Technical Memorandum 600.5

CSO Beach Projects

Demand Management Analysis

May 2010

King County

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Acronyms

BMP	Best management practices
CSO	combined sewer overflow
CSS	combined sewer system
Ecology	Washington State Department of Ecology
GIS	geographic information system
GSI	green stormwater infrastructure
LID	low-impact development
MOUSE	modeling software used by WTD for conveyance system planning
MS4	municipal separate storm sewer system
NPDES	National Pollutant Discharge Elimination System
OECA	EPA's Office of Enforcement and Compliance Assurance
ROW	right-of-way
SPU	Seattle Public Utilities
EPA	U.S. Environmental Protection Agency
WERF	Water Environment Research Foundation
WTD	King County Wastewater Treatment Division

EXECUTIVE SUMMARY

King County's Wastewater Treatment Division is considering implementation of green stormwater infrastructure as one of several means to control its combined sewer overflows (CSOs) so that they meet the Washington State standard of no more than one overflow on average per year at each CSO site.

Four county CSO control projects, collectively called the Puget Sound beach projects, are in the predesign phase. Early in the process, stakeholders recommended that "demand management" techniques be considered. Such techniques serve to reduce peak flow into the combined sewer system. Green stormwater infrastructure (GSI) is a cost-effective, sustainable, and environmentally friendly demand management approach to diverting and managing stormwater. The four basins that drain to the Puget Sound beach CSOs were evaluated to determine if any of the basins would be suitable for CSO control through GSI, and if basins were identified, to develop planning-level GSI alternatives to be considered along with other CSO control alternatives for those basins.

The GSI analyses and results are as follows:

- A geographic information system (GIS) analysis identified the destinations of stormwater flows from both private parcels and public rights-of-way in the four basins (and their subbasins).
- A GIS spatial analysis identified the impervious acreages in the subbasins that drain to the combined sewer system and the level of mitigation that various GSI techniques could achieve. The analysis identified Subbasin 416 in the Barton basin as the most feasible for GSI implementation and roadside rain gardens as the GSI technique that would realize the greatest benefit. The level of mitigation through rooftop disconnections in the Murray and South Magnolia basins may be explored further in subsequent analyses.
- Modeling of a number of rain garden design factors indicates that a total bottom area of about 0.88 acre in rain gardens would be needed to control CSOs in the Barton basin. Approximately 174 roadside rain gardens would meet this requirement.
- The planning-level capital cost estimate for rain gardens in Subbasin 416, developed based on national and local projects, is $8.3 million with contingency.

The GSI alternative and two storage alternatives for the Barton basin will be presented to the public in spring 2010. The public's input will help King County define a proposal that will, in spring 2011, go through the environmental review process required by state law. Design is expected to be completed and construction to begin on all Puget Sound beach projects in 2013.

1.0. INTRODUCTION

King County's Wastewater Treatment Division (WTD) plans to control all of its 38 combined sewer overflow (CSO) sites to an average of no more than one overflow per year by 2030.[2] Projects are under way to control four CSO sites near Puget Sound beaches—Barton Pump Station, Murray Pump Station, South Magnolia Overflow Weir, and North Beach Pump Station—all in the City of Seattle.

In addition to storage and treatment, WTD is investigating demand management options to control the Puget Sound beach CSOs. Demand management techniques reduce the amount of stormwater and groundwater in the combined sewer system. Examples include sewer separation, infiltration and inflow reduction, and stormwater diversion/management. Green stormwater infrastructure (GSI) is a cost-effective, sustainable, and environmentally friendly approach to diverting and managing stormwater.

The areas (basins) that send stormwater to the four Puget Sound beach CSOs were evaluated to determine whether GSI, either alone or in combination with other methods, can achieve CSO control.

This technical memorandum describes the methods and results of each step of the evaluation. The first step was to identify the sources of stormwater entering the combined sewer system. To do this, WTD conducted a geographic information system (GIS) analysis to calculate the acreages in assessed properties and in the right-of-way in the four Puget Sound beach CSO basins that contribute flow to the combined sewer system. Information from the GIS analysis was used to identify areas that showed potential for GSI applications. Subbasin 416 in the Barton basin emerged as the most promising area for GSI application. The next step was to determine appropriate GSI techniques for this basin and to estimate sizes of facilities and costs for implementing them. Initial analyses were done for areas with less potential. More information can be found in the technical memorandums that detail each step.[3]

The remainder of this chapter provides background on the alternatives development and review process, regulatory impetus for using GSI, and the study area for the Puget Sound beach projects.

What is Green Infrastructure?

The concept of green infrastructure originated in the strategic conservation planning field. In this context, large forests, wetlands, greenbelts, and so forth—all part of the *natural* environment—are viewed as infrastructure because they support essential ecosystem functions (Great City, 2009).[1]

The term is increasingly being used to refer to *engineered* infrastructure at a smaller scale in relation to green stormwater management practices such as rain gardens and green roofs. These practices make use of soils and vegetation, in combination with other decentralized storage and infiltration approaches such as rain barrels and permeable pavement, to infiltrate, evaporate, capture, and reuse stormwater.

In addition to helping reduce CSOs and the amount of untreated stormwater that finds its way to surface water, green stormwater management facilitates natural processes that recharge groundwater, preserve baseflow in streams, moderate impacts to water and air temperature, and protect hydrologic and hydraulic stability.

Other names for green stormwater management include low impact development (LID), natural drainage, and water-sensitive design. This technical memorandum uses the term "green stormwater infrastructure" (GSI).

[1] http://www.greatcity.org/campaigns/green-infrastructure/
[2] Averaged over a 20- year period.
[3] *Technical Memorandum 207.1, CSO Beach Project GIS Analysis.* September 2008.
Technical Memorandum 600.1, CSO Beach Projects, Green Infrastructure Analysis. December 2010.
Technical Memorandum 600.3, *Modeling for GSI Options.* March 2010.

1.1 Identifying and Reviewing CSO Control Alternatives

In 2007, King County held workshops with internal and external stakeholders to identify approaches to control each of the Puget Sound beach CSOs. Because rooftop disconnection was identified as a possible approach for one basin, demand management was added as an option for all four basins. The approaches under consideration are as follows:

- Store peak flows during large storms and send them to the West Point Treatment Plant after the storm.
- Increase pumping and conveyance capacity to direct peak flows to existing treatment facilities.
- Reduce peak flows of stormwater and groundwater into the combined sewer system (demand management).
- Treat peak flows at a new local treatment facility.
- Use combinations of the options.

In late 2009, the project team presented this range of approaches at public meetings. The GSI team then met with project staff to discuss how to apply the criteria used for evaluating other project approaches to GSI; the results of the meeting are in Appendix A.

In spring 2010, specific alternatives for CSO control in each basin will be presented to the public. The public's input will help King County define a proposal for each basin that will, in spring 2011, go through the environmental review process required by state law. Design is expected to be completed and construction to begin on all projects in 2013.

Three alternatives are being considered for the Barton basin: two storage alternatives and the GSI alternative presented in this technical memorandum. A planned upgrade of the Barton Pump Station will increase capacity to help control CSOs in the basin. Size limitations at the station do not allow for expanding capacity to manage the entire volume of peak flows necessary to achieve CSO control. The remaining volume that must be managed to meet regulatory requirements will depend on the type and location of each alternative being considered.[4]

The demand management analyses for the Puget Sound beach projects will be used as a basis for evaluating demand management alternatives for future CSO control projects.

1.2 Regulatory Context for Implementing GSI

King County's CSOs are regulated through the West Point Treatment Plant's National Pollutant Discharge Elimination System (NPDES) permit. The U.S. Environmental Protection Agency (EPA) has delegated management of NPDES permits in Washington State to the Washington State Department of Ecology (Ecology).

In March 2007, EPA's Office of Water sent a memorandum to EPA regional administrators stating that green infrastructure "can be both a cost effective and an environmentally preferable approach to reduce stormwater and other excess flows entering combined or separate sewer systems in combination with, or in lieu of, centralized hard infrastructure solutions" (EPA, 2007b). In August of the same year, EPA's Office of Enforcement and Compliance Assurance

[4] For more information on the alternatives and schedule for the Puget Sound Beach CSO controls projects, see http://www.kingcounty.gov/environment/wtd/Construction/Seattle/BeachCSO.aspx.

(OECA) sent a memorandum on use of green infrastructure in NPDES permits and enforcement to state NPDES directors, regional counsel/enforcement coordinators, and regional water division directors. In the memorandum, OECA encourages permitting authorities to structure permits and guidance/criteria for stormwater plans and long-term CSO control plans to encourage use of green infrastructure approaches where appropriate (EPA, 2007a). The memorandums are in Appendix B.

In January 2008, OECA audited King County's wet-weather management programs. Such audits are occurring across the country. OECA selects agencies to be audited based on size, population served, and system complexity. City of Seattle programs underwent a similar audit at the same time. OECA and EPA Region 10 staff, accompanied by Ecology staff, performed an intensive inspection over five days. Since that time, King County has met with EPA and provided additional information on programs and activities. EPA has not yet made its findings public. EPA also conducted an audit of Ecology's NPDES program around the same time.

Consent decrees often follow these audits. A consent decree is a legal document approved by a judge that formalizes an agreement between EPA and other parties. Recent consent decrees have required wastewater utilities to implement green infrastructure and/or to include evaluation of green infrastructure as a component of their long-term CSO control plans. Consent decrees for Washington D.C., Cincinnati, Philadelphia, Pittsburgh, and Mobile include green infrastructure clauses. Long-term CSO control plans for Philadelphia, Cleveland, Kansas City, Milwaukee, and Portland, to name a few, include green infrastructure in order to comply with EPA mandates.

To support these enforcement activities, EPA has issued guidance on employing green infrastructure for CSO control (EPA, 2008).[5]

1.3 Study Area

The basins and subbains that drain to the four Puget Sound beach CSOs are shown in Figure 1-1and Figure 1-2.[6] Figure 1-1 also shows the locations of other King County CSOs. Stormwater in these basins flows directly to the combined sewer system, directly to the separate municipal storm sewer system, or overland to a receiving water body. Characteristics of the basins are as follows:

- The North Beach basin, in the northwest corner of Seattle on a northwest facing slope, is 863 acres divided into three subbasins: 439, 440, and 441.
- The South Magnolia basin, between the Lake Washington Ship Canal and Elliott Bay on the west side of the city, is 771 acres divided into four subbasins: 151, 152, 153, and 154.
- The Murray basin, in West Seattle just north of Lincoln Park, is 992 acres divided into four subbasins: 419, 420, 421, and 423.
- The Barton basin, just south of both Lincoln Park and the Murray basin, is 863 acres divided into five subbasins: 414, 415, 416, 417, and 418.

