curb inlet; sheet flow through grass filter strip; downspout w/ energy dissipation
Outlet	Required to meet release rates
Overflow	Downstream inlet or catch basin set 6 inches above soil surface and connected to storm drainage network
Infiltration	Meet water quality volume requirement
Dewatering	Surface: ≤ 24 hours Sub-surface: ≤ 72 hours
5. Composition	
Surface Treatment	Vegetation and mulch
Soil Media	Meets dewatering requirement; supports plant growth
Side Slopes	Grass or mulch
Mulch	Triple-shredded hardwood
6. Pollutant	
Pretreatment	Required. May include grass filter strip, stone trench, forebay, sump inlets
7. Maintenance	
Access	Able to be accessed by a vehicle
Requirements	Designed and maintained to improve water quality; Maintenance plan should be in place

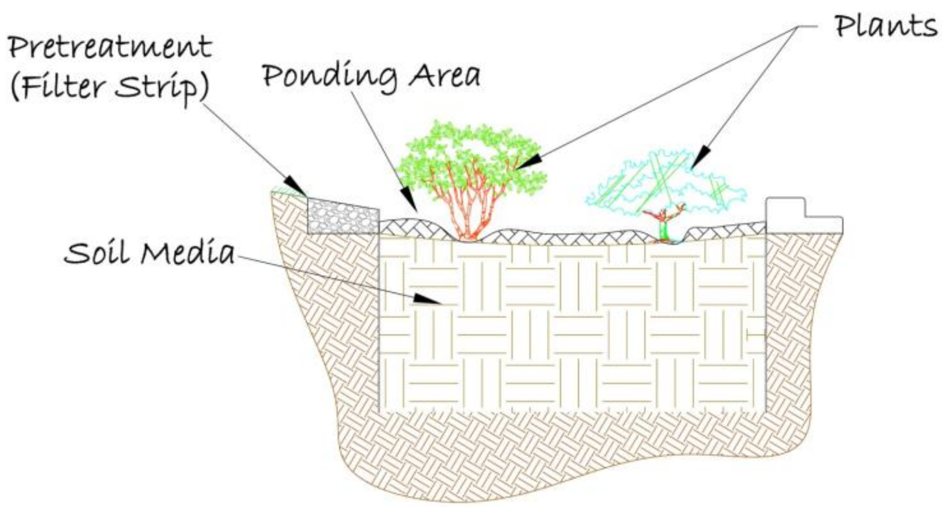


Figure 6-1. Typical bioretention configuration.

6.3. Permeable Pavement

General guidelines for applying permeable pavement are as follows:

- Permeable pavements can be substituted for conventional pavements 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 granular capping and sub-base 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 24 to 48 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 pavements from high sediment loads, particularly fine sediment, to reduce maintenance. Typical maintenance includes removing sediment with a vacuum truck. If the infiltration rates are greater than 0.5 in/hr and infiltration is feasible, the base layer may be reduced to 6 inches.

1. Siting Setbacks	
Pavement	No requirement
Building	No requirement with lined bottom; otherwise, Basement: ≥ 10 feet No Basement: ≥ 5 feet
Property lines/ROW	≥ 2 feet / ≥0 feet
2. Volume	
slope	Less than 0.5 percent
Side slopes	Not applicable
Freeboard	Not applicable
3. Vertical Component	
Surface Layer	Interlocking Concrete Pavers; Concrete Grid Pavers; Plastic Grid Pavers; Concrete; Asphalt
Growing Layer	Not applicable
Bedding	1) Perm. Interlocking Conc. Pavers: 1.5 to 3 inches of #8 or #78 washed stone 2) Concrete and Plastic Grid Pavers: 1 to 1.5 inches of bedding sand 3) Pervious Concrete and Asphalt: None
Structural Layer	12 to 30 in. of clean aggregate AASHTO #56 or equivalent; thickness depends on strength/storage needed; install 30 mil geotextile liner where aggregate meets soil
Undisturbed Base Soil	Compacted as sub-base

4. Drainage	
Inlet	Pavement surface
Outlet	Required to meet release rates
Overflow	Downstream inlet
Infiltration	Meet water quality volume requirement
Dewatering	≤ 72 hours
5. Composition	
Surface Treatment	For interlocking or grid-type pavers use fine aggregate, coarse sand, or top soil & grass in openings
6. Pollutant	
Pretreatment	Divert runoff from sediment sources away from pavement
7. Installation and Maintenance	
Installation	Per manufacturer's recommendation
Load Bearing	Designed for projected traffic loads using AASHTO methods
Requirements	Designed and maintained to improve water quality; Maintenance plan should be in place

Notes: A reinforced concrete transition width (12 -18 inches) is required where permeable pavement meets adjacent non-concrete pavement or soil.

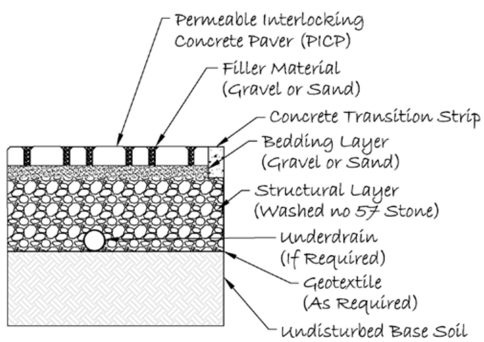


Figure 6-2. Permeable interlocking concrete pavers.

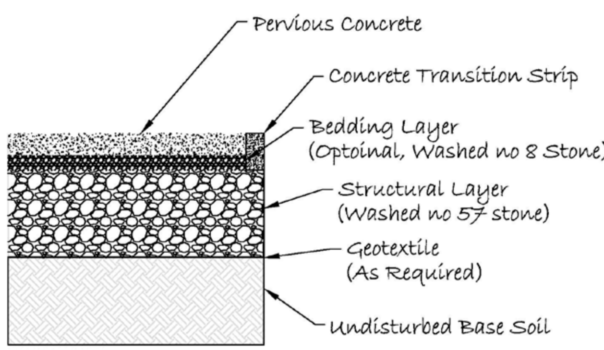


Figure 6-3. Pervious concrete.

6.4. Vegetated Infiltration Basin

Generally, vegetated infiltration basins should have the following design features:

- For unlined systems, maintain a minimum of 5 feet between the green infrastructre practice and any adjacent buildings and at least 10 feet between the green infrastructure practice and any adjacent basement.

- Dewater surface in a time of no greater than 24 hours and subsurface within 72 hours either through infiltration with soils of sufficient percolation capacity or with an underdrain system and outlet to a drainage system. Use of an underdrain system is very effective in areas with low infiltration capacity soils.
- Planted with native and noninvasive plant species tolerant of urban environments, frequent inundation, and Beaufort's humid subtropical climate (per Koppen Climate Classification).
- Inclusion of 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.

