CSS Long Term Control Plan Update

Alternatives Evaluation: Green Infrastructure

City of Alexandria, Virginia
Department of Transportation & Environmental Services

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GREELEY AND HANSEN

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Executive Summary

Green infrastructure (GI) is a source control that reduces runoff volumes, peak flows, and/or pollutant loads. GI utilizes the processes of infiltration, evapotranspiration, and capture for re-use to reduce the amount of runoff volume. GI can be used as a complementary CSO Control strategy in conjunction with gray infrastructure.

GI's benefits extend beyond reducing the flow of water into the CSS during wet weather events. Through mimicking a more naturalized system, GI can deliver a broad range of ecosystem services or benefits to people, some of which include: improved community livability (aesthetics and property values), human health, air quality, water quality, groundwater recharge, wildlife habitats and connectivity, reduced heat island effects, reduced energy use, green jobs, and recreational opportunities (USEPA, 2014).

GI opportunity is dependent on land use, impervious area, local topography, and underlying soils. It is important that the soils underneath GI are able to infiltrate the captured runoff, if they are not then an underdrain would be needed to convey the captured runoff into the stormwater sewer system. The three CSS areas (Pendleton, Royal, and King and West) were evaluated and found to have similar land use distributions. In general, the 544 acre total area has 71% impervious cover (primarily roads, alleys, and buildings) and 29% pervious cover. The CSS area was further analyzed to differentiate between City-owned parcels, the publicly owned right-of-way (ROW) and privately own properties. Cost estimates and performance predictions are based on the City-owned parcels and the publicly owned ROW.

This technical memorandum focuses on the following GI alternatives:

- Downspout Disconnects;
- Planter Boxes;
- Permeable Pavement;
- Bioretention (Rain Gardens); and
- Bioswales.

Table ES-1 provides a summary of estimated capital costs for potential GI opportunities. The potential GI projects are estimated to reduce the total CSO volume by 30-40% in a typical rainfall year and the implementation timeline will likely exceed the 2035 deadline. While this is a significant impact on CSO volume it does not have the same impact on CSO bacterial load. Most of the bacteria comes from sanitary flow rather than the stormwater runoff, so implementing GI will reduce the CSO volume but will not reduce the CSO bacterial load as much. As such, it is important to note that the GI alternatives will not achieve the TMDL bacteria reductions on their own or substantially reduce the number of overflows consistent with CSO Policy. However, GI is an environmental positive complementary control strategy and can be cost effective when the full benefits of GI are considered and when used in combination with other CSO control strategies.

Table ES-1
Estimated Capital Cost of Green Infrastructure

CSO Area	Construction Cost	Project Costs	Wet Weather Improvements	Total Capital Cost[1]
King and West (CSO 003 and 004)	$18.0	$6.3	$37.7	$62.0
Royal (CSO 002)	$30.4	$10.6	$0.0	$41.0

[1]The GI alternatives will not achieve the TMDL bacteria reductions on their own.

It is recommended GI alternatives be moved forward for scoring and ranking relative to the other alternatives; however, it is important to reiterate that the GI alternatives will not achieve the TMDL bacteria reductions on their own. As such, GI is more suited as a complementary alternative.

Section 1 Introduction

1.1 Green Infrastructure Screening

Green infrastructure (GI) is a source control that reduces runoff volumes, peak flows, and/or pollutant loads. GI utilizes the processes of infiltration, evapotranspiration, and capture for re-use to reduce the amount of runoff volume (USEPA, 2014). It is effective at increasing the time of concentration of remaining runoff and reducing pollutant loads through sedimentation and filtration. GI can be used alone in a scalable manner, or it can be used in conjunction with gray infrastructure.

GI's benefits extend beyond reducing the flow of water into CSSs during wet weather events. Through mimicking a more naturalized system, GI can deliver a broad range of ecosystem services or benefits to people, some of which include: improved community livability (aesthetics and property values), human health, air quality, water quality, groundwater recharge, wildlife habitats and connectivity, reduced heat island effects, reduced energy use, green jobs, and recreational opportunities (USEPA, 2014). It can also help reduce flooding and is flexible for addressing climate change (droughts or increased precipitation). The realistic potential for the implementation of GI technologies was first screened in the *CSO Control Technology Screening Technical Memorandum* and are summarized in Table 1-1 below. The table includes the area served, estimated volume of stormwater controlled during a 1" storm, appropriate location, and maintenance required for each item according to the VA SWM BMP Clearinghouse.

Table 1-1
Summary of GI Options

GI Item	Area Served	Estimated Controlled Stormwater Volume for 1" Storm	Location	Maintenance Required
Green Roofs	Installed area	45-60% reduction	Buildings	Semi-annual vegetation maintenance; annual cleaning of pipes
Blue Roofs	Installed area	45-80% reduction	Buildings	Semi-annual debris maintenance; annual cleaning of pipes
Rainwater Harvesting	Roof drainage area	Up to 90% reduction	Buildings	Semi-annual debris maintenance; annual cleaning of pipes
Permeable Pavements	2 to 4 x Installed area	45-75% reduction	Sidewalks, parking lanes, parking lots, driveways, and alleys	Semi-annual vacuuming; preventative measures against fine aggregates
Planter Boxes	10 to 20 x Installed area	40-80% reduction	Sidewalks and parking lanes	Semi-annual vegetation and mulch maintenance; annual cleaning of overflow pipes and underdrains
Bioswales	10 to 20 x Installed area	10-60% reduction	Open Space	Semi-annual vegetation and mulch maintenance
Free-form Rain Gardens	10 to 20 x Installed area	40-80% reduction	Open Space	Semi-annual vegetation and mulch maintenance; annual cleaning of overflow pipes and underdrains

In the *CSS Control Technology Screening Technical Memorandum* it was concluded the following technologies were identified for further evaluation:

- Planter Boxes;
- Permeable Pavement;
- Bioretention (Rain Gardens); and
- Bioswales.

Additionally, downspout disconnects are also consider herein.

1.2 Requirements

The City's VPDES Permit (VA0087068) for the Combined Sewer System includes the following requirements related to GI.