[5] http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf
[6] Subbasins were delineated for flow monitoring and modeling conducted in 2006.

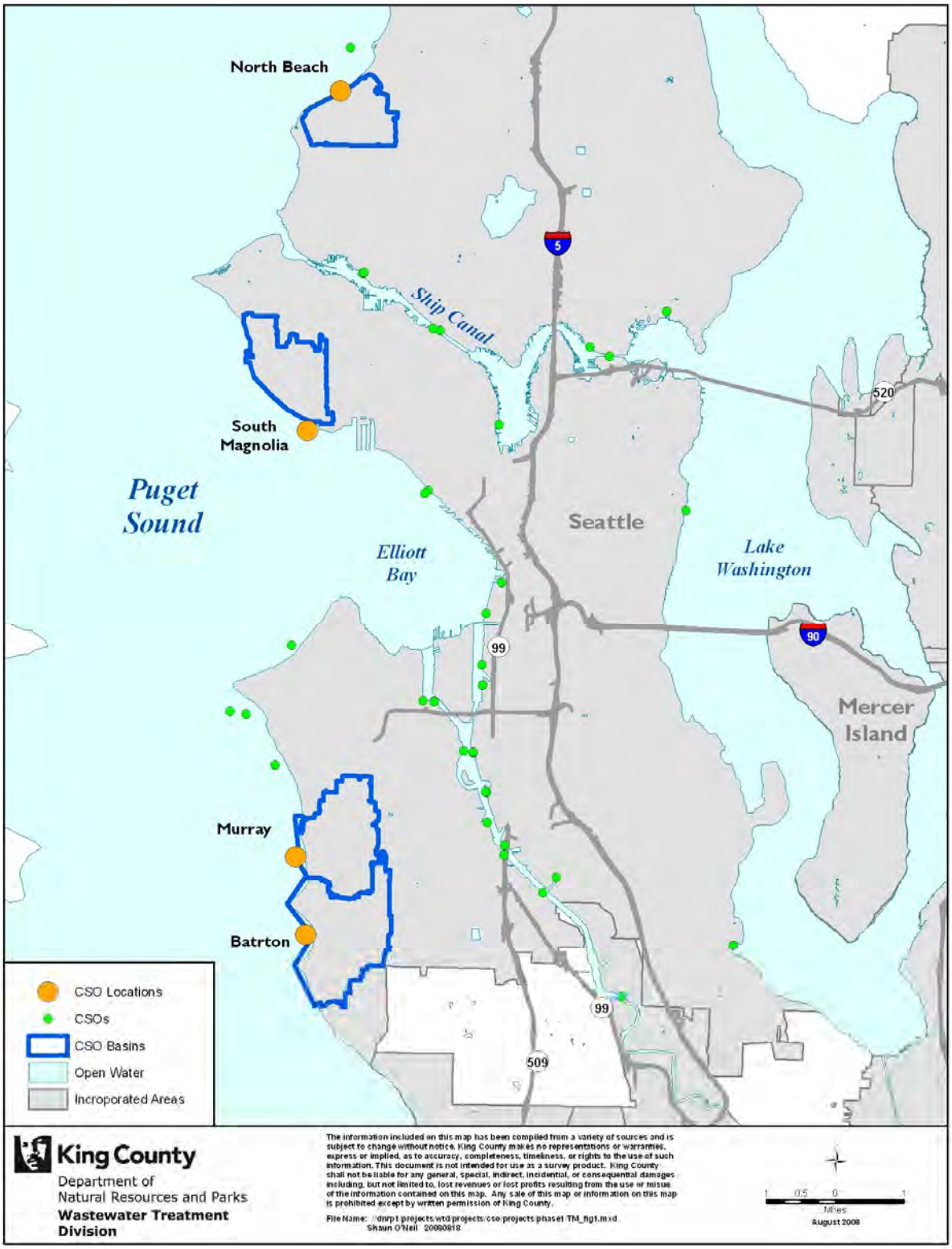


Figure 1-1. Location of Contributing Basins for Puget Sound Beach CSO Control Projects

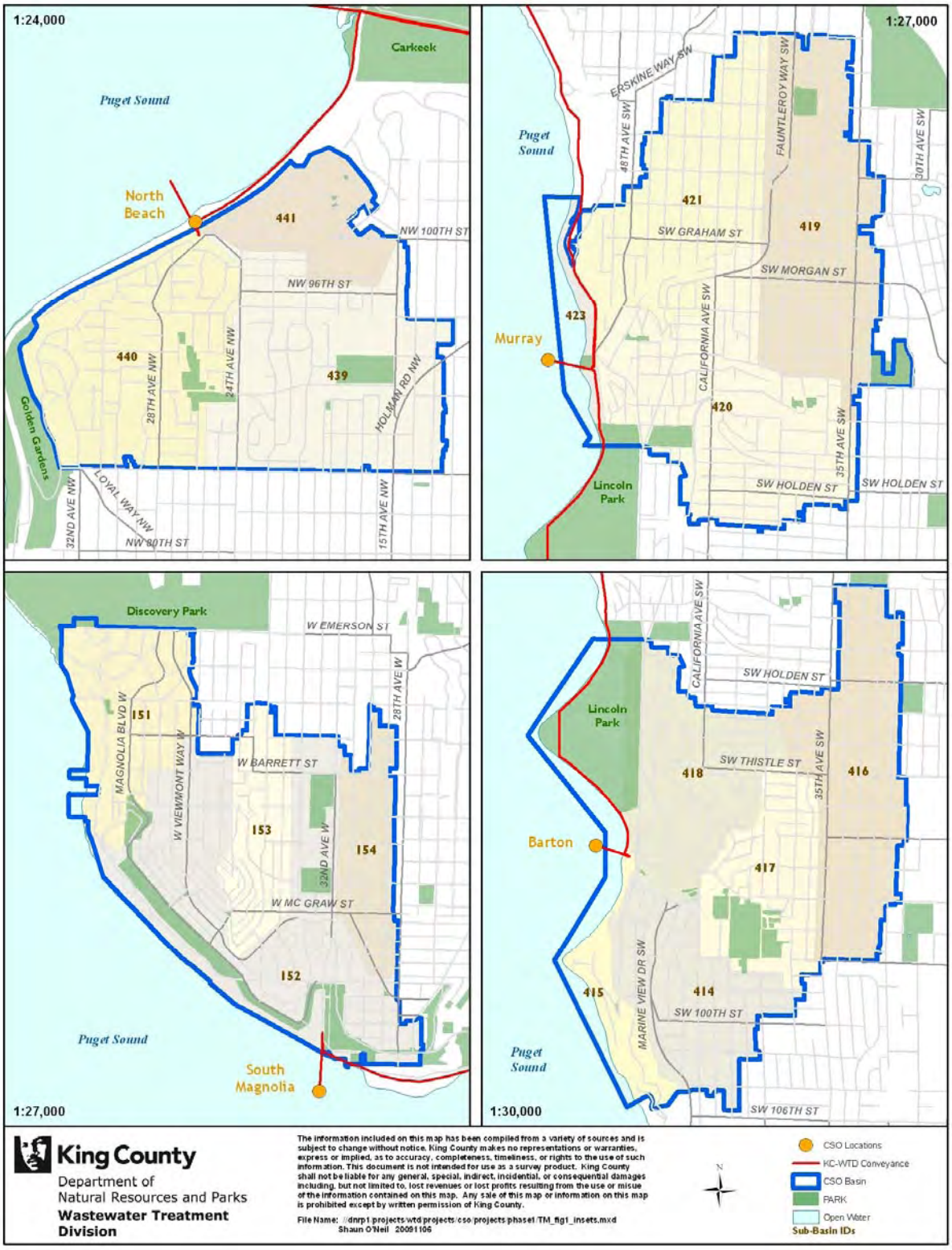


Figure 1-2. Location of Subbasins for Puget Sound Beach CSO Control Projects

2.0. IDENTIFYING POTENTIAL GSI AREAS AND OPTIONS

CSO programs need a strategy to identify large areas of impervious area connected to the combined sewer system (CSS) to mitigate stormwater runoff. Areas such as streets and other public rights-of-way (ROW) are potentially large sources of stormwater. Parcel-based solutions tend to have a smaller impact. Using individual single-family parcels requires the voluntary participation of property owners, which often requires offering an incentive; this option will work only if enough area is disconnected from the CSS. However, large parcels that are commercial, industrial, or institutional should be looked at when the street areas are separated or when it is cost-effective to reduce impervious parcel areas to reduce CSOs.

WTD performed a GIS analysis in 2008. The analysis identified sources of stormwater to the CSS and the separate municipal storm sewer system (MS4) and the characteristics of the basins as they relate to these sources. Impervious, pervious, and rooftop areas were identified, along with the destination of any flows originating from these locations, on both assessed property and the street ROW. The analysis built on flow monitoring and modeling in the CSS conducted in 2006. The results of the analysis were used as inputs, along with rain and flow data, into a model of the basins to identify the scale and location of CSO control options for all basins.

Results of the GIS analyses were used to conduct a GIS spatial analysis to assess the feasibility of GSI implementation in the study area, to identify the most promising basins for GSI implementation, and to review and select GSI techniques that could achieve desired results.

The following sections describe the methods and results of these analyses.

2.1 Identifying Where Stormwater Flows From the CSO Basins

2.1.1 Methodology

The GIS analysis of stormwater destinations in the four basins consisted of the following steps:

- Evaluated available King County and City of Seattle GIS data and selected applicable data.
- Input the data into a geodatabase and develop useable datasets.
- Developed a model for extracting information from the underlying datasets to identify characteristics for each parcel and ROW and their contributions to the CSS and MS4.
- Developed assumptions to account for inaccuracies in GIS data through an iterative process of data evaluation and comparison of GIS-identified impervious acres.
- Field-verified basin characteristics to check assumptions.
- Developed parcel and ROW acreages for each subbasin and the destinations of flows from these acreages.
- Identified subbasins with a significant area connected to the CSS.

To develop useable datasets, subsets of all available and pertinent GIS data were created for each of the four CSO basins. City of Seattle conveyance data were used as the base to delineate CSO basins; subbasins delineated in the 1990s before GIS data were available were adjusted to match the boundaries of their basins. Once the data were limited to the basin extents, the parcels and ROWs were characterized.