If the infiltration rates are greater than 0.5 in/hr and infiltration is feasible, the growing layer, filter layer, and drainage layer will not be necessary. Native material will be appropriate for the entire Vertical Component.

1. Siting Setbacks	
Pavement	No requirement
Building	No requirement with lined bottom; otherwise, Basement: ≥ 10 feet No Basement: ≥ 5 feet
Property lines/ROW	≥ 2 feet / ≥0 feet
2. Volume	
Bottom slope	Flat
Side slopes	2H:1V or flatter
Freeboard	6 inches
3. Vertical Component	
Ponding Area	2-10 ft typical
Growing Layer	≥ 12 inches soil media; 3 inches of mulch, max
Filter Layer	2 to 4 inches of clean medium sand (ASTM c-33) over 2 to 3 inches of #8 or #78 washed stone when drainage layer is used
Drainage Layer	Recommended 12 to 30 in. of clean coarse aggregate AASHTO #4, #5, or equivalent
Native Material	Test infiltration; ≥1/2 in/hr if designing with infiltration
4. Drainage	
Inlet	Curb inlet; sheet flow through grass filter strip; downspout w/ energy dissipation
Outlet	No requirement, infiltration shall meet release rates
Overflow	Downstream inlet or catch basin set 6 inches above soil surface and connected to storm drainage network
Infiltration	Meet water quality volume requirement
Dewatering	Surface: ≤ 24 hours Sub-surface: ≤ 72 hours
5. Composition	
Surface Treatment	Vegetation and mulch
Soil Media	Meets dewatering requirement; supports plant growth
Side Slopes	Grass or mulch
Mulch	Triple-shredded hardwood
6. Pollutant	
Pretreatment	Required. May include grass filter strip, stone trench, forebay, sump inlets
7. Maintenance	
Observation Wells	Perforated PVC pipe 4- to 6-inches in diameter with a tamper-proof lockable cap in center of trench
Access	Able to be accessed by a vehicle
Requirements	Designed and maintained to improve water quality; Maintenance plan should be in place

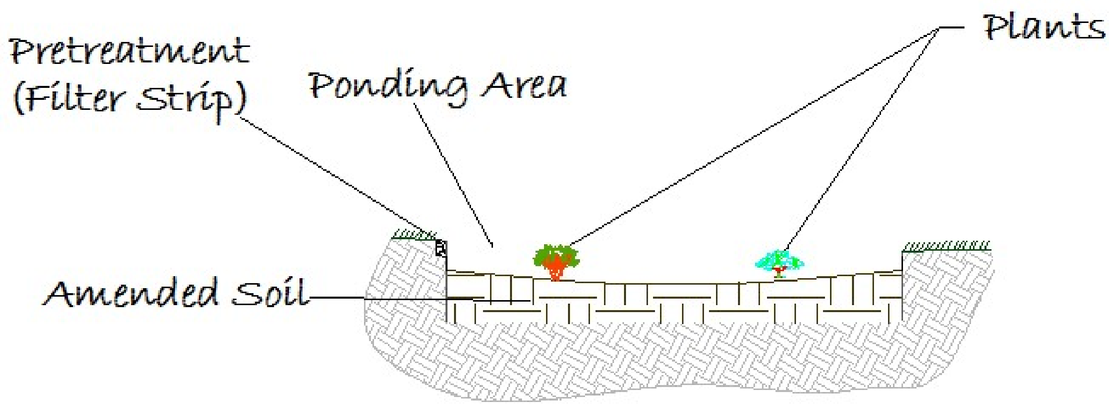


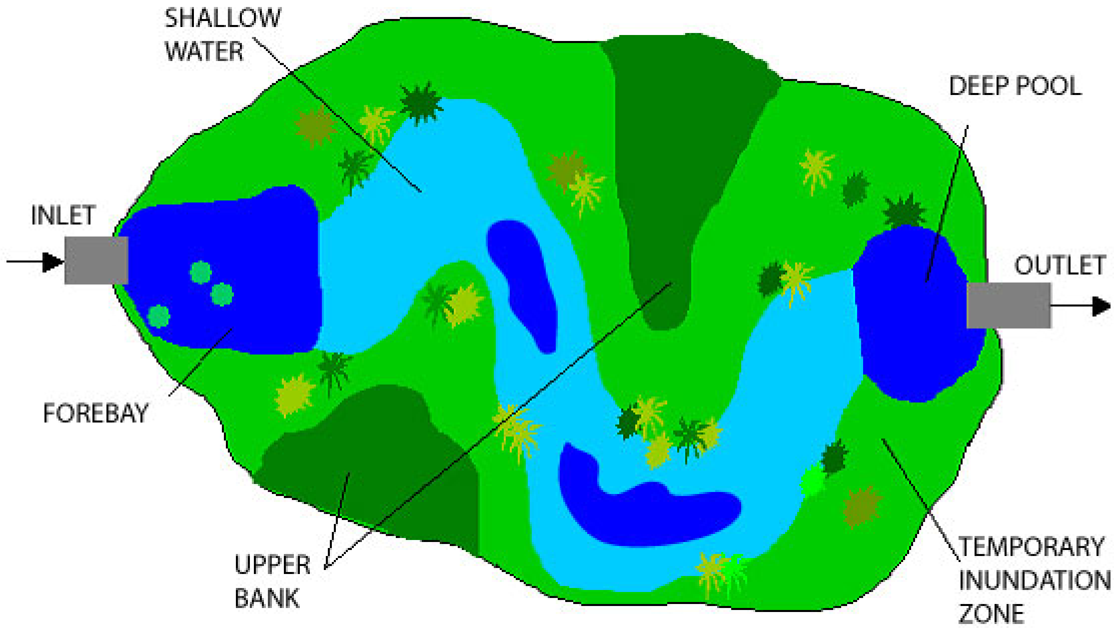
Figure 6-4. Typical vegetated infiltration basin configuration.