- Green Initiative: *The permittee shall study, implement, and promote green infrastructure projects within the CSS sewershed during this permit term. Projects evaluated shall include, but are not limited to: rainfall harvesting, permeable pavements, rain gardens, green roof installation, bioretention cells, urban forestation/reforestation, and public education.*
- Green Public Facilities: *The permittee shall evaluate the practicality of incorporating green infrastructure during major maintenance/enhancement projects at all city facilities (offices, schools, libraries, etc) located within the CSS sewershed. The permittee shall include with the annual reports, commencing with the report for 2014: (1) a schedule of maintenance/ enhancement projects at city facilities within the CSS sewershed for the forthcoming fiscal year; (2) the City's process for evaluating inclusion of green infrastructure; and (3) green infrastructures planned for selected projects. Technologies to be considered shall, at a minimum, include those listed under the aforementioned Green Initiative Special Condition. Maintenance/enhancement projects for historic designated facilities/structures are exempt from this Special Condition.*
- Green Maintenance: *The permittee shall establish, or alternatively incorporate, a database to manage information on all green infrastructure practices put in place that are owned and/or maintained by the City. The database shall schedule and track maintenance activities to ensure infrastructures are maintained for proper performance. The permittee shall submit to DEQ two updates on the status of the database development. The first update shall be provided on or before 23 August 2014 and the second on or before 23 August 2015. On or before 23 August 2016, the permittee shall submit to DEQ a final report detailing the full database development and implementation.*

It is important to note that these permit requirements are not explicitly required under the LTCPU; however, there are opportunities for synergies with the LTCPU where appropriate.

Additionally, as described in "*Greening CSO Plans: Planning and Modeling Green Infrastructure for Combined Sewer Overflow (CSO) Control*" (USEPA, March 2014), the USEPA requires that any incorporation of GI into a LTCP include analysis in two areas:

1. Community and political support for GI; and
2. Realistic potential for GI implementation.

The City will assess the public support from stakeholders in the community and government for the GI alternatives through the implementation of the LTCPU Public Participation Plan.

1.3 Definitions

The USEPA provides the following definitions in their vocabulary catalog online at www.epa.gov.

- Green infrastructure (GI) is "an adaptable term used to describe an array of products, technologies, and practices that use natural systems - or engineered systems that mimic natural... processes - to enhance overall environmental quality and provide utility services. As a general principal, GI techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff. When used as components of a stormwater management system, GI practices such as green roofs, porous pavement, rain gardens, and vegetated swales can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits."
- Best Management Practice (BMP) is "a practice or combination of practices that are determined to be the most effective and practicable (including technological, economic, and institutional... considerations) means of controlling point and nonpoint source pollutants at levels compatible with environmental quality goals."
- Low Impact Development (LID) is "a comprehensive stormwater management and site-design technique. Within the LID framework, the goal of any construction project is to design a hydrologically functional site that mimics predevelopment conditions. This is achieved by using design techniques that infiltrate, filter, evaporate, and store runoff close to its source. Rather than rely on costly large-scale conveyance and treatment systems, LID addresses stormwater through a variety of small, cost-effective landscape features located on-site. LID is a versatile approach that can be applied to new development, urban retrofits, and revitalization projects. This design approach incorporates strategic planning with micro-management techniques to achieve environmental protection goals while still allowing for development or infrastructure rehabilitation to occur."

A GI program incorporates natural and constructed assets, such as BMPs and LID.

1.4 Engineering Considerations

As with all infrastructure, consideration is necessary for all lifecycle phases: design, construction, operations, and maintenance. Green infrastructure design considerations include proximity to other infrastructure (utilities, pavements, stormwater facilities, etc.) as well as natural conditions (soil types and infiltration rates, water table level, etc.) and, in some cases, pedestrian facilities (ADA curb ramps, sidewalk widths, etc.). Design consideration should be given to simplify construction, operations, and maintenance, such as providing access points to piping systems and eliminating excess pipe fittings, bends, and wye branches.

Proper construction is necessary for proper operation. Some green infrastructure items are propriety kits with manufacturer installation, but most include engineered media, specific grading and drainage, and/or particular plantings. Training and supervision of crews during installation is necessary for proper installation since it is impossible to confirm proper installation after construction is complete.

1.5 Collaboration and Policies

Use of green infrastructure provides an opportunity to collaborate across City departments and with external groups. Collaboration across departments is necessary to address all policies and requirements for infrastructure impacting or abutting the green infrastructure features (roads, sidewalks, parks, buildings, etc.). It also allows for sharing of department expertise to improve the assets and gain support for the assets, including the future operations and maintenance responsibilities.

The use of green infrastructure as part of the City's LTCPU also addresses nine of the eleven items listed in the vision of the Eco-City Charter and seven of the nine items in the Environmental Action Plan 2030 (transportation and solid waste are not directly addressed). In addition, the City's citizen education and support services in the *"Build Your Own Rain Barrel Workshops"* promote green infrastructure at the homeowner scale. The City's Green Sidewalks BMP Design Guidelines provides specific instructions for provided stormwater best management practices in the City's Public rights-of-way.

Section 2 Options for the City of Alexandria

2.1 Existing Infrastructure

The three CSS areas (Pendleton, Royal, and King and West) have similar land use distributions as listed in Table 2-1. The 230 acre Pendleton area has slightly more parking lot area and less pervious cover than the Royal and King and West areas. In general, the 544 acre total area has 71% impervious cover (primarily roads, alleys, and buildings) and 29% pervious cover.

Table 2-2 indicates the distribution of land use areas of City-owned parcels which total 12 acres (2% of the total 544 acres). Fifty-four percent (54%) of the City-owned parcel area is impervious (6.7 acres). This data is illustrated for each area in Figure 2-1 and Figure 2-2
City-Owned Parcels I the King and West Area (CSO 003/4. The low acreage of City-owned parcels indicates that green infrastructure will need to serve non-City-owned parcels to have a significant impact on stormwater management.