Parcel and ROW Characterization

The first step in parcel characterization involved investigating the entire basin area and including any parcel that was depicted as being directly connected to the MS4. A geoprocessing model was created that evaluated the existence of conveyance features—infiltration pits, storm drain laterals, sewer laterals, catch basins, and downspouts—in each parcel and then attributed the parcels in the GIS layer with this information. The various combinations of the existence of the conveyance features with any contributions to the MS4 provided all of the information needed to allocate the different areas of the parcel—rooftop, impervious, and pervious—to the CSS or MS4. The square footages for the different area categories in each parcel were then calculated. Finally, the destination of the flow coming from the rooftops and the impervious/pervious areas for two sets of assumptions (described below) was indentified. For each field, the options were CSS, MS4, overland to receiving water body, via the ROW to the CSS, and via the ROW to the MS4. Each code was determined by selecting parcels that met the set of assumptions in that circumstance.

The ROW in each basin was characterized according to destination of flow using the terrain (described by 2-foot contours), catch basins, a ditch/culvert/curb system, and the underlying CSS and MS4 systems. The pervious and impervious areas of the ROW were split into three categories based on whether the flow from the ROW ended up in the CSS, the MS4, or the receiving water body via overland flow.

Assumptions and Field Verification

Because the GIS data are inconsistent in the depiction of features in different areas, assumptions were developed to help model catch basin, downspout, and conveyance locations and connectivity (Appendix C). Acreages were calculated for two scenarios, designated as Scenarios A and B, to provide a range of values for areas that contribute to the CSS. Each scenario had its own group of assumptions. Each was developed to capture as many combinations of depicted features that would indicate the accurate characteristics for a given property. Both scenarios are considered valid for estimating surface area that could potentially be diverted from the CSS.

Both King County and Seattle Public Utilities (SPU) conducted field investigations to test the assumptions and to gauge the level of confidence in the GIS data. County fieldwork consisted of visual surveys from the ROW to verify the existing downspout and catch basin locations in the GIS datasets and to identify any others not currently in the datasets. Overall, the GIS data regarding catch basins were accurate. The data representing downspouts were, as was expected, variable in accuracy across all four basins. In areas that drain to the CSS, about 15 to 30 percent of properties investigated had downspouts not in the GIS. For the two areas that were separated with no MS4 available to convey flow, 50 and 84 percent of the houses investigated, respectively, had downspouts that were not in the GIS and that conveyed flows from the roof or property into an underground conveyance, assumed to flow overland to the receiving water body.

In 2009, SPU performed a filed investigation of the four CSO basins. The investigation indicated that the accuracy of King County's GIS approach was well within planning-level expectations (SPU, 2009). Depending on the basin, the range of uncertainty is 10–39 percent. The

assumptions result in conservatively low results with respect to parcels, more specifically to roofs connected to the CSS. The accuracy of the downspout data on which these connections rely depend, in part, on the year the structure was built. For example, houses built prior to 1979 tend to be connected to the sanitary sewer system, whereas houses built after 1979 tend to be connected to the MS4. The SPU testing shows that this method of estimating connections to the CSS will underestimate the number of homes connected. Areas connected to the CSS in a partially separated basin will be greater than shown in the GIS model.

2.1.2 Results

The analysis provided total square footage for the parcel rooftop, impervious, and pervious areas and the ROW impervious and pervious areas and the final destinations of the associated flows for the two scenarios outlined in the assumptions. The acreages for each basin, broken down by the component areas, are shown in Table 2-1. The acreages were further defined by subbasins. Figure 2-1 shows the percentage of impervious area with connections to the CSS in each subbasin.

Table 2-1. Rooftop, Impervious, and Pervious Acreage by Basin

	Barton		Murray		North Beach		South Magnolia	
	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B	Scenario A	Scenario B
ROW	**287**	**287**	**281**	**281**	**152**	**152**	**243**	**243**
Impervious	224	224	232	232	119	119	195	195
Pervious	64	64	48	48	32	32	48	48
Parcels	**824**	**824**	**790**	**790**	**481**	**481**	**529**	**529**
Roof	185	185	184	184	128	128	144	144
Impervious	234	234	238	238	160	160	175	175
Pervious	405	405	368	368	193	193	210	210
Total	**1,112**	**1,112**	**1,071**	**1,071**	**633**	**633**	**771**	**771**

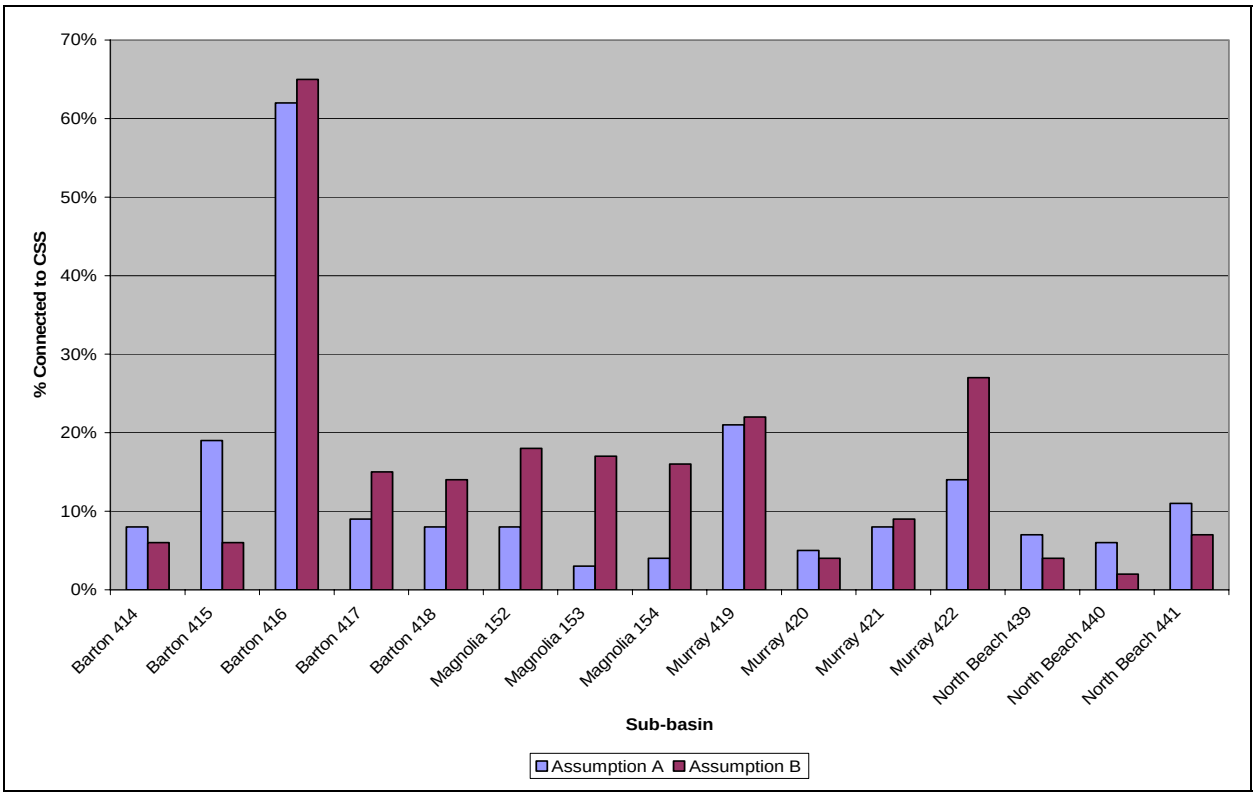


Figure 2-1. Percentage of Connected Impervious Surface to Combined Sewer System by Subbasin

2.2 GIS Spatial Analysis—Potential for Green Stormwater Infrastructure

King County based its feasibility analysis of the potential for GSI in the four CSO basins on a white paper published in October 2007 titled "Low Impact Development: San Francisco's Green Approach to Stormwater Management" (Kennedy et al., 2007). The San Francisco approach appears to be a cost-effective way to evaluate large areas of a city for GSI potential. WTD is using this approach as a basis for developing its GSI program. The City of Seattle is also developing an approach for GSI in its CSO control program. WTD is consulting with the city and modifying its approach as more is learned from completed city projects and as improved flow information becomes available.

San Francisco conducted a literature review and case studies, reviewed existing San Francisco programs that could complement or support GSI, conducted a GIS spatial analysis of potential GSI implementation, modeled GSI scenarios in the collection system model, and conducted a cost-benefit analysis. The GIS spatial analysis relied on a set of criteria developed to help identify suitable locations for each of five GSI techniques: Ecoroofs (green roofs), roof disconnection, street trees, bioretention, and permeable pavement. This section describes the methods and results of King County's GIS spatial analysis.

2.2.1 Methodology

The steps in King County's GSI feasibility analysis were as follows:

- Developed criteria to identify types of areas suitable for application the five GSI techniques, starting with the San Francisco criteria and modifying them to accommodate data available for Seattle (Table 2-2).
- For each GSI technique, identified the number of acres connected to the CSS in each of the 16 subbasins where stormwater could potentially be diverted or attenuated.
- Recommended one subbasin and one GSI technique for further analysis.

With the exception of areas identified for street tree planting, the analysis did not identify specific locations for GSI facilities. The facilities may be located outside an area that contributes to the CSS. For example, bioretention may occur on a property that will attenuate flow from the adjacent ROW that would otherwise have gone into the CSS.

Each GSI technique was evaluated for both Scenarios A and B. All of the criteria for a given scenario and source of flow—rooftop, impervious, or pervious—had to be met for that area to be considered as a source of flow for GSI techniques. Acreages identified for one GSI technique could also be included for another technique. For example, the acres under green roofs for a subbasin are also included in acres under roof disconnection for the same subbasin.

GSI Techniques

Ecoroofs (green roofs) consist of shallow layers of growing medium, low-growing vegetation, subsurface drainage, and a waterproof membrane.

Roof disconnection is a type of rainwater harvesting that involves removing water that flows from a roof through a downspout to a CSS and redirecting it to some other location. It is not considered a GSI technique, but rather an alternative to be considered for reducing flows to the CSS.

Street trees are different from tree boxes, which filter runoff from streets and other impervious surfaces, Street tress retain some rain in their canopies and uptake a portion of the rain that infiltrates to the soil.