6.5. Stormwater Wetland

Generally, stormwater wetlands contain five zones: the forebay, deep pools, shallow water, temporary inundation, and upland zones. These zones are generally differentiated by water level, and each has a specific role in the wetland's intended function. The zones should have the following design features:

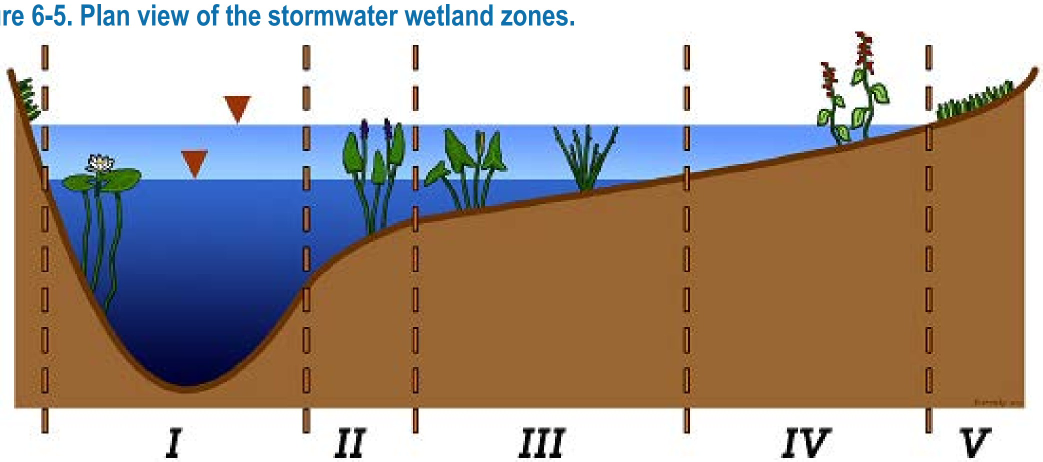
- The **forebay** should be armored to prevent erosion and disperse flow as much as possible. The forebay should represent 10% to 15% of the total area of the stormwater wetland.
- **Deep pools (I)** are approximately 2 to 2.5 feet deep and connected with shallow water channels no more than six inches in depth. The temporary inundation zone is no more than six inches above the top of the shallow water channels. Deep pools generally represent 20% to 25% of the wetland area, in addition to the forebay, and are deep enough to retain water during droughts (usually at least 18-in deep).
- **Deep to Shallow Water Transitions (II)** provide a connectin between the deep pools and the shallow water at a slope no steeper than 1.5h:1v.
- **Shallow water (III)** generally represents 30% to 40% of the total wetland surface area and are typically 6 inches in depth (2 to 4 inches will support a more diverse plant community).

  Temporary inundation (IV) zones provide storage above the permanent pool to capture a required volume of stormwater runoff and represents 30% to 40% of the total stormwater wetland area. This temporary inundation zone is temporarily submerged during runoff events and then dries over a period of 2 to 5 days as runoff is slowly discharged from the wetland. Because it is not permanently inundated, a greater variety of vegetation is adapted to life in this zone.
- The **upper bank (V)** region of the wetland is the area that surrounds the temporary inundation zones, and is sloped as needed to tie the wetland into the surrounding landscape. This area is not typically inundated, and can support a variety of upland plants.



Source: NCSU BAE

Figure 6-5. Plan view of the stormwater wetland zones.



Source: NCSU BAE

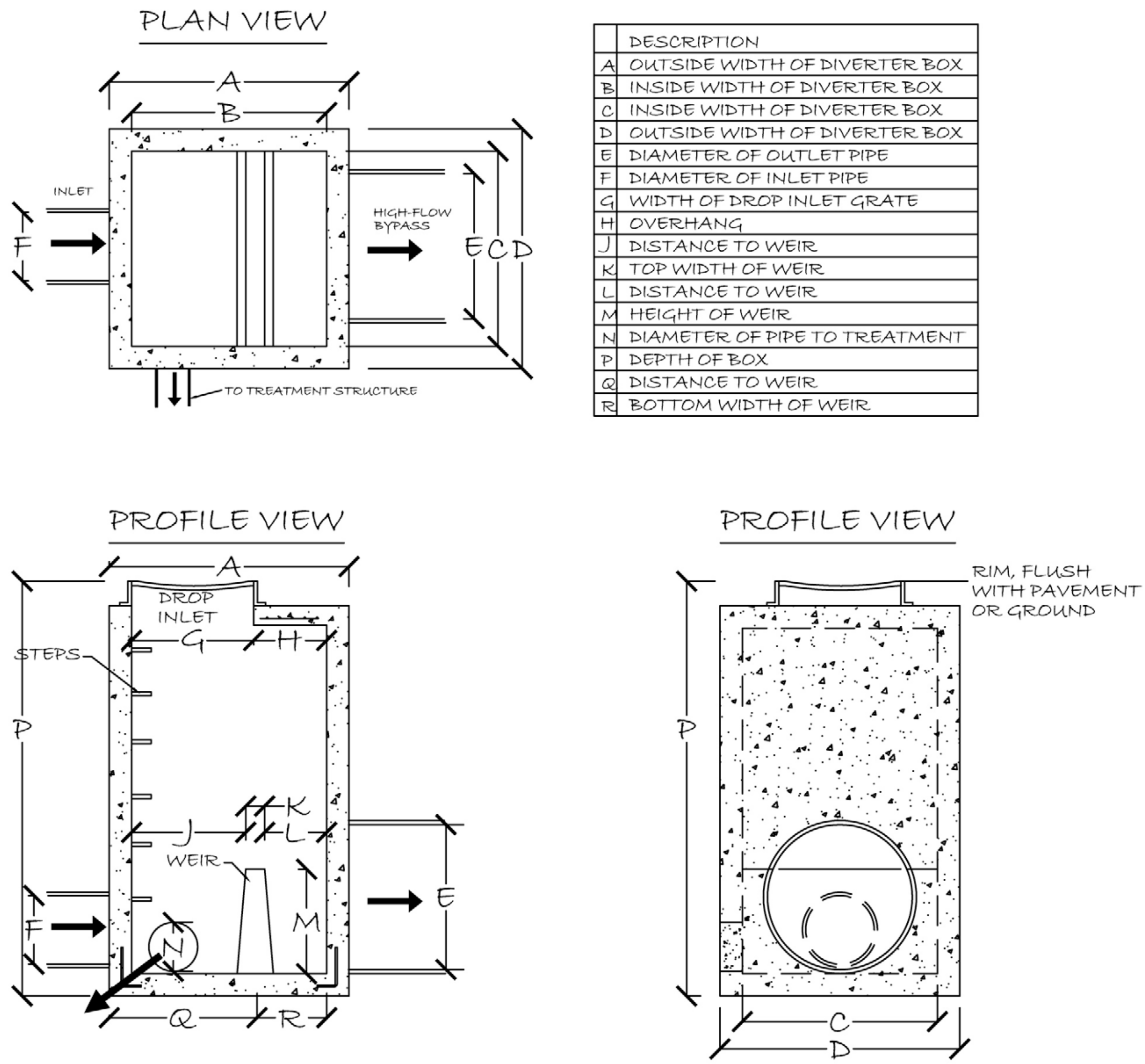
Figure 6-6. Profile view of the stormwater wetland zones: (I) Deep Pool, (II) Transition, (III) Shallow Water, (IV) Temporary Inundation, and (V) Upper Bank

If infiltration rates are greater than 0.01 in/hr, a hydraulic restriction layer will be required to maintain a permanent pool within the wetland area. The infiltration rates of the existing site will make maintaining a permanent pool impractical; therefore, a vegetated infiltration basin is more appropriate for the site.