Table 2-1
CSS Area

Land Use	Royal Area (CSO 002) acres (%)	King and West Area (CSO 003/4) acres (%)
Buildings	48.8 (25.0%)	32.3 (27.4%)
Roads	41.4 (21.2%)	22.6 (19.1%)
Alleys	0.7 (0.4%)	1.4 (1.2%)
Sidewalks	19.4 (10.0%)	10.1 (8.6%)
Driveways	2.5 (1.3%)	2.7 (2.3%)
Parking Lots	18.3 (9.4%)	9.0 (7.6%)
Pervious Cover	63.9 (32.8%)	39.8 (7.6%)
Total	**195**	**118**

Table 2-2
City-Owned Parcels Only

Land Use	Royal Area (CSO 002) acres (%)	King and West Area (CSO 003/4) acres (%)
Buildings	0.6 (17%)	1.0 (33%)
Driveways	0.0 (0%)	0.0 (0%)
Parking Lots	1.0 (28%)	0.4 (13%)
Pervious Cover	2.0 (55%)	1.6 (54%)
Total	**3.6**	**3.0**

Figure 2-1
City Owned Parcels in the Royal Area (CSO 002)

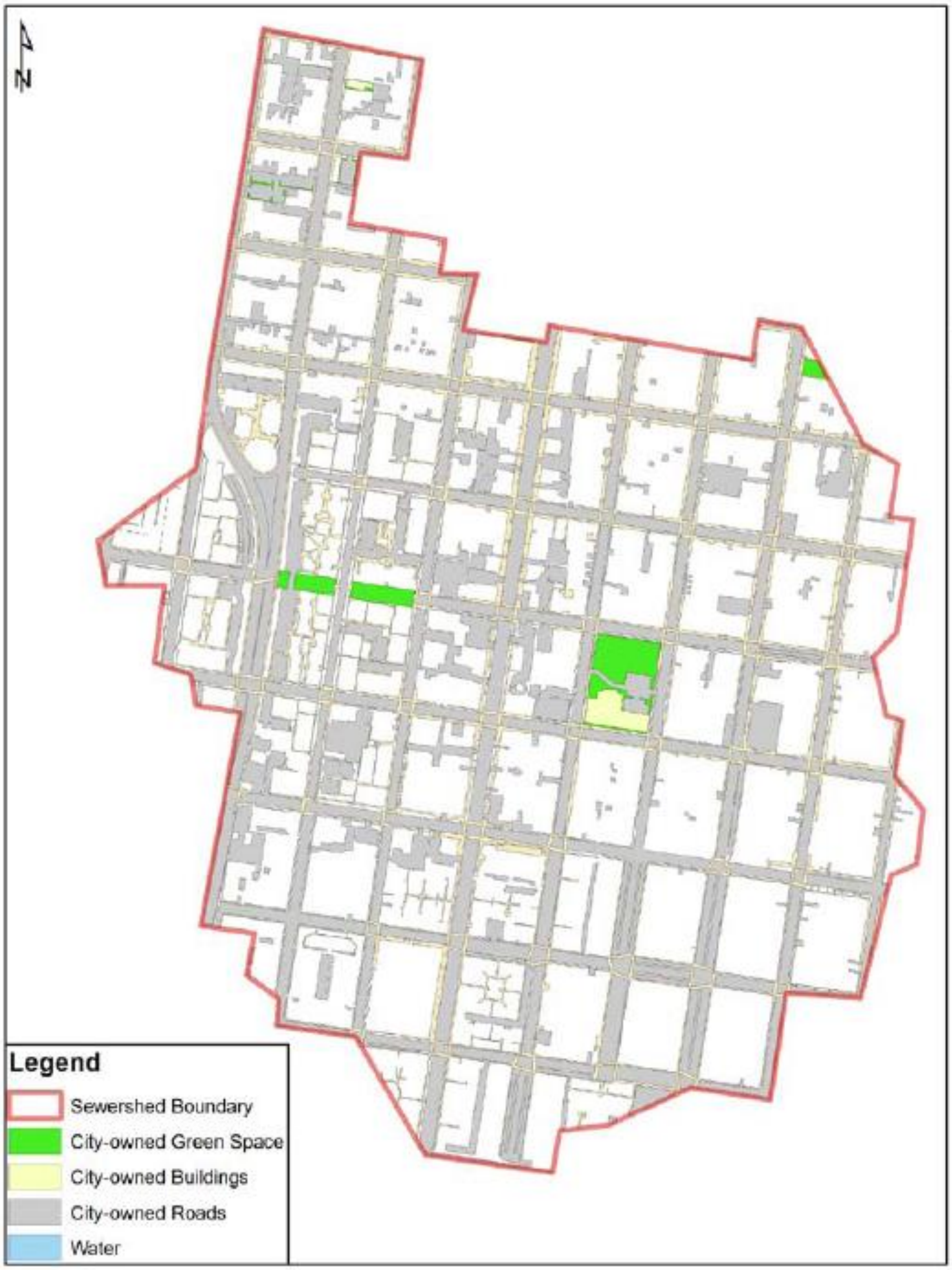
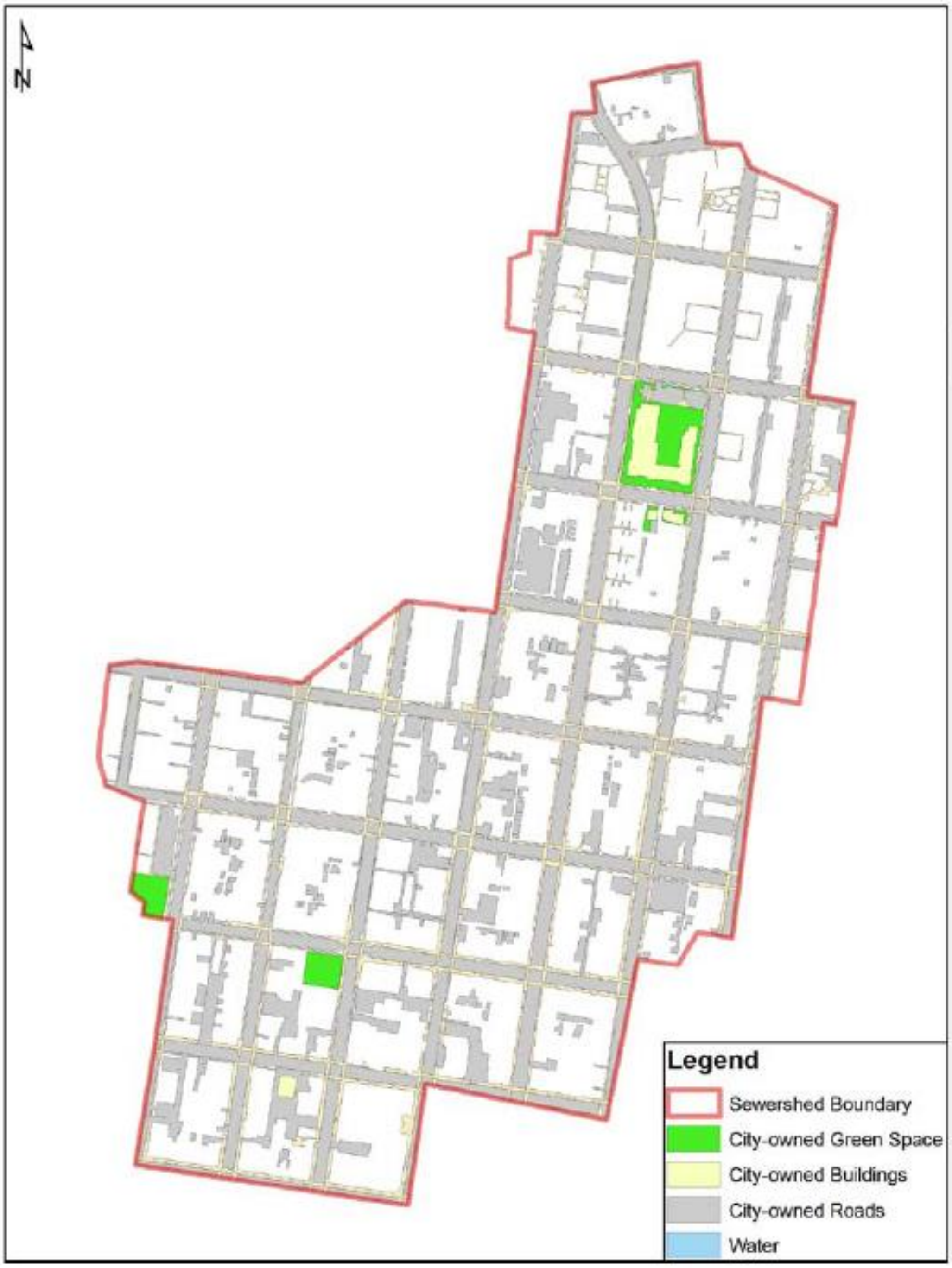