Bioretention involves dispersed small-scale landscape features designed to attenuate and treat stormwater (Kennedy et al., 2007). These features are typically vegetation-filled areas, such as rain gardens and swales, with a drainage mechanism, often located in parking lots, median strips, or streets.

Permeable pavement allows rainfall to penetrate the pavement into a porous material that retains stormwater before it enters a combined sewer, thereby attenuating or removing the effects of the stormwater on the sewer. Permeable pavement is not suited for high-traffic areas.

Rain Garden in a Residential Area

Green Roof on Chicago's City Hall

Table 2-2. Criteria Used to Identify Areas Suitable for Green Stormwater Infrastructure Techniques

Technique	Criteria
Green roofs	Roofs connected to CSS Roofs over 5,000 square feet Roofs with slopes between 5 and 20 degrees Buildings and garages selected from City of Seattle building footprint dataset (does not include decks, patios, etc.)
Roof disconnection	Roofs connected to the CSS
Street trees	Areas identified in LIDAR as less than 5 feet higher than ground elevation Areas in the right-of-way Areas connected to the CSS Pervious areas
Bioretention	Non-rooftop areas in the right-of-way or on private property Impervious areas Areas connected to the CSS Ground slope less than 5%
Permeable pavement	Impervious areas of low-traffic streets, alleys, and parking lots greater than 10,000 square feet Areas connected to the CSS Ground slope less than 5%

CSS = combined sewer system; LIDAR = Light Detection and Ranging.

In addition, King County looked at other CSO programs in the country to see which GSI techniques were used in urban areas. Specifically, the team looked for projects that involved large areas of impervious surfaces that were in the public ROW:

- The City of Portland has implemented many projects using curb-contained rain gardens.
- SPU is planning on constructing similar roadside rain gardens to control city CSOs in the Ballard neighborhood.
- Chicago has implemented several projects using permeable pavers in alleyways.
- Rooftop disconnection programs exist in most CSO communities, including some in Washington State.

2.2.2 Results

The results of the GSI feasibility analysis are shown in Table 2-3. For each GSI technique, the table shows the number of acres connected to the CSS where stormwater could potentially be diverted or attenuated. The analysis indicates that Subbasin 416 in the Barton basin holds the highest potential across all GSI techniques, that Subbasin 152 in the South Magnolia basin holds a similar potential but only for roof disconnection, that the Murray basin holds some potential for roof disconnection, and that the North Beach basin shows little potential for GSI implementation.

A preliminary analysis of the Murray and South Magnolia basins, documented in Appendix D, indicates that these basins do not have enough ROW area to support roadside rain gardens and that the estimated volume of stormwater removed from the CSS through the city's Residential RainWise Program, which promotes GSI on private properties with rooftops connected to the

CSS, would not meet target reductions in CSO storage volumes. Additional analyses may be conducted for these basins to supplement the preliminary RainWise analysis.

Subbasin 416 was carried forward for further evaluation for feasible GSI techniques. As shown in Table 2-3, roof disconnection, bioretention, and permeable pavement would mitigate the greatest number of acres in the basin. For this and other reasons, green roofs and street trees were eliminated from further consideration. Green roofs may show more potential in commercial and industrial areas of the city where large roofs are prevalent. A more robust analysis of potential benefits from street trees could be performed; however, the probability of using this technique for CSO control for the CSO beach projects is low. The time necessary for an evergreen tree to grow to maturity is too long, and waiting to realize the potential of this technique would delay implementation of the King County CSO Control Program.

Table 2-3. Acreages Connected to the Combined Sewer System that Show Potential for Green Stormwater Infrastructure Techniques

	Green Roofs		Roof Disconnection		Street Trees		Bioretention		Permeable Pavement	
	Scenario									
Subbasin	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Barton										
414	0.8	1.2	3.6	7.2	0.0	0.1	0.9	0.4	0.1	0.1
415	1.0	0.8	2.5	2.2	0.0	0.1	1.5	0.8	1.2	0.4
416	5.1	5.4	37.8	48.6	8.1	10.9	40.1	40.1	26.3	26.3
417	1.2	1.6	2.9	18	0.2	0.3	1.4	1.4	2.5	2.9
418	1.2	4.1	5.6	28.2	0.0	0.0	2.8	2.3	2.7	2.7
Murray										
419	3.1	2.1	12.2	29.4	2.1	2.1	10.6	10.3	8.4	8.4
420	0.4	0.0	5.2	7.9	0.0	0.0	1.2	0.7	0.3	0.6
421	2.3	3.3	6.7	23.4	0.1	0.1	3.5	3.2	1.9	3.2
423	0.3	0.3	0.9	0.6	0.0	0.0	0.1	0.1	0.3	0.3
South Magnolia										
151	2.0	5.1	0.0	0.0	0.7	0.7	3.0	2.4	1.7	0.5
152	1.8	8.7	4.5	48.6	0.0	0.0	2.6	1.6	0.7	0.4
153	0.4	1.1	1.1	18.2	0.0	0.0	0.3	0.1	0.0	0.0
154	0.8	2.4	1.4	15.1	0.0	0.0	0.7	0.6	0.0	0.0
North Beach										
439	2.8	4.4	6.9	5.2	0.0	0.0	3.4	5.4	3.8	3.8
440	0.7	0.9	3.7	3.1	0.0	0.0	0.2	0.9	0.2	0.2
441	0.5	1.0	2.5	1.5	0.0	0.0	1.0	1.0	3.3	3.3

Note: The highlighted cells indicate the subbasin with highest potential for each GSI technique.

Roadside rain gardens were recommended as the GSI technique for Barton Subbasin 416. Most rain gardens are between 500 and 800 square feet. They can be constructed in curb bulb, planting strip, or central rotary (roundabout) locations. The primary reasons for selecting rain gardens are as follows:

- A rain garden acts as a retention/infiltration facility rather than a conveyance facility. This means that the stormwater retained by the rain gardens is completely kept out of the CSS, leaving less stormwater to flow to downstream pump stations and treatment plants.
- Because roadside rain gardens are used in areas with an existing curb and gutter system, they do not require reconstruction of the entire ROW. Existing planter strips are modified, including moving the curb out into the parking area of the roadway for a short distance.
- Existing SPU and City of Portland specifications, drawings, and performance data can be used in developing planning-level calculations.
- SPU recommends that King County use rain gardens for CSO Control Program projects that include a GSI component. If necessary, roadside rain gardens can be supplemented with permeable alleyway systems.

2.2.3 Additional Data Collection

After roadside rain gardens were selected as the recommended GSI option, additional preliminary data were collected on Subbasin 416 to help identify prospective areas for rain gardens:

- A windshield survey was conducted in 2009 to look at the ways streets were used during different times of the week. The survey noted streets that were used for parking, patterns of street use, and flow of stormwater into catch basins and along streets (Appendix E).
- A GIS topographical analysis using digital elevation modeling was conducted to better understand the general flow of surface water through streets and to identify which streets had higher concentrations of surface water runoff (Appendix F).
- Utility-related infrastructure locations were reviewed to identify utility impediments to roadside rain garden construction. Except for fire hydrants and water and sewer lines, there are no apparent impediments (Appendix G). Gas lines were not located during this review. Their locations will be included in more detailed investigations if the GSI alternative is selected for Barton.
- Infiltration rates in the subbasin areas were identified as high (0.25 inch/hour), medium (0.5 inch/hour), and low (1 inch/hour). A map showing the infiltration rates is included in Appendix H.

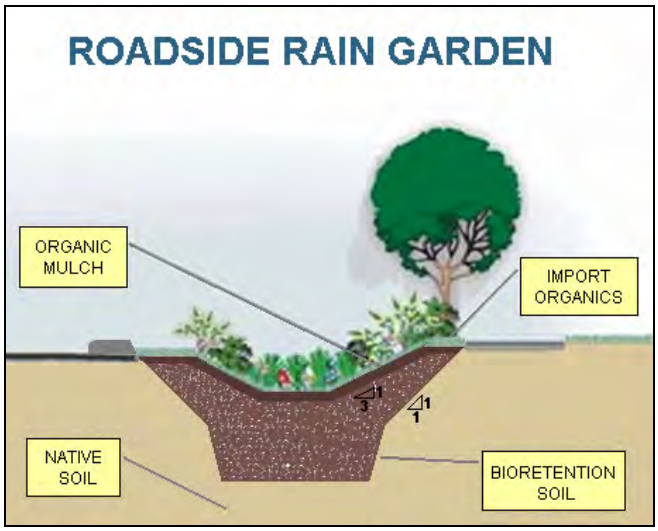
3.0. ESTIMATING RAIN GARDEN SIZE AND COSTS

Roadside rain gardens were simulated mathematically to help determine the approximate size of the total rain garden area needed in Barton Subbasin 416. The calculations did not assume that all stormwater that enters the CSS from the subbasin would be captured by the rain gardens—only the amount needed, after the capacity of the Barton Pump Station has been expanded, to reduce the flow into the CSS to the extent that the Barton CSO is controlled to the state standard.

Structures, such as tanks, simply store the water once the flow into the pump station has surpassed the station's maximum capacity. When the flow becomes less than the maximum capacity, the tank begins to release the detained stormwater back into the system. A rain garden, on the other hand, begins collecting stormwater as soon as the rain starts and continues retaining water until the storm has passed. The performance of rain gardens and other GSI methods, therefore, has to be considered for an entire storm event, not just the peak of the storm.

After estimating the total area that would be needed for rain gardens in the subbasin, planning-level cost estimates were prepared.

Roadside Rain Garden in Portland



Cross-Section of Typical Roadside Rain Garden

3.1 Rain Garden Area Estimate

3.1.1 Methodology

Microsoft Excel worksheets were used to simulate flow to the CSS from Subbasin 416 and calculate the size of rain gardens required to control the Barton CSO. The bottom area of the rain garden is determined through the calculations. Because the sides of rain gardens are usually sloped, the surface area can be calculated based on the side slope ratio. The actual ground area needed for the rain gardens will be calculated as part of the design of specific rain gardens.

Three worksheets were tested to arrive at a method that most suits King County's needs for sizing rain gardens:

- The City of Seattle's GSI pre-sizing model
- A King County–modified version of the city's model, using additional data and recommendations from a consultant's memorandum to the city[7]
- A mass balance worksheet, which balances the rain failing on the mitigated area with the stormwater entering the rain garden and the flow into the Barton Pump Station.