1. Siting Setbacks	
Pavement	≥ 10 ft
Building	Basement: ≥ 10 ft
Property Lines/ROW	≥ 10 ft / ≥ 50 ft
Groundwater/Karst/Bedrock	≥ 2 ft
Septic System/Wells	≥ 50 / ≥100 ft
2. Volume	
Internal slope	1.5H:1V or flatter
Side slopes	3H:1V or flatter
Permanent Pool Depth	30 inches minimum
Inundation Zone Depth	0 to 12 inches above permanent pool depth
3. Vertical Component	
Inundation Storage	0 to 12 inches above permanent pool depth
Permanent Pool Storage	The mean depth shall be 30 inches
Native Material	Test infiltration; ≥ 0.5 in/hr if designing with infiltration
4. Drainage	
Inlet	Include sediment removal device and diversion structure
Underdrain	No requirement
Outlet	No requirement, infiltration shall meet release rates
Overflow	Back-up above ground; Weir; Standpipe
Infiltration	Meet water quality volume requirement
Dewatering	Per allowable release rate
5. Pollutant	
Pretreatment	Required; May be SCM, prefabricated device, or forebay
6. Maintenance	
Observation well	Perforated PVC pipe 4- to 6-inches in diameter with a tamper-proof lockable cap in center of trench
Access	Able to be accessed by a vehicle
Requirements	Designed and maintained to improve water quality; Maintenance plan should be in place

6.6. Stormwater Diversion

To divert runoff from the storm drainage system running along Hamar Street into the green infrastructure practice at Prince Street and Hamar Street, a diversion structure should be installed just south of the catch basins on the south side of the intersection. The diversion structure should be sized to limit erosive flows entering the vegetated infiltration basin while allowing peak flows that exceed the treatment pipe capacity to bypass the control entirely. Figure 6-7 shows an example of a typical diversion structure that can be retrofitted into the existing storm sewer system.



	DESCRIPTION
A	OUTSIDE WIDTH OF DIVERTER BOX
B	INSIDE WIDTH OF DIVERTER BOX
C	INSIDE WIDTH OF DIVERTER BOX
D	OUTSIDE WIDTH OF DIVERTER BOX
E	DIAMETER OF OUTLET PIPE
F	DIAMETER OF INLET PIPE
G	WIDTH OF DROP INLET GRATE
H	OVERHANG
J	DISTANCE TO WEIR
K	TOP WIDTH OF WEIR
L	DISTANCE TO WEIR
M	HEIGHT OF WEIR
N	DIAMETER OF PIPE TO TREATMENT
P	DEPTH OF BOX
Q	DISTANCE TO WEIR
R	BOTTOM WIDTH OF WEIR

Figure 6-7. Typical diversion structure.

7. Operations and Maintenance

Maintenance activities should be focused on the major system components, especially landscaped areas and permeable pavement. Landscaped components should blend over time through plant and root growth, organic decomposition, and develop a natural soil horizon (Table 7-1). 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 sweeping with a vacuum-powered street sweeper (Table 7-2).

Irrigation for the vegetated systems might be needed, especially during plant establishment periods or in periods of extended drought. Irrigation frequency will depend on the season and type of vegetation. Native plants might require less irrigation than nonnative plants.

The following tables outline the required maintenance tasks, their associated frequency, and notes to expand upon the requirements of each task.

Table 7-1. Vegetated green infrastructure practice operations and maintenance considerations

Task	Frequency	Maintenance notes
Monitor infiltration and drainage	1 time/year	Inspect drainage time (12–24 hours). Might have to determine 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 in/hr).
Pruning	1–2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2–12 times/year	Frequency depends on the location, plant selection and desired aesthetic appeal.
Mulching	1–2 times/ year	Recommend maintaining 1”–3” uniform mulch layer.
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; sporadically 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, 10% 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.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, 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 flow onto the permeable pavement is not restricted. Remove any accumulated sediment, vegetative debris, or trash. Stabilize any exposed soil.
Vacuum street sweeper	Twice per year as needed	Portions of pavement should be swept with a vacuum street sweeper at least twice per year or as needed to maintain infiltration rates.
Replace fill materials (applies to pervious pavers only)	1-2 times per year (and after any vac 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 per year or as needed for aesthetics	Tasks include trash collection, sweeping, and spot weeding.

Table 7-3. Stormwater wetland operations and maintenance considerations

Task	Frequency	Maintenance notes
Forebay cleanout	As needed, typical 5 – 10 years	Check for sediment accumulation to ensure that flow into the retention area is as designed. Remove any accumulated sediment.
Invasive species/tree control	Semi-annual	Within the first year, 10% of plants can die. Survival rates increase with time.
Bank mowing and stabilization	Monthly or as needed	Frequency depends on the location, plant selection and desired aesthetic appeal.
Outlet inspection and cleanout	Monthly and after storms greater than 2 inches	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Trash removal	As needed	Remove accumulated debris throughout the area.
Rodent & mosquito management	As needed	Inspect for signs of vector control issues. Proper eradication measures should be used.

8. Green Infrastructure Practice Cost Estimates

The estimates for implementing the green infrastructure practices at the 3BGI project site are found in Table 8-1 and Table 8-2. Duke Street costs are estimated based on the existing site conditions and providing treatment of the 1.95 inch 24-hour Type III distributed storm per requirements. The vegetated infiltration basin costs are estimated based on the existing site conditions and providing treatment of the 1.22 inch 24-hour Type III distributed storm per maximum available implementation space. It is assumed that all construction is a retrofit.