Figure 2-2
City-Owned Parcels I the King and West Area (CSO 003/4)



2.2 Green Infrastructure Options

In the City of Alexandria CSS area, grade level impervious surfaces make up 44% of the total area (compared to previous cover at 29% and buildings at 27%), so this is largest surface type to be addressed. Runoff from theses surfaces can potentially be reduced or managed by planter boxes, permeable pavement, or pervious surfaces (natural or constructed green infrastructure, such as bioswales or rain gardens).

2.2.1 Planter Boxes

Planter boxes are well suited for highly developed areas where space allows. Sidewalk planter boxes are small, decentralized stormwater management units that can be installed block-by-block to contain, infiltrate, and evapotranspirate stormwater runoff. Wide sidewalks, such as along Washington Street, could be suitable planter box locations. However, many sidewalks already have healthy trees and no room for the installation of GI planter boxes. The minimum size of planter boxes is controlled by the City's Green Sidewalks BMP Design Guidelines that require the planter boxes have at least 450 cu.ft. of uncompacted soil volume per tree. The Guidelines also provide recommendations for areas suitable for planter boxes. Larger curb bump-out planter boxes should be considered relative to the high demand for traffic lanes and roadside parking spots.

2.2.2 Permeable Pavement

Permeable pavement is more appropriate for the parking lanes since it contains and infiltrates runoff in similar engineered media without reducing the number of parking spots. This is also the case for narrow sidewalks that could not provide adequate pedestrian space if planter boxes were installed. Permeable pavement is also feasible for alleys and parking lots. Depending on the design, permeable pavement use in parking lots can be provided in select areas to serve larger lots, thus reducing the amount of pavement replacement necessary. Parking lots, like the public lot on the south side of King Street east of Route 1 North, could be considered.

2.2.3 Vegetated swales (Bioswales)

A vegetated swale is a shallow, linear channel planted with a variety of vegetation to slow, filter, and infiltrate stormwater runoff. These channels are designed to filter water through the vegetation and, if sufficiently permeable, through the underlying soils. A permeable, engineered soils mix can also be included where in-situ soils are not permeable in order to provide some additional stormwater volume reduction and pollutant removal opportunities. In this instance, an underdrain or aggregate layer is also included. These retrofits are typically less expensive since no impervious surfaces need to be removed. They also tend to enhance the natural environment of parks and other green spaces thus garnering public support, provided they do not interfere with the intended property usage (for example, sports fields). Depending on the intended functionality, these systems can range from a simple channel lined with turf grass, to a more complex swale containing an engineered soil mix, underdrain, check dams, and diverse landscaping design.

Vegetated swales are known by various names, including bioswales, dry swales, wet swales, grass channels, grass swales, and biofiltration swales. These names typically vary based on design intent and are primarily influenced by soil type and extent of soil amendments, vegetation used, and period of intended ponding or saturation. Vegetated swales are typically designed as flow-through systems with little detention or storage. However, an underlying aggregate layer and/or check dams can be employed to slow flow and enhance infiltration capacity.

2.2.4 Biorention (Rain gardens)

Bioretention is a practice whereby runoff is collected in shallow depressions and is allowed to infiltrate through an engineered soil media consisting of sand, soil, and organic matter. The cell is planted with suitable vegetation capable of withstanding the hydrologic extremes (periods of inundation followed by periods of dryness, which are a result of the high sand content). The surface of the facility is covered by a layer of mulch and, depending on the permeability of the in-situ soils, often includes an underdrain that collects and discharges water to a suitable outlet. Water quality and quantity benefits are achieved through physical filtering, biological, and chemical mechanisms, as well as through retention, absorption and infiltration.

Bioretention facilities can be known by many names, including bioretention basins, bioretention filters, or rain gardens, among others. These names are sometimes based on the size (with rain gardens typically referring to smaller scale facilities) and/or functionality (without or without underdrains), but all act in the same manner. Drainage patterns around areas of pervious cover will indicate appropriate locations for these features, such as in Washington Street median. In addition, rain gardens are popular on school properties for providing opportunities to educate students on the water cycle, hydraulics, horticulture, and other topics. Schools and areas near schools can be evaluated for siting rain gardens.