The worksheets relied on a number of factors, both constants and variables, to calculate rain garden bottom area.[8] For example, one constant used in all the worksheets was a 26-acre mitigated area. This area was estimated using WTD's MOUSE hydraulic model for conveyance system planning.

The design storm varied depending on the worksheet. The 24-hour event with a 2-year recurrence interval was built into the first two worksheets (Seattle's model and King County's adaptation of the model). The mass balance worksheet used a storm event with a 1-year recurrence interval. This is the storm event used in the MOUSE model to calculate the size of storage needed to control CSOs in the system. The MOUSE model allows for analysis in 10-minute time increments to account for different intensities of rain during the event. These intensities need to be considered because the dependency on soil infiltration rates may make it difficult for rain gardens to control sharp peaks in rainfall during a storm.

Rain Garden Simulation Factors

Design storm. A storm of a determined frequency of occurrence used to size rain gardens. The duration and intensity of the storm are modeled based on historical record.

Entrance factor. The percent of water flowing down the street toward the rain garden that is assumed to enter the garden.

Infiltration rate. The amount of stormwater that can enter the soil in a specified time interval.

Mitigated area. The impervious area contributing stormwater to rain gardens.

Ponding depth. The maximum depth of standing water in a rain garden at any point during the design storm.

Rain depth. The total number of inches of water that falls during the design storm during a specified time interval. It is equivalent to the depth of water that would accumulate in a bucket left outside during that time.

Sizing factor. The calculated relationship between the size of the rain garden and the mitigated area.

Volume of water controlled. The amount of stormwater a rain garden keeps out of the CSS through detention and infiltration. The volume is calculated by multiplying the rain depth and the mitigated area by the entrance factor and then subtracting the volume of water not captured by the rain garden.

Although all worksheets resulted in similar estimates of rain garden size, the mass balance worksheet provides more flexibility and thus is recommended for sizing rain gardens in the Barton basin. The mass balance worksheet (1) can be modified to fit an individual storm and time increments to a degree that is not possible in the other two worksheets, (2) allows for analysis of attenuation as flow moves toward the pump station, and (3) provides a conservative estimate of the amount of rain garden area needed because the worksheet requires a balance between water in and water out. Table 3-1 shows values for factors used in the mass balance worksheet. MOUSE modeling provided values for base wastewater flow into the Barton Pump Station (1 mgd) and percent of total flow to the station contributed by Subbasin 416 (54 percent).

[7] Herrera Environmental Consultants. 2009. *Pre-Sized Approach for City of Seattle Stormwater BMPs*. Technical memorandum prepared for Seattle Public Utilities.
[8] Appendix C shows the assumptions used in the worksheets.

Table 3-1. Modeling Values Used in Mass Balance Model to Estimate Rain Garden Size

Factor	Value Assigned	Source
Ponding depth	10 inches	Director's Rule 17-2009, SPU 2009-005, Volume III, Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual: • 12-inch maximum • 6-inch maximum in high-density ROW • 24-hour maximum time for water at maximum ponding depth to infiltrate into soil http://www.cityofseattle.net/dpd/Codes/StormwaterCode/DirectorsRules/default.asp
Mitigated area	26 acres (1.3 million square feet) of impervious surface area	WTD's MOUSE model for conveyance system planning
Design storm	1-year recurring storm	WTD's MOUSE model for conveyance system planning
Side slope	3 feet:1 foot	Herrera, 2009.
Native soil infiltration rate	0.5 inch per hour	The Pacific Northwest Center for Geologic Mapping http://geomapnw.ess.washington.edu/
Bioretention soil	• Depth: 18 inches • Infiltration rate: 2.5 inches per hour • Porosity: 40 percent	SPU's specifications for bioretention soil

Another version of the mass balance worksheet was used to determine the number of rain gardens that would be needed in Subbasin 416. Inputs included the overall bottom area required to mitigate a 26-acre area, the number and dimensions of streets and blocks in the subbasin, and the constraints on rain garden size by type of street. For example, the city restricts rain garden size on north-south streets to an area equivalent to one parking space but allows multiple rain gardens on each block. Three historical storms with associated CSOs were run through this "block" mass balance simulation. The November 1–2, 1984, storm was the design storm used in previous simulations. This storm was a long storm with a sudden peak, making it the hardest of the three to control. The November 2– 22, 1988, storm was short with an extended dry period before the heavy rain started, and the March 1–2, 1987, storm had a lot of rain before the peak of the storm.

3.1.2 Results

King County is using the preliminary results of the mass balance worksheet as the starting point for rain garden design in the Barton basin. Table 3-2 shows that a total of 0.88 acre of rain garden bottom area would reduce peak flow at the Barton Pump Station by 15 mgd, the amount required to control the Barton CSO to one event on average per year. Figure 3-1 and Figure 3-2 illustrate how by capturing the high-intensity rainfall at the peak and throughout the duration of the design storm, rain gardens with the total required area both delay and reduce peak flow into the pump station.

Table 3-2. Results of Each Storm Event Modeled

November 1st - 2nd, 1984			November 21st - 22nd, 1988			March 1st - 2nd, 1987		
CSO Total Volume (gal)			**CSO Total Volume (gal)**			**CSO Total Volume (gal)**		
Before RG	After RG	Retained	Before RG	After RG	Retained	Before RG	After RG	Retained
146,845	**0**	146,845	77,842	**0**	77,842	77,842	**0**	77,842
Max Flow into PS (MGD)			**Max Flow into PS (MGD)**			**Max Flow into PS (MGD)**		
Before RG	After RG	PS Capacity	Before RG	After RG	PS Capacity	Before RG	After RG	PS Capacity
47.81	32.83	33	42.58	18.22	33	40.68	16.22	33
Total Volume – Rain Garden (gal)			**Total Volume – Rain Garden (gal)**			**Total Volume – Rain Garden (gal)**		
Entering	Retained		Entering	Retained		Entering	Retained	
780,845	**780,845**		528,951	**522,797**		1,007,042	**1,002,421**	

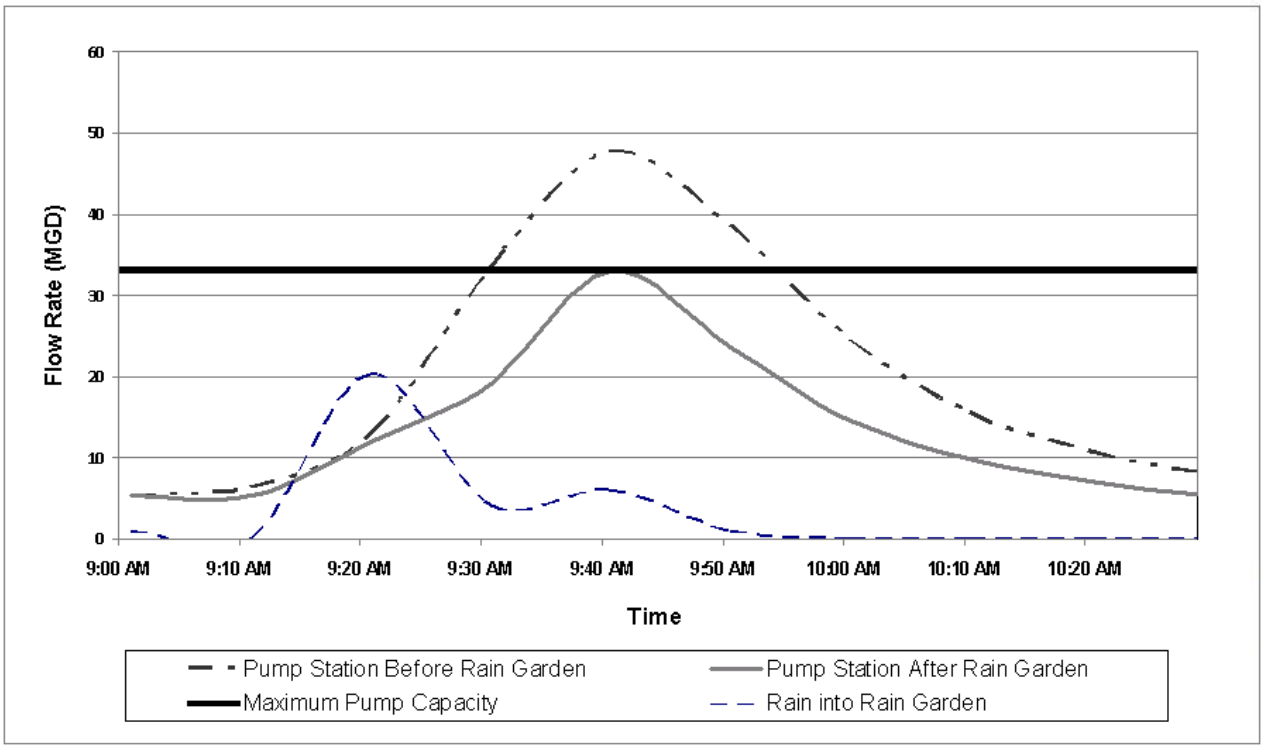
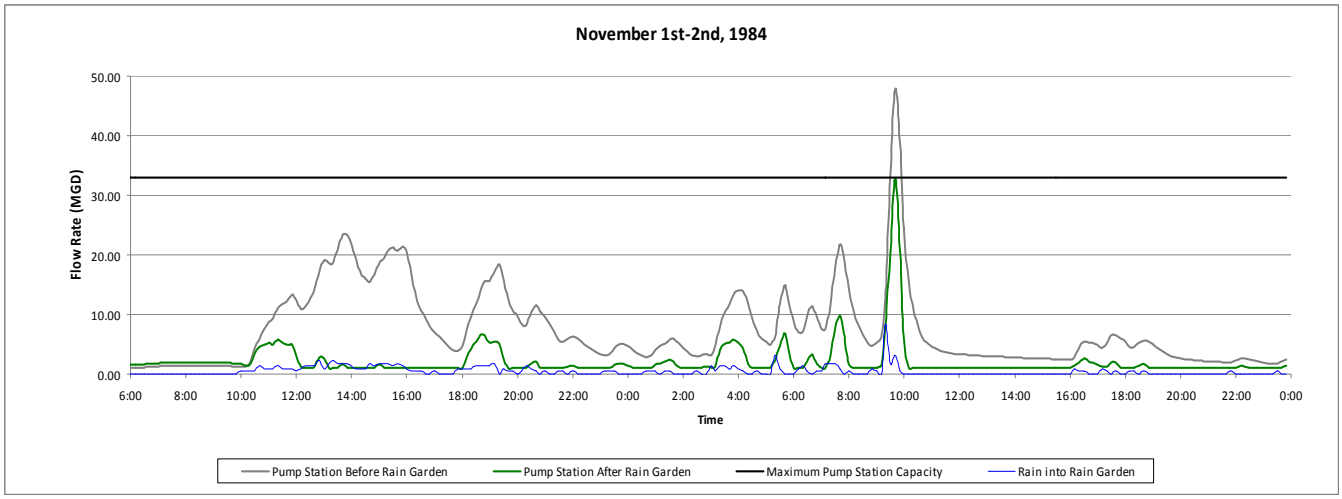
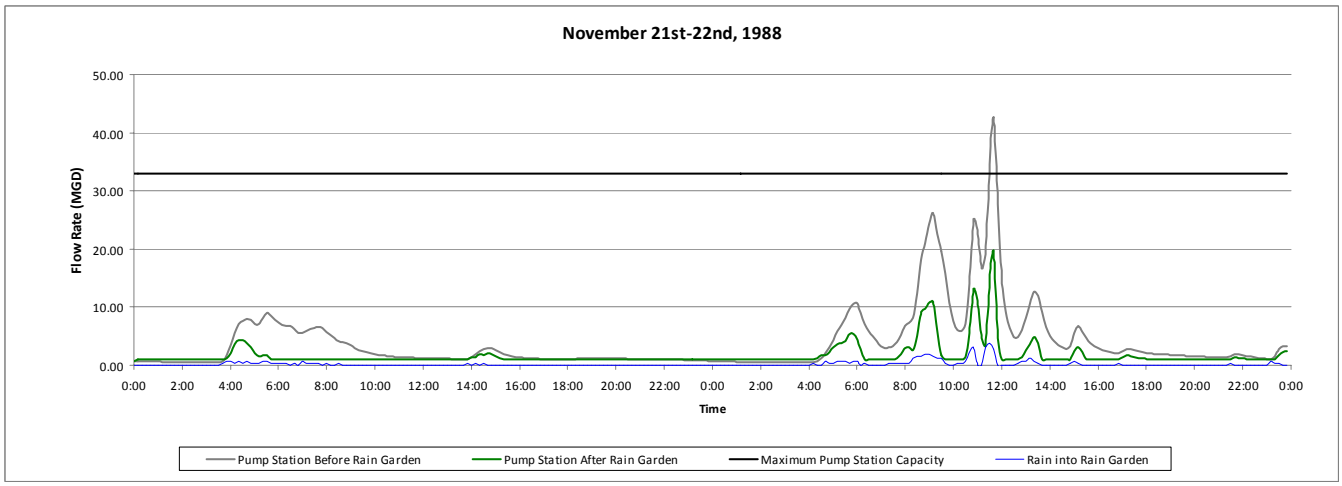