Table 8-1. Duke Street cost estimate

Item No	Description	Quantity	Unit	Unit Cost	Total
	Preparation				
1	Traffic Control	15	day	$1,000.00	$15,000
2	Temporary Construction Fence	545	LF	$2.50	$1,363
3	Silt Fence	545	LF	$3.00	$1,635
	Site Preparation				
4	Curb and Gutter Removal	545	LF	$3.30	$1,799
5	Excavation and Removal	296	CY	$45.00	$13,320
	Traditional Bioretention				
7	Fine Grading	1,453	SF	$0.72	$1,046
8	Soil Media	162	CY	$40.00	$6,480
9	Filter Layer (sand and No. 8 stone)	18	CY	$45.00	$810
10	Vegetation	1,453	SF	$4.00	$5,812
11	Mulch	14	CY	$55.00	$770
12	Curb and Gutter	278	LF	$22.00	$6,116
	Permeable Pavement				
13	Curb and Gutter	363	LF	$22.00	$7,986
14	Permeable Pavement	2906	SF	$12.00	$34,872
15	Structural Layer (washed no 57 or no 2 stone)	54	CY	$50.00	$2,700
16	Concrete Transition Strip	363	LF	$4.00	$1,452
17	Utility Conflicts	1	LS	$10,000.00	$10,000
Construction Subtotal					$111,160
21	Bond (5% of subtotal)				$5,558
22	Mobilization (10% of subtotal)				$11,116
23	Construction contingency (20% of subtotal)				$22,232
Construction Total					**$150,066**
24	Design (40% of Construction Total)				$60,026
Total Cost					**$210,093**

Table 8-2. Vegetated infiltration basin cost estimate[1]

Item No	Description	Quantity	Unit	Unit Cost	Total
	Preparation				
1	Traffic Control	15	Day	$1,000.00	$15,000
2	Temporary Construction Fence	500	LF	$2.50	$1,250
3	Silt Fence	500	LF	$3.00	$1,500
	Site Preparation				
4	Excavation and Removal	775	CY	$45.00	$34,875
5	Clearing and Grubbing	15,700	SF	$0.75	$11,775
	Vegetated Infiltration Basin				
6	Fine Grading	15,700	SF	$0.72	$11,304
7	Inlet Diversion Structure	1	LS	$15,000	$15,000
8	Vegetation	15,700	SF	$4.00	$62,800
Construction Subtotal					$153,504
9	Bond (5% of subtotal)				$7,675
10	Mobilization (10% of subtotal)				$15,350
11	Construction contingency (20% of subtotal)				$30,701
Construction Total					**$207,230**
12	Design (40% of Construction Total)				$82,892
Total Cost					**$290,123**

1. Cost estimate does not include the cost of acquiring the property currently held by private individuals

Typical annual routine maintenance costs are included in Table 8-3. Costs were adapted from WERF estimates to account for the scale of the green infrastructure practice (WERF 2009). Typical routine maintenance is similar to maintenance for landscape 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 8-3. Annual maintenance cost estimate

Green Infrastructure Practice	Area (ft^2)	Unit Cost (per ft^2)	Routine Maintenance (monthly to 2 years)
Bioretention	1,453	$2.28	$3,312.84
Permeable pavement	2,906	$0.67	$1,947.02
Vegetated Infiltration Basin	15,700	$1.91	$29,987.00

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Appendix A – Conceptual Design Layouts

Appendix B – EPA SWMM Design Parameters

Beaufort EPA SWMM Parameter Tables – Duke Street

Hydrology	
Rain Gages	24-hour Type III Distribution

Subcatchment (Bioretention)		
Area	0.5	acres
Width	1000	ft
% Slope	0	
% Imperv	50	
N-Imperv	0.012	
N-Perv	0.1	
Dstore-Imperv	0.05	in
Dstore-Perv	0.3	in
%Zero-Imperv	0	
Subarea Routing	Outlet	
Percent Routed	100	
Infiltration	Horton	

Subcatchment (Permeable Pavement)		
Area	1	acres
Width	1000	ft
% Slope	0	
% Imperv	50	
N-Imperv	0.012	
N-Perv	0.1	
Dstore-Imperv	0.05	in
Dstore-Perv	0.3	in
%Zero-Imperv	0	
Subarea Routing	Outlet	
Percent Routed	100	
Infiltration	Horton	

Horton Infiltration Parameters		
Max Infil. Rate	3	in/hr
Min Infil. Rate	0.5	in/hr
Decay Constant	4	1/hr
Drying Time	7	days
Max Volume	0	in

LID Controls					
Bioretention					
Surface			**Storage**		
Storage Depth	6	in	Height	0.1	in
Vegetative Cover Fraction	0.05		Void Ratio	0.4	
Surface Roughness (Mannings n)	0.1		Conductivity	2	in/hr
Surface Slope	0.0	%	Clogging Factor	0	
Soil			**Underdrain**		
Thickness	36	in	Drain Coefficient	0	in/hr
Porosity	0.4		Drain Exponent	0.5	
Field Capacity	0.25		Drain Offset Height	0	in
Wilting Point	0.1				
Conductivity	2	in/hr			
Conductivity Slope	10				
Suction Head	3.5	in			

LID Controls

Permeable Pavement					
Surface			**Storage**		
Storage Depth	1	in	Height	6	in
Vegetative Cover Fraction	0.0		Void Ratio	0.4	
Surface Roughness (Mannings n)	0.014		Conductivity	2	in/hr
Surface Slope	0.0	%	Clogging Factor	0	
Pavement			**Underdrain**		
Thickness	6	in	Drain Coefficient	0	in/hr
Void Ratio	0.15		Drain Exponent	0.5	
Impervious Surface Fraction	0		Drain Offset Height	0	in
Permeability	100	in/hr			
Clogging Factor	0				

Routing

Permeable Pavement --> Bioretention --> Outlet

Beaufort EPA SWMM Parameter Tables – Basin

Hydrology	
Rain Gages	24-hour Type III Distribution

Subcatchment		
Area	36.29	acres
Width	1500	ft
% Slope	0.5	
% Imperv	32	
N-Imperv	0.012	
N-Perv	0.1	
Dstore-Imperv	0.05	in
Dstore-Perv	0.3	in
%Zero-Imperv	0	
Subarea Routing	Outlet	
Percent Routed	100	
Infiltration	Horton	

Horton Infiltration Parameters		
Max Infil. Rate	3	in/hr
Min Infil. Rate	0.5	in/hr
Decay Constant	4	1/hr
Drying Time	7	days
Max Volume	0	in

Storage Units		
Max Depth	1	ft
Initial Depth	0	ft
Ponded Area	0	ft2
Evap Factor	0	
Infiltration	Yes	
Storage Curve	Functional	

Storage Infiltration Parameters		
Green-Ampt		
Suction Head	1.93	in
Conductivity	3	in/hr
Initial Deficit	0	

Functional Curve Parameters	
Coefficient	17000
Exponent	0
Constant	0

Appendix C – Charrette Process Review Memo

City of Beaufort Design Charrette

Design Charrette Summary

On November 13, 14, and 15, 2012 the EPA project team facilitated a design charrette intended to identify potential green infrastructure retrofit projects in the North West Quadrant neighborhood in the City of Beaufort, SC. The design charrette provided the opportunity for the EPA project team to coordinate and interact with planning and public works staff from the City of Beaufort to determine the most beneficial and cost-effective strategy for implementing green infrastructure. The intent of this memo is to document and present the results from the design charrette.