2.2.5 Downspout Disconnects

It is possible that installation of cisterns or downspout disconnects could also have an impact. The City is already encouraging residential collection and reuse of rainfall with the "*Build Your Own Rain Barrel Workshops*". Commercial use of cisterns is less common, unless there is a means for reusing the water or some other incentive like a stormwater tax credit. Downspout disconnects are easy and inexpensive to construct and therefore relatively easier to recommend for private buildings. However, unless the downspout is connected to a rain barrel, planter box, or other pervious surface, downspout disconnections will have minimal impact on CSO discharges.

Section 3 Green Infrastructure Opportunities

This section describes the GI technologies use for developing cost estimate and criteria evaluation. Detailed analysis of existing site conditions, cost effectiveness of green infrastructure options, and comparison to City historic standards and review process are necessary if the GI alternative is retained. This data could be used in combination with the gray CSO control alternatives to evaluate green and green/gray hybrid solutions for CSO control.

The recommendations are customized for three groups: City-owned parcels, City right-of-way, and privately-owned parcels.

3.1 City-owned Parcels

For City-owned Parcels, the following GI technologies are considered:

- For new buildings or building undergoing major renovations, cisterns and downspout disconnects are recommended where practical;
- For existing buildings, continued implementation of the City's rain barrel program and downspout disconnects are recommended;
- Permeable pavement is recommended for parking lots; and
- Bioswales and bioretention/rain gardens are recommended for green spaces.

3.2 City Right-of-Way

As noted in Section 2, City-owned parcels make up only 2% of the acreage in the CSS area. However, the sidewalks, alleys, and roads in the public right-of-way make up 33% of the acreage. Green infrastructure retrofits in the public right-of-way have the potential to have a significant impact on the stormwater volume. According to the City's Green Sidewalks BMP Design Guidelines, "facilities which can reduce non-point source pollution … in stormwater run-off are required to the maximum extent practicable within the City's Public rights-of-way." Table 2-1 above indicated that sidewalks and alleys total 55 acres.

Permeable pavement in sidewalks, alleys, and parking lanes in the public right-of-way has the greatest potential to reduce stormwater runoff in the CSS area. Planter boxes can also be utilized for the sidewalks in the right-of-way. Detailed analysis of existing site conditions, including usage patterns (HOV lanes), and the cost effectiveness of green infrastructure is necessary to determine the locations of permeable pavement in the public right-of-way.

3.3 Privately-owned Parcels

Implementing green infrastructure on privately-owned parcels is a unique challenge. Approaches include, but are not limited to:

- Expanding the public outreach program to encourage downspout disconnects and rainwater harvesting;

- Updating the building code to require new buildings or renovations to disconnect downspouts and include stormwater BMPs (such as planter boxes, bioswales, rain gardens, and permeable pavements);
- Providing impervious tax incentives and fee discounts;
- Proffers; and
- Long term redevelopment requirements.

The general recommendations for GI on privately-owned parcels are listed below. While the City generally encourages and supports GI projects on private property, the City cannot impose GI retrofits on privately owned property. As such, no credit is included for the private parcel in terms of volume reduction and other performance measures.

- Buildings – Commercial and medium and high density residential
  - Downspout disconnects are recommended.
- Buildings – Low density residential
  - Rainwater harvesting and downspout disconnects are recommended.
- Impervious Cover
  - Permeable pavement is recommended.
- Pervious Cover
  - Bioswales and rain gardens are recommended.

3.4 Basin Sizing Assumptions

3.4.1 Target Served Area

Planning level estimates, as percentage of the land use area, are made for the two drainage basins in the CSS area regarding a target service area for each GI technology. For the purposes of this technical memorandum, it is assumed that 100% of all impervious areas for the City-owned parcels and the City Right-of-Way will be retrofitted with GI. This assumption is counter to the guidance in the "*Greening CSO Plans: Planning and Modeling Green Infrastructure for Combined Sewer Overflow (CSO) Control*" (USEPA, March 2014), which suggests planning for the realistic potential for GI implementation. This assumption is made when considering GI as a primary CSO control technology in order to approach the performance requirements of the TMDL.

3.4.2 Target Installed Area

Estimates for the area required for the installation of the GI technology are based a ratio of target served area to the target installed area. In most cases the runoff is directed to the GI technology such that the area served is much larger than the installed area. Generally, the following ratios were used:

- Downspout Disconnects: 1:1
- Planter Boxes: 4:1
- Permeable Pavement: 4:1

- Bioswales, Bioretention and Rain gardens: 20:1

3.4.3 Implementation Timeline

Ideally, GI will be installed in conjunction with redevelopment and/or infrastructure renewal projects (e.g. road resurfacing, side walk replacement); however, in order to meet the 2035 LTCPU deadline a more aggressive implementation timeline will be required. Approximately 37 acres of installed area is identified in the following sections.

3.5 Potential GI Impact in the CSS area

Estimates of the potential impact of GI on both the drain areas are provided in the following sections for both the city-owned parcels and the city-owned right-of-way.

3.5.1 Royal Area (CSO 002)

The potential impact of the green infrastructure projects are summarized in Table 3-1 and Table 3-2 below for the Royal area of the CSS.

Table 3-1
Potential GI Impact for City-Owned Parcels in the Royal Area (CSO 002)

Land Use	GI	Royal Area (CSO 002) (acres)	Target Served Area (acres)	(%)	Target Installed Area (acres)	(%)	Estimated Controlled Stormwater Volume for 1" Storm (% reduction)	Estimated Volume Reduction per 1" Storm (gallons)
Buildings	Downspout disconnect	0.6	0.64	100%	0.64	100%	10%	1,734
Impervious Cover	Permeable pavement	1.0	0.77	80%	0.19	20%	60%	12,580
	Bioretention/ Rain garden		0.10	10%	0.005	0.5%	60%	1,572
	Bioswales		0.10	10%	0.005	0.5%	40%	1,048
Total		**1.6**	**1.60**	**100%**	**0.84**			**16,935**

Table 3-2
Potential GI Impact for City-Owned Right-of-Way in the Royal Area (CSO 002)

Land Use	GI	Royal Area (CSO 002)	Target Served Area		Target Installed Area		Estimated Controlled Stormwater Volume for 1" Storm	Estimated Volume Reduction per 1" Storm
		(acres)	(acres)	(%)	(acres)	(%)	(% reduction)	(gallons)
Roads	Permeable pavement in parking lanes	44.0	43.99	100%	11.00	25%	60%	716,722
Alleys	Permeable pavement	0.7	0.68	100%	0.17	25%	60%	11,049
Sidewalks	Planter Boxes	19.4	9.71	50%	2.43	13%	40%	105,456
	Permeable pavement		9.71	50%	2.43	13%	60%	158,184
Total		**64.1**	**64.08**	**100%**	**16.02**			**991,411**

3.5.2 King and West Area (CSO 003 and 004)

The potential impact of the green infrastructure projects are summarized in Table 3-3 and Table 3-4 for the King and West area of the CSS.