Figure 3-1. Estimated Flows Captured by Rain Gardens and Diverted from the Barton Pump Station During 30-Minute Period of High-Intensity Rainfall





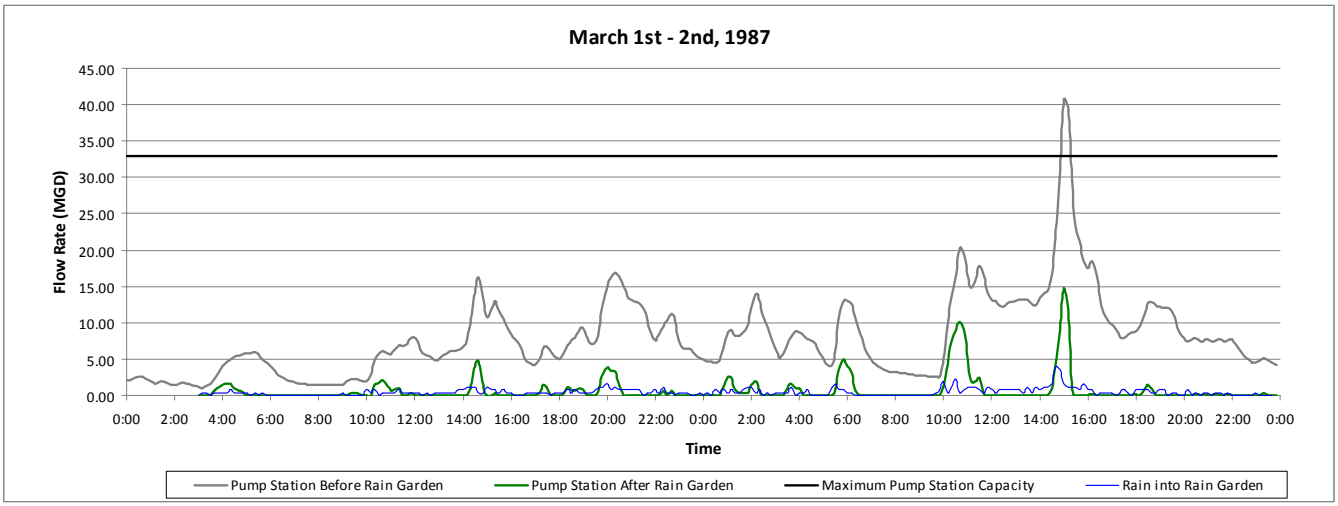


Figure 3-2. Estimated Flows Captured by Rain Gardens and Diverted from the Barton Pump Station During Design Storms

Table 3-3 shows the estimated number and the surface and bottom areas of rain gardens by type of street in Subbasin 416. Surface area is used to determine the land needed for each rain garden. The actual number and size of individual rain gardens will be determined during project design, if this alternative is selected for the Barton basin.

Table 3-3. Estimated Rain Garden Number and Sizes by Streets in Subbasin 416

Street Direction	Number of Streets	No. of Rain Gardens per Block	Surface Area of Each Rain Garden	Total No. of Rain Gardens	Total Rain Garden Surface Area	Total Rain Garden Bottom Area
North-west	30	5	450 sq. ft.	150	67,500 sq. ft.	37,500 sq. ft.
East-west	6	4	500 sq. ft.	24	12,000 sq. ft.	5,400 sq. ft.
				174	**79,500 sq. ft.**	**42,900 sq. ft.**

3.2 Cost Estimates

King County estimated planning-level costs to construct, operate, and maintain rain gardens in Barton Subbasin 416 with a total surface area of 79,500 square feet. The estimate was based on the average cost per square foot for projects in Portland, Seattle, and Chicago, ranging from $55to $69 per square foot. King County's estimate uses $69, which includes allied costs. The total cost in this estimate, including contingency, is around $8.3 million. Table 3-4 shows a breakdown of the estimate.

Planning-level cost estimates are based on generic facility concepts. Specific details of a project such as location, technologies, and environmental impacts and potential mitigation of such impacts are determined later during project predesign. Costs for projects in planning can have a rough order-of-magnitude estimate in the range of –50 to +100 percent. By the time a project enters the construction phase, estimates typically narrow to a range of –10 to +15 percent of the final cost.

Table 3-4. Planning-Level Cost Estimate for Barton Rain Gardens

Cost per square foot	$69
Total square feet (surface area)	79,500
Base facility cost (cost per square foot times total square feet)	$5,485,500
Cost adjustment for retrofit (16% of base cost)	$877,680
Total Facility Cost	**$6,363,180**
Contingency (30%)	$8,272,134

4.0. NEXT STEPS

King County has identified Barton Subbasin 416 as the area with the greatest potential for implementing GSI in the study area. The GIS analyses identified roof disconnection, rain gardens, and permeable paving as feasible GSI options in the subbasin. The results of preliminary screening of these options led to the recommendation of curb-contained roadside rain gardens as an alternative for CSO control in the Barton basin.

Because the stormwater captured in a rain garden and other GSI options never enters the CSS, downstream capacity in the CSS is freed up to handle other flows. Less flow enters the West Point Treatment Plant, thus reducing the cost to convey and treat the flow. GSI alternatives are especially useful in Barton because the water flowing from the Barton Pump Station continues downstream to several other pump stations that could benefit from reduced flows.

If the GSI alternative is selected as the preferred alternative for Barton, detailed site-specific investigations should be conducted during the next phase of alternatives development and evaluation. Examples include conducting additional soil and groundwater investigations and infiltration tests, developing WTD-specific operating and maintenance cost estimates, and adjusting final rain garden size and locations based on input from residents. In addition, King County, in cooperation with SPU and the Puget Sound Partnership, will need to establish a project monitoring program, including preconstruction and post-construction monitoring of system performance.

5.0. REFERENCES

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Appendix A. Criteria for Evaluating CSO Control Alternatives

Barton, Murray, Magnolia and North Beach CSO Projects
BARTON BASIN ALTERNATIVES

CATEGORY / CRITERIA	GREEN STORMWATER INFRASTRUCTURE SUB BASIN 416	
	IMPACT RATING (green = low; yellow = medium; red = high)	**DESCRIPTION**
LAND USE AND PERMITTING		
1. City of Seattle Comprehensive Plan	3	GSI should meet goals of Comp Plan
2. Seattle Municipal Code (SMC/Zoning Code)	3	Will need to insure that facilities do not impede emergency vehicle access, set design standards will be implemented to meet SDOT requirements
3. Shoreline Master Program Compatibility	3	Project not within Shoreline Zone
4. Permitting Complexity	2	Permit(s) required from SDOT. Verify layout with emergency services. SPU is working with SDOT and Fire Marshall to resolve before summer 2010.
5. Property Acquisition Complexity	3	No property acquisition is necessary
ENVIRONMENT		
1. Cultural Resources	3	No known archaeological sites. No known cultural resources in project area. Based on site characteristics, project area has low probability of containing archaeological resources. Disconnections in upper basin not expected to impact cultural resources.
2. Fish and Wildlife	3	Construction and operation of this alternative would not adversely affect fish and wildlife, or their habitat. GSI could provide additional wildlife habitat.
3. Wetlands, Streams, and Shoreline	3	Construction of this alternative would not impact wetlands, streams or shoreline. Operation would not impact wetlands or shoreline, but could result in increased base flows in Longfellow Creek.
4. Soils and Sediments	3	No known contaminated soils. GSI cannot be built on or within 300 feet of steep slopes or landslide areas
5. Water Quality	3	No new untreated discharges to surface waters.
TECHNICAL		
1. Technical Complexity	3	Facilities are flow through faciliites with no mechanical systems
2. Compatibility with Existing WW system	3	GSI is independent from County wastewater system
3. Flexibility/Adaptive Management	3	GSI project can expand as necessary, a small percentage of feasible area is being used for project