Day 1

Day 1 began with an introductory meeting with Lauren Kelly (City Planner), Isaiah Smalls (Public Works Director), Monica Holmes (Planning consultant), Katherine Snyder (EPA Region IV), and other members of the project team. The city team discussed their goals for the project and provided some background information on current projects. The city is currently implementing a green street along Bladen Avenue, which incorporates permeable pavement in the parking lanes. Additionally, the project team provided an introductory presentation discussing the concepts of LID and green infrastructure focusing on implementing permeable pavement and bioretention in the right-of-way. Given the multiple definitions and perceptions of LID and green infrastructure, it was important to present some of the basic concepts to ensure that the city team was using similar terminology in describing green infrastructure and specific Stormwater Control Measures (SCM).

For the remainder of the first day, Lauren Kelly and Monica Holmes led the team on a tour of the downtown Beaufort area and the Northwest Quadrant neighborhood. Anne Keller (EPA Region IV) joined the team in the tour of the neighborhood. Lauren and Monica provided details on the unique climate and topography in the historic neighborhood and identified potential areas for SCM implementation. Lamar Taylor (City of Beaufort Public Works) joined the tour of the Northwest Quadrant Neighborhood to identify known problem areas where SCMs could possibly be implemented to alleviate flooding issues. Lamar also provided details on the green streets currently being implemented on Bladen and Duke Streets (Figure 1 and Figure 2). Multiple approaches to SCM implementation with multiple site configurations were discussed throughout the tour of the neighborhood. Projects were discussed based on a parcel approach with SCMs that could be implemented to treat larger drainage areas or SCMs that could be implemented in the right-of-way. Seven potential sites were identified through the course of the field tour with multiple options for improvement or SCM implementation.


Figure 1. Permeable pavement on Bladen Street.


Figure 2. Green street construction on Duke Street.

Day Two

Day two focused on refining the potential sites and recommended options for improvement or SCM implementation. Figure 3 shows the location of the seven potential sites and Table 1 presents potential sites and recommended improvements in order of feasibility or preference. Projects were evaluated based on implementation on a full parcel or block scale and implementing SCMs within the right-of-way or street scale. Each identified site was evaluated for potential to improve drainage or reduce flooding, potential water quality improvement based on treatment volume, potential for SCM demonstration, multi-use benefit for the surrounding neighborhood, and ancillary benefits such as aesthetic improvement. The potential for SCM demonstration was evaluated based on the proximity to parks, schools, or other BMPs that would attract the public. Integration into the transects is discussed in the following sections. Full conceptual designs will be developed for the top two sites. Additional details and recommendations for the remaining 5 sites are presented below.

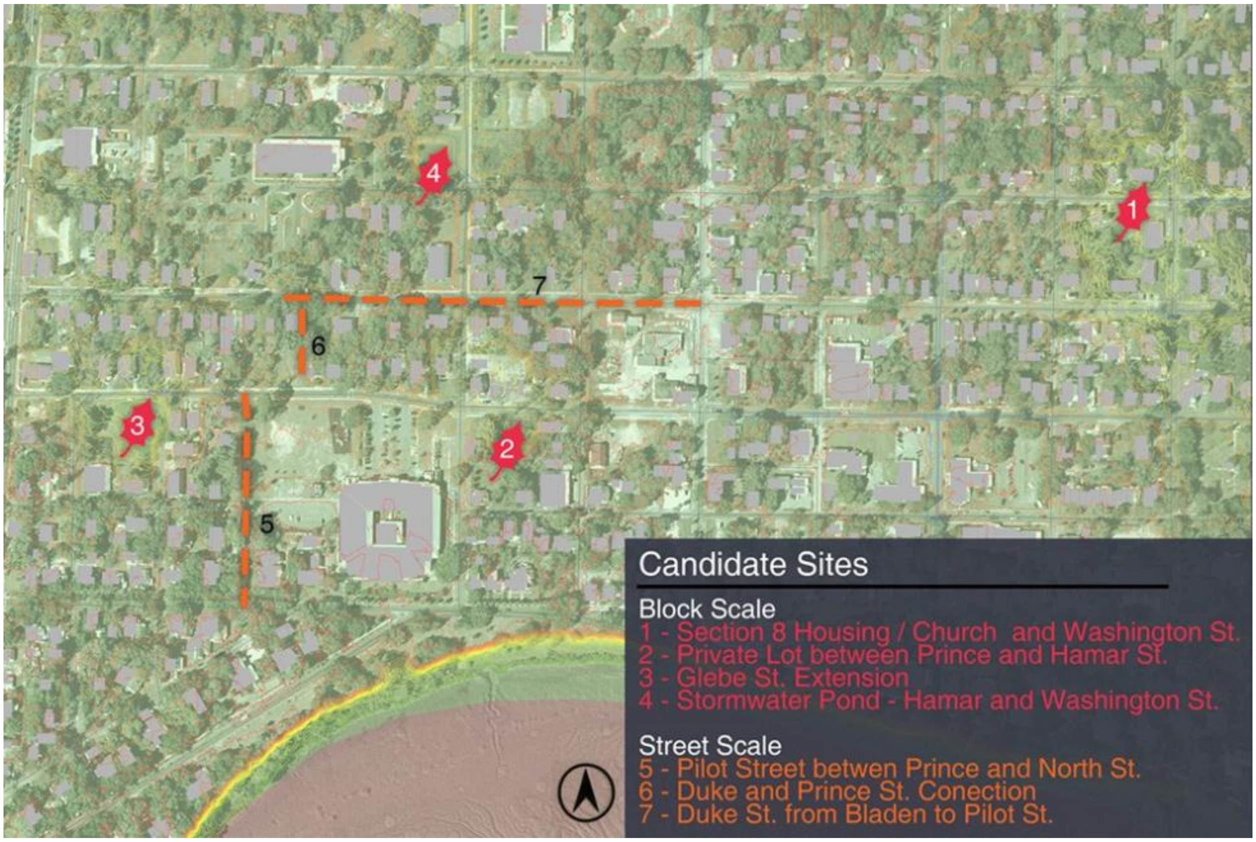

Figure 3. Potential sites for SCM implementation or improvement.