Table 3-3
Potential GI Impact for City-Owned Parcels in the King and West Area (CSO 003/4)

Land Use	GI	King and West Area (CSO 003/4)	Target Served Area		Target Installed Area		Estimated Controlled Stormwater Volume for 1" Storm	Estimated Volume Reduction per 1" Storm
		(acres)	(acres)	(%)	(acres)	(%)	(% reduction)	(gallons)
Buildings	Downspout disconnect	1.0	0.98	100%	0.98	100%	10%	2,649
Impervious Cover	Permeable pavement	0.4	0.33	80%	0.08	20%	60%	5,330
	Bioretention/ Rain garden		0.04	10%	0.002	0.5%	60%	666
	Bioswales		0.04	10%	0.002	0.5%	40%	444
Total		**1.4**	**1.38**	**100%**	**1.06**			**9,089**

Table 3-4
Potential GI Impact for City-Owned Right-of-Way in the King and West Area (CSO 003/4)

Land Use	GI	King and West Area (CSO 003/4)	Target Served Area		Target Installed Area		Estimated Controlled Stormwater Volume for 1" Storm	Estimated Volume Reduction per 1" Storm
		(acres)	(acres)	(%)	(acres)	(%)	(% reduction)	(gallons)
Roads	Permeable pavement in parking lanes	26.7	26.68	100%	6.67	25%	60%	434,696
Alleys	Permeable pavement	1.3	1.35	100%	0.34	25%	60%	21,940
Sidewalks	Planter Boxes	10.1	5.07	50%	1.27	13%	40%	55,033
	Permeable pavement		5.07	50%	1.27	13%	60%	82,550
Total		**38.2**	**38.16**	**100%**	**9.54**			**594,218**

3.6 Site Specific Opportunities

Through a cursory review of the GIS data and images from Google Maps the following tables provide an initial list of potential parcel-specific opportunities.

Table 3-5
Potential GI Opportunities for City-Owned Parcels with Buildings

Area	Name	Address	Existing GI	Potential GI Opportunities for Buildings (major renovation)	Potential GI Opportunities for Sites
King and West	Black History Resource Center	906 Wythe St.	Downspout disconnect	None	Permeable pavement in parking lot
King and West	Black History Resource Center	902 Wythe St.	Downspout disconnect	None	None
King and West	Fire Station #55	1210 Cameron St.	None	Downspout disconnect	Sidewalk planter box; permeable pavement in parking lot
King and West	Charles Houston Rec Center	901 Wythe St.	Green Roof	None	None
Royal	Lyles Crouch Elem. School	530 S. St. Asaph St.	None	Downspout disconnect	Permeable pavement in parking lot; Rain garden
Royal	Safe Haven Facility	115 N Patrick St	None	Downspout disconnect	None

Table 3-6
Potential GI Opportunities for Further Analysis for City-Owned Parcels without Buildings

Area	Name	Address	Existing GI	Potential GI Opportunities
King and West	Fayette and Queen Park (Helen Miller / Bernard Hunter Park)	250 N. Fayette St.	None	Bioswale or rain garden
King and West	Durant Rec. Center	1501 Cameron St.	None	Bioswale or rain garden
Royal	Parking Lot	120-122 ½ N. Patrick St.	None	Permeable pavement
Royal	Armory Tot Lot	208 S. Royal St.	None	Permeable pavement or sidewalk
Royal	Parking Lot	916-920 King St.	None	Permeable pavement
Royal	Parking Lot	116 S. Henry St.	None	Permeable pavement
Royal	Former Wilkes St. ROW	500 S. Patrick St.	None	Permeable pavement
Royal	Former Wilkes St. ROW	850 Wilkes St.	None	Permeable pavement

Section 4 Evaluation Criteria

The GI alternatives are evaluated based criterion defined in the *Evaluation Criteria Technical Memorandum* and include:

- Cost
- CSO Reduction (CSO Volume)
- Effectiveness
- Implementation Effort
- Impact to the Community
- Expandability
- Net Environmental Benefit
- Nutrient Credits for the Chesapeake Bay TMDL
- Permitting Issues
- Required Maintenance

The *Alternatives: Ranking and Recommendation Technical Memorandum* will rank the alternatives based on the above criteria and established weighting. The follow sections are provided to illustrate how the individual CSO alternatives will rank.

Cost estimates and performance predictions are based on the City-owned parcels and the publicly owned ROW. No credit is included for the private parcels in terms of volume reduction and other performance measures.

4.1 Cost

GI unit costs are from the *Basis of Cost Opinions Technical Memorandum*. Due to the urban nature of the combined sewer area and the associated complications that are likely to occur (including issues such as existing infrastructure and utilities, limited construction access, and smaller project footprints), it was generally assumed that implementation costs would be at the higher end of documented construction costs. It was also assumed that most, if not all, of the GI work would be in the form of retrofits (as opposed to new construction) which also adds considerably to project costs as a result of the above-mentioned constraints.

4.1.1 Capital

The capital costs for the GI alternatives associated with the combined sewer sheds are shown in Table 4-1. A complete cost estimate is provided in Attachment A.

Table 4-1
Estimated Capital Cost of GI

CSS Area	Construction Cost	Project Costs	Wet Weather Improvements	Total Capital Cost
Royal (CSO 002)	$30.4	$10.6	$0.0	$41.0
King and West (CSO 003/4)	$18.0	$6.3	$37.7*	$62.0
*Select wet weather improvements, including hydraulic grade line control structure, AlexRenew WRRF upgrades, and the wet weather pump station, will be shared facilities with Fairfax County. The cost split for these shared facilities will be determined at a later date				

There is a project, independent of the LTCPU, currently under consideration by the City, AlexRenew, and Fairfax County to provide wet weather improvement, address basement backups during large wet weather events, as well other benefits for the King and West sewer shed (CSOs 003 and 004). Unlike other alternatives (i.e. tunnels), these wet weather improvements cannot be addressed through GI alone. In order to normalize the cost of the alternatives, the estimated capital costs of these wet weather improvements are included for the King and West area.