Barton, Murray, Magnolia and North Beach CSO Projects
BARTON BASIN ALTERNATIVES

CATEGORY / CRITERIA	GREEN STORMWATER INFRASTRUCTURE SUB BASIN 416	
	IMPACT RATING (green = low; yellow = medium; red = high)	**DESCRIPTION**
4. Constructability/ Implementation Schedule	1	WTD is unfamiliar with GSI and has no experience with GSI projects
O&M		
1. Staffing	3	Facilities require no operation. Flows enter system without any mechanical systems
2. Training	2	WTD is unfamiliar with GSI and has no experience with GSI projects. However, O&M staff would have limited responsibility for projects. There are no operational interactions, only routine maintenance.
3. Reliability	2	GSI has not been implemented for CSO control in the City of Seattle. Other CSO communities have implemented GSI with success
4. Maintenance	2	There are well established maintenance guidelines. WTD has no prior experience with GSI maintenance; if WTD hires a contractor, this should be considered in maintenance complexity.
5. Safety	3	Projects are accessable and maintained in areas that do not expose workers directly to traffic
COST EFFECTIVENESS		
1. Relative Cost	3	GSI is less expensive and has the potential to apply for and receive GSI-specific state/federal funding.
2. Risk and Variability	1	Costs and sizing are based on data from multiple agencies around the country. There is no internal historical cost data to compare with.
COMMUNITY IMPACT		
1. Location	1	Facilities will reduce on street parking
2. Potential Community Impacts	3	GSI is part of community vision. Limited amount of maintenance visits to maintain landscaping and clean up facilities
3. Construction Impacts	2	Small scale construction in residential streets, may limit traffic for a short period during normal business hours. Each facility would take approximately 2-3 months to build.

Appendix B

EPA Memorandums on Green Infrastructure

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 5 2007

OFFICE OF WATER

MEMORANDUM

SUBJECT: Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and other Water Programs

FROM: Benjamin H. Grumbles
Assistant Administrator

TO: EPA Regional Administrators

Green infrastructure can be both a cost effective and an environmentally preferable approach to reduce stormwater and other excess flows entering combined or separate sewer systems in combination with, or in lieu of, centralized hard infrastructure solutions. EPA Water Programs are in a pivotal position to exert leadership in the consistent and reliable implementation of green infrastructure approaches. This memo is to highlight opportunities for the Regions, States, and Headquarters efforts to increase the development and use of green infrastructure in water program implementation.

Several cities, searching for alternatives to traditional hardscape solutions to wet weather discharge problems, have initiated some green infrastructure approaches. The Natural Resources Defense Council (NRDC) has recently published a document with information and case studies on these efforts. I strongly support the use of green infrastructure approaches described in the NRDC report and I suggest you share the report with States and promote other tools for green infrastructure. *Rooftops to Rivers: Green strategies for controlling stormwater and combined sewer overflows* (NRDC, June 2006) is available at:
http://www.nrdc.org/water/pollution/rooftops/contents.asp

Green infrastructure approaches essentially infiltrate, evapotranspirate or reuse stormwater, with significant utilization of soils and vegetation rather than traditional hardscape collection, conveyance and storage structures. Common green infrastructure approaches include green roofs, trees and tree boxes, rain gardens, vegetated swales, pocket wetlands, infiltration planters, vegetated median strips, reforestation, and protection and enhancement of riparian buffers and floodplains. Green infrastructure can be used where soil and vegetation can be worked into the landscape. It is most effective when supplemented with other decentralized storage and infiltration approaches, such as the use of permeable pavement, and rain barrels and cisterns to capture and re-use rainfall for watering plants or flushing toilets. These approaches can be used to keep rainwater out of the sewer system to reduce sewer overflows and to reduce the amount of untreated stormwater discharging to surface waters. Green infrastructure

facilitates or mimics natural processes that also recharge groundwater, preserve baseflows, moderate temperature impacts, and protect hydrologic and hydraulic stability.

Green infrastructure has a number of benefits:

- *Cleaner Water* – Vegetation and green space reduce the amount of stormwater runoff and, in combined systems, the volume of combined sewer overflows.
- *Enhanced Water Supplies* – Most green infiltration approaches result in stormwater percolation through the soil to recharge the groundwater and the base flow for streams.
- *Cleaner Air* – Trees and vegetation improve air quality by filtering many airborne pollutants and can help reduce the amount of respiratory illness.
- *Reduced Urban Temperatures* – Summer city temperatures can average 10°F higher than nearby suburban temperatures. High temperatures are linked to higher ground level ozone concentrations. Vegetation creates shade, reduces the amount of heat absorbing materials and emits water vapor – all of which cool hot air.
- *Increased Energy Efficiency* – Green space helps lower ambient temperatures and helps shade and insulate buildings, decreasing energy needed for heating and cooling.
- *Community Benefits* – Trees and plants improve urban aesthetics and community livability by providing recreational and wildlife areas and can raise property values.
- *Cost Savings* - Green infrastructure may save capital costs on digging big tunnels and stormwater ponds, operations and maintenance expenses for treatment plants, pipes, and other hard infrastructure; energy costs for pumping water; and costs of wet weather treatment and of repairing stormwater and sewage pollution impacts, such as streambank restoration.

The Office of Water is working with a coalition of organizations, including the Natural Resources Defense Council, the National Association of Clean Water Agencies, and the Low Impact Development Center, to develop additional strategies for green infrastructure approaches to water quality challenges. As those strategies take shape, we will send you additional tools and information on implementing green infrastructure in our water programs.

I am pleased that EPA Regions and States are looking for opportunities to incorporate green infrastructure. We would be very interested in hearing about your efforts, and to the extent they can be applied elsewhere, assist in disseminating information and tools. If you have any questions, please contact me or have your staff call Jenny Molloy at (202) 564-1939 with any questions, comments, ideas or information on green infrastructure approaches.

cc: Water Division Directors
OW Office Directors

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG 16 2007

OFFICE OF
ENFORCEMENT AND
COMPLIANCE ASSURANCE

MEMORANDUM

SUBJECT: Use of Green Infrastructure in NPDES Permits and Enforcement

TO: Water Division Directors, Regions 1 – 10
Regional Counsel/Enforcement Coordinators, Regions 1 - 10
State NPDES Directors

FROM: Linda Boornazian, Director
Water Permits Division (MC 4203M)

Mark Pollins, Director
Water Enforcement Division (MC 2243A)

Administrator Stephen Johnson entered into an agreement on April 19, 2007, with State, environmental and wastewater utility groups to formalize the use of green infrastructure[1] approaches.[2] As part of the agreement, the Agency committed to develop "memoranda … that would explain how regulatory and enforcement officials should evaluate and provide appropriate credit for the use of green infrastructure in meeting Clean Water Act requirements." One frequently encountered question is how green infrastructure practices fit into existing regulatory programs.

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[1] Green Infrastructure uses natural or engineered systems – such as green roofs, rain gardens and permeable pavement – that mimic natural processes and direct stormwater to areas where it can be infiltrated, evapotranspirated or re-used. Green infrastructure can provide many environmental benefits: stormwater control, air quality improvements, urban heat island mitigation, energy demand reductions, carbon sequestration, headwaters protection, etc.

[2] Green Infrastructure Statement of Intent, http://www.epa.gov/npdes/pubs/gi_intentstatement.pdf.

In developing permit requirements[3], permitting authorities may structure their permits, as well as guidance or criteria for stormwater plans and CSO long-term control plans, to encourage permittees to utilize green infrastructure approaches, where appropriate, in lieu of or in addition to more traditional controls.

EPA will also consider the feasibility of the use of green infrastructure as a water pollution control technology in its enforcement activities, and encourages state authorities to do likewise.

We are working on more specific guidance to help facilitate implementing this message -- e.g., model permit and enforcement consent decree language, and we are compiling examples of where green infrastructure has been incorporated into permits and enforcement mechanisms in an appropriate and effective manner.

If you have examples of permits, CSO long term control plans or settlements that utilize green infrastructure, or have any questions on this matter, please contact either of us, or have your staff contact Jenny Molloy of Water Permits Division at molloy.jennifer @epa.gov, 202 564-1939 or Gary Hudiburgh of Water Enforcement Division at hudiburgh.gary@epa.gov, 202 564-0626.

cc: Steven Neugeboren, Office of General Counsel, (MC 2355A)

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[3] NPDES permits require compliance with effluent limitations developed to meet technology-based requirements, as well as more stringent water quality-based requirements; the permits also contain general and special conditions, including monitoring and reporting. The discharger makes the decision on how to achieve compliance with limitations and conditions contained in an NPDES permit, and may decide to make use of green infrastructure to comply with NPDES permit terms, limitations and conditions. These permits must meet the requirements of CWA §§ 301, 302, 306, 307, 308, and 313. EPA has issued regulations to implement the NPDES program, 40 CFR Parts 122 – 125, and guidance and policy.

Appendix C. Assumptions Used in GSI Analyses

Assumptions Used in the GIS Analysis of Stormwater Flow Destinations in the Four Puget Sound Beach CSO Basins

Parcels

Directly to MS4			Directly to CSS		
	Scenario			Scenario	
Rooftop	A	Parcel shown directly connected to MS4	Rooftop	A	Parcel not connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel			Parcel contains no infiltration pit
					A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel shown directly connected to MS4		B	Parcel not connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel			Parcel contains no infiltration pit
		Parcel contains a downspout			Parcel contains a downspout
Impervious	A	Parcel shown directly connected to MS4	Impervious	A	Parcel not connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel			Parcel contains no infiltration pit
					A lateral identified as carrying storm drainage flow lies in the parcel
	B	Parcel shown directly connected to MS4		B	Parcel not connected to MS4
		A lateral identified as carrying storm drainage flow lies in the parcel			Parcel contains no infiltration pit
		Parcel contains no infiltration pit			Parcel contains a catch basin
		Parcel contains a catch basin			
Pervious	A	Same as Impervious areas, A assumption collection	Pervious	A	Same as Impervious areas, A assumption collection
	B	Same as Impervious areas, B assumption collection		B	Same as Impervious areas, B assumption collection
To MS4 via ROW			**To CSS via ROW**		
Rooftop		Flow not directly to CSS or MS4	Rooftop		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter MS4 conveyance for that ROW section			Terrain indicates flow will enter ROW and enter CSS conveyance for that ROW section
Impervious		Flow not directly to CSS or MS4	Impervious		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter MS4 conveyance for that ROW section			Terrain indicates flow will enter ROW and enter CSS conveyance for that ROW section
Pervious		Flow not directly to CSS or MS4	Pervious		Flow not directly to CSS or MS4
		Terrain indicates flow will enter ROW and enter MS4 conveyance for that ROW section			Terrain indicates flow will enter ROW and enter CSS conveyance for that ROW section
Overland to Receiving Water Body					
Rooftop		Flow not directly to CSS or MS4			

	Terrain indicates flow will enter ROW and not be captured by the CSS or MS4
Impervious	Flow not directly to CSS or MS4
	Terrain indicates flow will enter ROW and not be captured by the CSS or MS4
Pervious	Flow not directly to CSS or MS4
	Terrain indicates flow will enter ROW and not be captured by the CSS or MS4

ROWs

Flows will be collected downhill by the first inlet structure encountered

Area contributing flow is bounded uphill by the location of the next encountered inlet point.