Table 1. Candidate sites

	Candidate Project/Transects	**Drainage Improvement**	**Water Quality**	**Integration of Transects**	**Demonstration of Technology**	**Neighborhood Benefit**	**Ancillary Benefits**
7	Duke Street from Bladen to Pilot Street	●	●	●	◒	◒	●
2	Private Lot at intersection of Prince and Hamar	●	●	○	◒	●	●
3	Glebe Street Extension	●	●	◒	◒	●	◒
4	Stormwater Dry Pond Hamar and Washington	○	◒	○	◒	●	●
5	Green Street along Pilot from Prince to North Street						
6	Connection of Duke and Princeton	○	◒	◒	◒	●	●
1	Section 8 Housing Church and Washington Streets	○	◒	○	○	◒	◒
	Candidate Improvements						
	Bump Outs for Tree Space	●	●	◒	◒	●	●
	Vegetated Curb Extensions	●	●	◒	◒	●	●
	Residential on-lot Permeable Pavement	●	●	●	◒	●	●

Glebe Street Extension

The catch basin at the low point of Prince Street between Pilot Street and Euhaw Street is continually clogged causing flooding on Prince Street (Figure 4). Drainage collecting in the low point along Prince Street could be diverted to a bioswale implemented in the city controlled right-of-way intended to extend Glebe Street to Prince Street shown in Figure 5. A SCM at this location would treat runoff from a small and isolated drainage area. Some of the flooding could potentially be alleviated by cleaning the catch basin on Prince Street. Therefore, this project was given a lower priority.

Figure 4. Clogged catch basin.

Figure 5. Right-of-way extending Glebe Street to Prince Street.

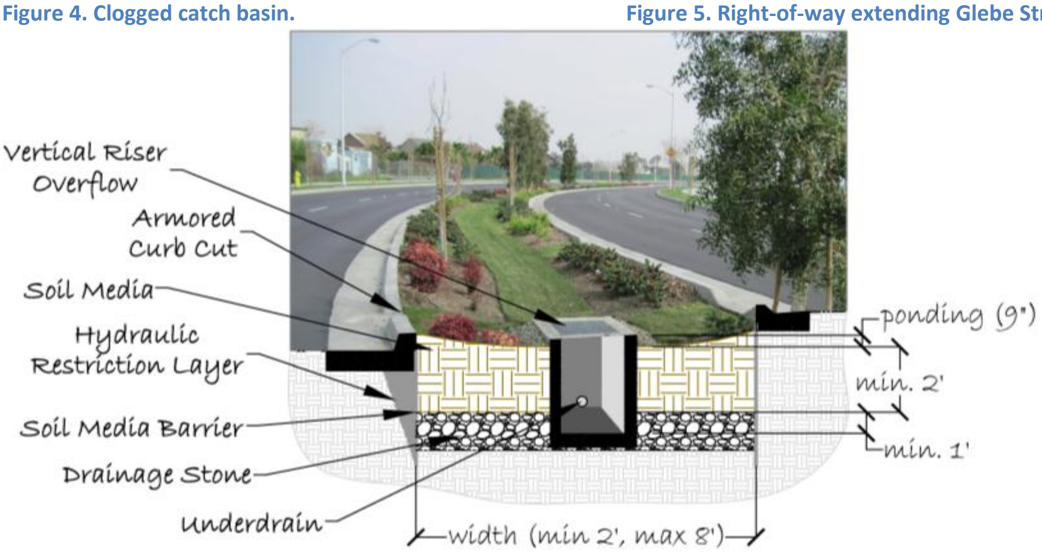

Figure 6. Example bioswale.

Figure 7. Example of a bioswale in the right-of-way.

Stormwater Dry Pond at Hamar Street and Washington Street

A dry pond or infiltration basin is currently treating the runoff from the parcel owned by the Department of Social Services at 1905 Duke Street (Figure 8). This pond could benefit from some aesthetic improvements and could benefit from conversion to a bioretention area (Figure 9) or could potentially be converted to a stormwater wetland (Figure 10). It is possible that some additional runoff could be converted from the surrounding parcels and Washington or Hamar Streets to increase the water quality treatment benefit. The design treatment capacity of the dry pond should be verified before additional runoff is diverted for treatment. Because the existing dry pond is already providing treatment and the as build design plans are not available, this potential project was given a lower priority.

Figure 8. Dry pond at Hamar and Washington Streets.

Figure 9. Example bioretention area.

Figure 10. Example stormwater wetland.

Green Street along Pilot from Prince to North Street

Implementing permeable pavement in the parking stalls and bioretention in the right-of-way would provide treatment for the runoff from Pilot Street and provide a demonstration project and outdoor classroom for the students at Beaufort Elementary. Concepts similar to those already implemented along Bladen Street incorporating permeable pavement could be utilized along Pilot Street.

Connection of Duke and Prince Streets

Utilizing the four vacant lots surrounding 1880 Prince Street to connect Prince Street and Duke Street will provide an additional avenue for traffic around Beaufort Elementary School. The area within the right-of-way can then be utilized for parking with permeable pavement parking stalls, similar to the concepts incorporated along Bladen Street and at city hall, to provide treatment for runoff from Prince and Duke Streets. Given the close proximity to Beaufort Elementary School, this project could also serve as an excellent demonstration opportunity. Because the project would require acquiring the parcels and the limited treatment that would be provided, this project was given a lower priority.

Figure 11. Permeable pavement parking stalls.

Section 8 Housing Church and Washington Streets

Bioretention and permeable pavement could be incorporated into the landscaping and parking areas of the public housing located at 1200 Washington Street. This area is a low spot and known to flood. Therefore, incorporating LID SCMs concepts into the site could provide water quality improvement as well as reduce the flooding in smaller storm events. Because of the extreme flooding and potential for vandalism, this site was given a lower priority.

Figure 12. Residential bioretention with permeable pavement.

Figure 13. Bioretention at a residence.

It was determined, through discussion with the city team including the public works director, that the potential sites at Hamar Street and Prince Street and the right-of-way along Duke Street best fit the needs of the city by providing the greatest potential for drainage improvement, water quality benefit, SCM demonstration, mutil-use opportunities, and aesthetic enhancement. Once the top two sites had been determined the team returned to the neighborhood to perform additional field reconnaissance and further refine the approach to implementing green infrastructure at each site. While in the field the team took additional photos, noted the approximate drainage area, the existing drainage network and drainage patterns, existing conditions of each potential site, and discussed possible multiple uses and community benefit.

The team then returned to the town hall with the additional information for each site and began compiling the relevant information gathered during the field reconnaissance. Concepts were developed illustrating potential SCM configuration at each site. It was determined that a green street concept would be implemented along Duke Street, utilizing bioretention, to treat the runoff before entering the catch basin closest to the intersection with Bladen Street. Grass pavers could be implemented in the right-of-way west of Bladen Street to stabilized the shoulder and maintain a healthy patch of grass. The gutter in that section would be reconfigured to allow sheet flow onto the shoulder. Figure 14 and Figure 15 show rough concepts for a green street on Duke Street.