4.2 CSO Reduction (CSO Volume)

Based on the GI technologies and target area percentages identified above, and applying the estimated volume reductions for a 1" storm, the estimated annual CSO reductions for the Typical Year and TMDL periods are summarized below.

CSS Area	Year	Total Overflow Volume (MG)	CSO Volume Reduction (MG)	Volume Reduction (%)	Rating
Royal (CSO 002)	1984	43	17	39%	Low
King and West (CSO 003/4)	1984	18	10	56%	Low

CSS Area	Year	Total Overflow Volume (MG)	CSO Volume Reduction (MG)	Volume Reduction (%)	Rating
Royal (CSO 002)	2004/2005	117	43	37%	Low
King and West (CSO 003/4)	2004/2005	102	27	27%	Low

The CSO volume reductions associated with the GI result in a modest reduction in overflows per year from 50-60 overflows to 40-50 overflows in the typical year.

4.3 Effectiveness

As a standalone CSO control strategy, GI will not achieve the bacteria reduction requirements.

Effectiveness Rating	Description	Royal (CSO 002)	King and West (CSO 003/4)
Very High	Removal of all bacteria from Hunting Creek		
High	High bacteria reduction		
Medium	Moderate bacteria reduction		
Low	Low bacteria reduction		
Minimal	Minimal reduction	X	X
None	No reduction		

4.4 Implementation Effort

The retrofit of existing infrastructure with GI is fairly disruptive in the urban environment of Old Town Alexandria. The implementation the GI technologies described in this technical memorandum on a wide scale basis is estimated at 10 to 30 years. As such, GI will have difficulty achieving the 2035 deadline.

Implementation Questions	Royal (CSO 002)	King and West (CSO 003/4)
Are construction projects low in complexity or utilize commonly implemented technology?	Yes	Yes
Is land available in the proposed project areas?	Yes	Yes
Are there adequate amount of resources, labor, and expertise to complete projects?	Yes	Yes
Can the proposed project(s) be reasonably constructed in the highly urban environment of Old Town Alexandria?	Yes	Yes
Is it likely the LTCP deadlines will be met?	No	No
Rating	High	High

4.5 Impact to the Community

The impact of GI on residents and business during the construction will be considerable. The associated disruption includes street closures, sidewalk closures, construction noise, construction dust, and utility outages. Access to residential properties and commercial properties during construction will be negatively impacted. In order to minimize these impacts, the GI improvements would ideally be paired with redevelopment or other infrastructure renewal programs. Once constructed GI will have many potential benefits including, improved community livability (aesthetics and property values), human health, air quality, water quality, groundwater recharge, and wildlife habitats.

Impact on Business and Public Rating	Description	Royal (CSO 002)	King and West (CSO 003/4)
High	Improved quality of life and minimal negative impact during implementation	X	X
Medium	Some negative impact during implementation		
Low	Excessive negative impact during implementation		

4.6 Expandability

The progressive approach of GI provides good opportunities for expansion. The target percentages for areas served presented above are considered optimistic, but could be increased with a more aggressive program and/or exceptional adoption of GI retrofits on private property.

Expandability Rating	Description	Royal (CSO 002)	King and West (CSO 003/4)
High	Multiple options and space for expansion	X	X
Medium	Few options and space for expansion		
Low	Limited options and space for expansion		
Minimal (or none)	No opportunities for expansion		

4.7 Net Environmental Benefit

The net environmental benefit is based on each alternative's Envision base score. More information about this ranking can be found in the *Evaluation Criteria Technical Memorandum.*

Net Environmental Benefit Rating	Envision Checklist Score	Royal (CSO 002)	King and West (CSO 003/4)
Very High	Base score + >35	X	X
High	Base score + 26-35		
Medium	Base score + 16-25		
Low	Base score + 6-15		
Minimal	Base score + 0-5		

4.8 Nutrient Credits for the Chesapeake Bay TMDL

There is only limited opportunity to generate nutrient or sediment credits for the Chesapeake Bay TMDL for the GI alternative. The values below only represent the credits associated with the CSO volume reduction and do not attempt to estimate any additional treatment performance through the BMP, as the remaining runoff will have minimal treatment. Additionally, the published treatment data (percent removal) varies widely, and does not distinguish between pollution removal for retention and infiltration vs. pollutant removal of the remaining runoff through treatment.

CSS Area	Nitrogen	Phosphorous	TSS	Rating
Concentration Removed (mg/l)	5.88	0.78	70.5	N/A
Royal (CSO 002) lbs/yr	178	24	2,131	Minimal
King and West (CSO 003/4) lbs/yr	109	14	1,301	Minimal

4.9 Permitting Issues

The GI alterative is given a moderate risk for permitting issues. While there are no major permits required, GI will require various construction permits that will continuously need to be requested and maintained for each individual project, including, but not limited to: the Virginia Stormwater Management Program (VSMP), noise permits, and traffic permits.

Permitting Issues Rating	Description	Royal (CSO 002)	King and West (CSO 003/4)
High	Minimal risk of permit issues		
Medium	Moderate risk of permit issues	X	X
Low	Significant risk of permit issues		

4.10 Required Maintenance

Green infrastructure facilities are typically self-operating by design to accommodate variable weather patterns. Performance monitoring, if desired, would require operations involvement.

Maintenance of green infrastructure is necessary for proper operation and long-term use. The level of effort for maintenance varies based on the type of green infrastructure and is typically focused on above ground visual inspections and landscaping type upkeep. It is recommended to make a plan in advance of who is responsible for maintenance since this work may not obviously fall within the typical maintenance tasks addressed by any one department. There may be an opportunity to engage nearby homeowners or civic groups in maintenance activities since GI is typically a visible feature that communities value.

Requirement Maintenance Rating	Description	Royal (CSO 002)	King and West (CSO 003/4)
High	Few and infrequent maintenance		
Medium	Frequent maintenance	X	X
Low	Frequent and expensive		

4.10.1 O&M Costs

Annual operation and maintenance (O&M) costs are estimated for the GI alternatives based on the *Basis of Cost Opinions Technical Memorandum*.

Area	Annual O&M
King and West (CSO 003/4)	$0.9
Royal (CSO 002)	$1.5

4.11 Net Present Worth

The NPW is estimated based on a twenty (20) year period and a 3.0% discount rate. The NPW includes the capital costs and annual O&M of the GI alternatives.

Area	Total Capital Cost	O&M PW	NPW
King and West (CSO 003/4)	$62.0	$13.4	$75.4
Royal (CSO 002)	$41.0	$22.6	$63.7

4.12 Recommendation for Alternative Scoring

It is recommended GI alternatives be moved forward for scoring and ranking relative to the other alternatives; however, it is important to note that the GI alternatives will not achieve the TMDL bacteria reductions on their own. As such, GI is more suited as a complementary technology.

Section 5 Opportunities for Synergy with Other Technologies

After scoring and ranking the separation relative to the other alternatives, it is likely that GI will not be recommended as a primary strategy for the City's LTCPU. However, GI offers many advantages as a complementary technology.

5.1 GI as a Complementary Technology

GI is an environmentally positive complementary control strategy and can be cost effective when the full benefits of GI are considered and when used in combination with other CSO control strategies. A few notable examples of how other communities are implementing GI has a complementary technology in their Long Term Control Plans include:

- DC Water is targeting approximately 5% reduction in their overflow volume through the use of GI as a complementary technology.
- New York City is targeting to manage 1" of stormwater runoff from 10% of impervious surfaces in combined sewer areas.
- The City of Philadelphia is targeting to manage 1" of stormwater runoff from 34% of impervious surfaces in combined sewer areas.

Section 6 Additional Investigation Needs

If the GI alternative is retained the following additional investigations should be considered:

- Geotechnical and soil permeability studies;
- Detailed site selection evaluations;
- Develop a GI demonstration project;
- Develop a detailed phasing and implementation plan; and
- Monitor ongoing GI projects for construction pricing trends.

Attachment A

Green Infrastructure Cost Estimates

COA LTCPU
GI Cost Summary

Date: 28-Mar-15
Prepared By: J. McGettigan
Checked By: C. Wilber
Rounding: 3 Digits

100% of Impervious Public Parcels and ROW

Area	Construction Cost	Project Costs	Wet Weather Improvements	Total Capital Cost
King and West	$18.0	$6.3	$37.7	$62.0
Royal	$30.4	$10.6	$0.0	$41.0
Pendleton	$34.8	$12.2	$0.0	$47.0

Area	Annual O&M
King and West	$0.9
Royal	$1.5
Pendleton	$1.7

Area	Total Capital Cost	O&M PW	NPW
King and West	$62.0	$13.4	$75.4
Royal	$41.0	$22.6	$63.7
Pendleton	$47.0	$25.9	$73.0

Alternative King and West GI
Date: 28-Mar-15
Prepared By: J. McGettigan
Checked By: C. Wilber

Table 1: Capital Cost Estimate

Item		QTY	Units	Unit Cost	Total	Comments
City Owned Parcels						
Downspout disconnect		0.98	ac	$80,000	$78,000	
Permeable pavement		0.08	ac	$1,306,800	$107,000	
Bioretention or rain garden		0.002	ac	$2,613,600	$5,000	
Bioswale		0.002	ac	$653,400	$1,000	
Right-Of-Way						
Roads	Permeable Pavement	6.67	ac	$1,306,800	$8,716,000	
Alleys	Permeable Pavement	0.34	ac	$1,306,800	$440,000	
Sidewalks	Planter Boxes	1.27	ac	$1,829,520	$2,317,000	
Sidewalks	Permeable Pavement	1.27	ac	$1,306,800	$1,655,000	
Private Parcels						
Downspout disconnect			ac	$80,000	$0	
Permeable pavement			ac	$1,306,800	$0	
Biorention or rain garden			ac	$2,613,600	$0	
Bioswale			ac	$653,400	$0	
Subtotal					*$13,319,000*	
Construction Contingency		35%			$4,662,000	
Construction Subtotal					*$17,981,000*	
Planning, Design, CM, Administration, Permitting and Easements		35%			$6,293,000	
Total Project					**$24,274,000**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Maintenance Costs					
Percentage of Construction	5.00%			$ 899,050	DC LTCP Assumption
Annual O&M				$ 899,050	
Net Present Worth				$ 13,376,000	

Alternative	Royal Area GI
Date:	28-Mar-15
Prepared By:	J. McGettigan
Checked By:	C. Wilber

Table 1: Capital Cost Estimate

Item		QTY	Units	Unit Cost	Total	Comments
City Owned Parcels						
Downspout disconnect		0.64	ac	$80,000	$51,000	
Permeable pavement		0.19	ac	$1,306,800	$252,000	
Bioretention or rain garden		0.00	ac	$2,613,600	$13,000	
Bioswale		0.00	ac	$653,400	$3,000	
Right-Of-Way						
Roads	Permeable Pavement	11.00	ac	$1,306,800	$14,371,000	
Alleys	Permeable Pavement	0.17	ac	$1,306,800	$222,000	
Sidewalks	Planter Boxes	2.43	ac	$1,829,520	$4,440,000	
Sidewalks	Permeable Pavement	2.43	ac	$1,306,800	$3,172,000	
Private Parcels						
Downspout disconnect			ac	$80,000	$0	
Permeable pavement			ac	$1,306,800	$0	
Biorention or rain garden			ac	$2,613,600	$0	
Bioswale			ac	$653,400	$0	
Subtotal					*$22,524,000*	
Construction Contingency		35%			$7,883,000	
Construction Subtotal					*$30,407,000*	
Planning, Design, CM, Administration, Permitting and Easements		35%			$10,642,000	
Total Project					**$41,049,000**	

Table 2: Operational and Maintenance Cost Estimate

Item	QTY	Units	Unit Cost	Total	Comments
Maintenance Costs					
Percentage of Construction	5.00%			$ 1,520,350	DC LTCP Assumption
Annual O&M				$ 1,520,350	
Net Present Worth				$ 22,619,000	

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