Figure 14. Bioretention on Duke Street.

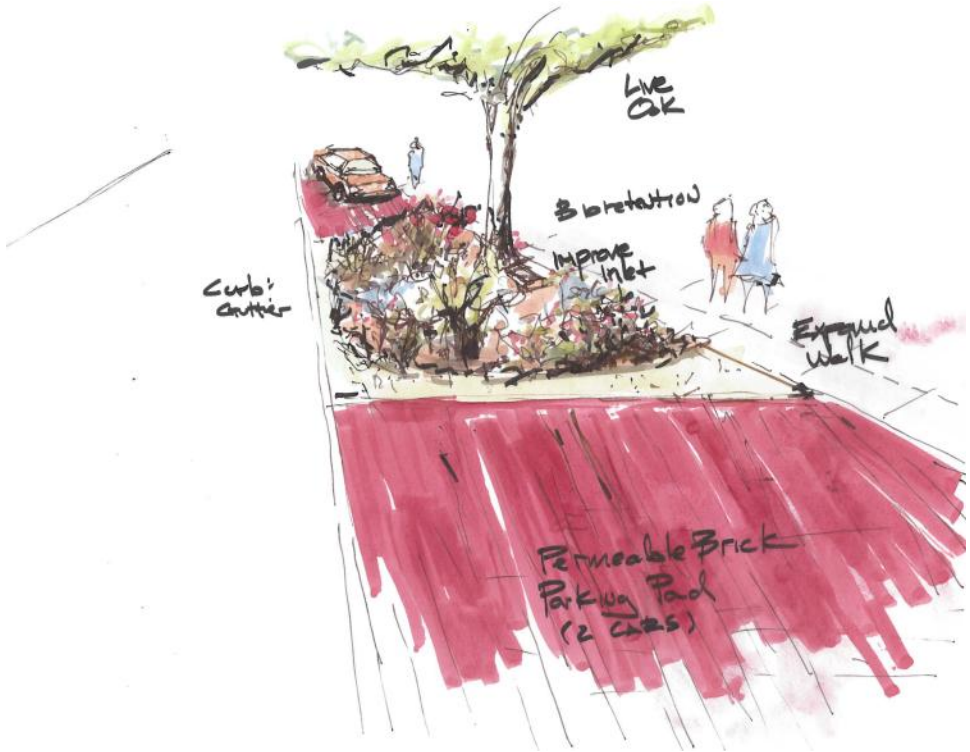

Figure 15. Green street on Duke Street.

The vacant portion of the parcels closest to 1798 Prince Street could be developed as a neighborhood park incorporating stormwater treatment. A diversion structure placed just south of the catch basin closest to Hamar and Prince would divert flow from the storm drain running along Hamar Street for treatment in the park. A stormwater wetland or bioretention area, depending on the depth to the water table and infiltration capacity, could be used for water quality treatment similar to the concepts shown in Figure 16 and Figure 17.

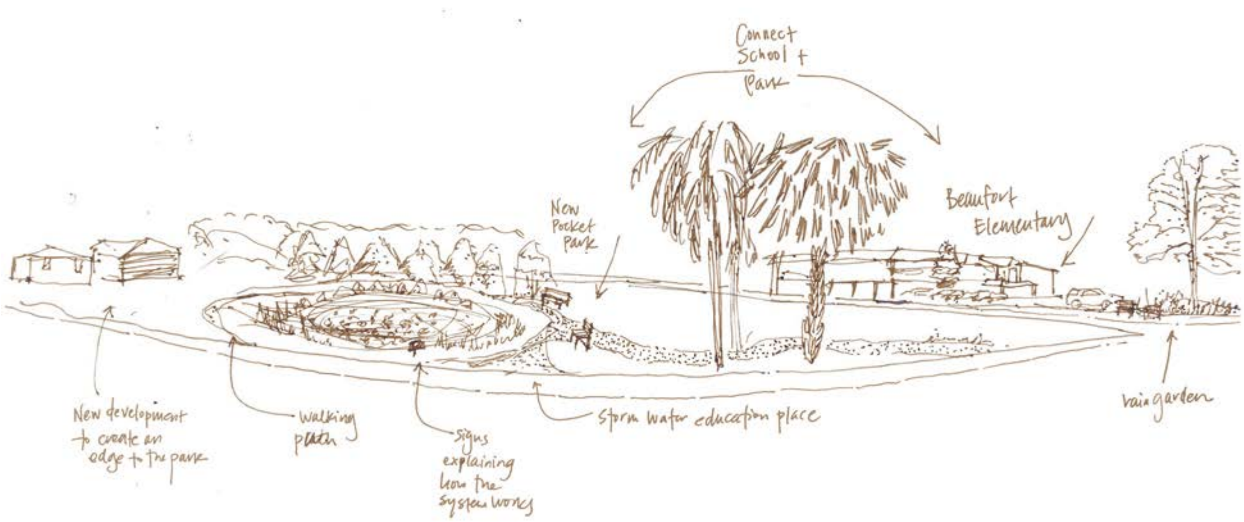

Figure 16. Concept for Hamar and Prince.

Figure 17. Potential SCM configuration for Hamar and Prince.

In addition to the plan for a conceptual design for each site, the team discussed possible opportunities for developing tools to incorporate into the Regulating Plan for the City of Beaufort. Transects describing typical street sections in the City of Beaufort with the typical neighborhood setting, average street configuration, and level of urbanization were developed for the Regulating Plan. Concepts for integrating green infrastructure into each transect were developed that could possibly be integrated into the Regulating Plan.

Day three

The information gathered during the site visits in day one and day two, the concepts developed for each transect for the Regulating Plan, and the concepts developed for both potential sites was compiled into a presentation. The presentation was then delivered by the city team to the director of public works, the planning director, and the city engineer outlining the charrette process and the conceptual plan for each of the two potential sites. The presentation is included as an attachment.

Next Steps

The EPA project team will incorporate the knowledge gained from the charrette and the conceptual plan for the two sites in the Northeast Quadrant into a full conceptual design for each site. The conceptual design will provide additional details for incorporating stormwater management into the features of the site that utilize green infrastructure concepts. The sketches and renderings developed during the charrette will be modified to show additional details for the green infrastructure practices including the appropriate depths and materials. Performance specifications will be included for each SCM including the approximate square footage of each SCM and SCM type required to meet multiple treatment goals.