CSS

First Inlet structure is connected to the CSS

MS4

First Inlet structure is connected to the CSS

Overland to Receiving Water Body

No inlet structure is encountered and all flow continues to the receiving water body.

King County's Assumptions for Rain Garden Sizing Models

- A linear relationship between the sizing factor and the ponding depth
- Seattle's data on which they calculated their sizing factor is accurate
- The soil being used has the "Design Infiltration Rate"
- The soil being used in the rain garden has been properly classified
- The infiltration rate of the different classes of soil has been correctly identified
- The amount of water entering the rain garden
  - Volume from the ROW
  - Minus bypass factor

City of Seattle's Assumptions for Rain Garden Sizing Model

- Ponding Depth (in) – 6"/12"
- Bioretention soil depth (ft) – 1' for flow control, 1.5' for water quality treatment
- Bioretention soil porosity – 0.4
- Infiltration rate into bioretention soil (in/hr)– 2.5
- Side slopes (ft/ft) - 3:1
- Swale length and bottom width (ft) – varied
- Swale bottom elevation (ft) – 0
- Effective depth (ft) – 2.167/2.5/3
- Bottom slope of swale – 0.001
- Freeboard/ponding depth (ft) – 0.167/0.5/1
- Over-road flooding (ft) – 1
- Width of over-road flooding (ft) – one side of square facility
- Vertical orifice diameter (in)/elevation (in) – 0/0
- Bioretention soil infiltration rate (in/hr) – 2.5
- Native soil infiltration rate (in/hr) – 0.25, 0.5, 1.0
- Infiltration reduction factor – 1
- Use wetted surface area – yes
- Underdrain used – no
- Layer 1 thickness (ft) – 1/1.5
- Layer 1 porosity – 0.4
- Rain/evaporation – yes
- POC connected to Outlet 1 only

Source: Herrera Environmental Consultants. 2009. *Pre-Sized Approach for City of Seattle Stormwater BMPs*. Technical memorandum prepared for Seattle Public Utilities.

Appendix D
Residential RainWise Analysis for Murray and Magnolia CSO Basins

Residential RainWise is a program initiated by Seattle Public Utilities (SPU) to provide individual homeowners the necessary tools to reduce runoff from their properties. A series of tools is identified and described on SPU's Residential RainWise Web site (http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/GreenStormwaterInfrastructure/ResidentialRainwiseProgram/index.htm). Homeowners can use information on this site to select and best management practices (BMPs) for their property.

SPU provided King County's CSO beach projects team with the necessary planning level information to evaluate the Murray and South Magnolia CSO basins for implementing Residential RainWise to reduce the size of the storage needed to control CSOs in these basins.

To identify the rational for implementing RainWise, the project team used the GIS analysis for connected impervious surfaces as discussed in Section 2.1 of TM 600.5. A map was created by using City of Seattle critical area data for steep slopes to identify parcels farther than 300 feet from a steep slope and rooftops connected to the combined sewer system (CSS). The map follows the text of this appendix.

To remove runoff from the parcels connected to the CSS, the project team looked for available area on the parcels for construction of a rain garden to retain water on site The number of parcels, average roof size, average parcel size, and total acreage for each basin are as follows:

	Murray	**South Magnolia**
Number of parcels	1,075	1,370
Average roof size	1,098 square feet	2,054 square feet
Average parcel size	6,205 square feet	6,197 square feet
Total acreage	28 acres	65 acres

Based on the criteria for rain garden design, each rain garden should mitigate no more than 700 square feet of impervious area and each homeowner would have available area to construct one rain garden. For Murray, 63 percent of the roof area is available for mitigation (0.63 x 1.098 = 691.74). For South Magnolia, 34 percent of the roof area is available for mitigation (0.34 x 2,054 = 698.36).

Owner participation in a voluntary program and the characteristics of a property also need to be considered. To address these factors, SPU estimates approximately 35 percent participation under a standard program and 40–45 percent under an aggressive outreach program. The participation rates are based on pilot projects run by SPU in different areas of the city. They include an incentive for participation of approximately $4 per square foot mitigated. The maximum payout per property is $2,800, which would be well within the local costs for a professional built rain garden.

The project team looked at the effectiveness of implementing RainWise in the context of the ultimate CSO control project size. The storage reduction target for each basin was chosen based on a reasonable level of RainWise participation and on available acreages for rooftop

disconnection. To reduce the Murray storage requirements by 280,000 gallons or 30 percent, 24 acres of impervious area would need to be disconnected from the CSS (see the table below). Implementing RainWise using SPU criteria would eliminate only 7 acres and approximately 148,000 gallons of storage. To reduce storage in the South Magnolia by 700,000 or 75 percent, 15 acres of impervious area would need to be removed. Implementing RainWise in this basin would only eliminate 9 acres of impervious area and approximately 272,000 gallons of storage.

	Murray	**South Magnolia**
Parcels	1,075	1,370
Roof area	1,098 square feet	2,054 square feet
Acres	27 acres	65 acres
Roof area for mitigation	700 square feet	700 square feet
Acres	17 acres	22 acres
Participation acres at 40%	7 acres	9 acres
Gallons eliminated from storage	148,350 gallons	271,956 gallons
Number of parcels	435	559

Although this preliminary analysis found that RainWise would not reduce the needed storage by a great enough volume to affect the overall size of the CSO control facility in these basins, the use of RainWise may be evaluated further for these basins and will be evaluated for future CSO control projects.

Appendix E

Windshield Survey of Barton Subbasin 416

Barton 416 GSI Alternatives
SW Webster St btw 31st & 32nd Ave SW
Existing Alley Conditions

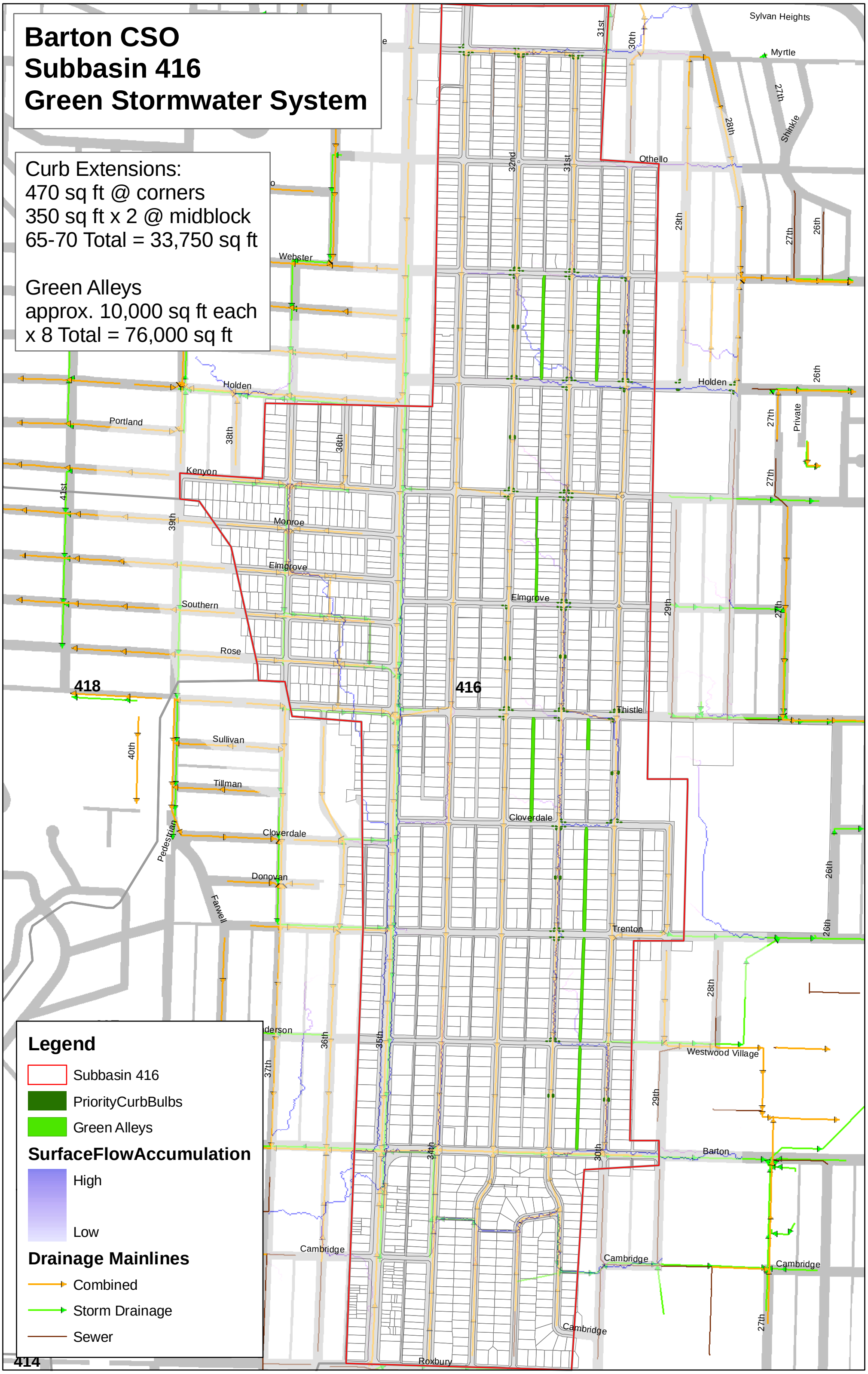
Barton 416 GSI Alternatives
SW Webster St @ 32nd Ave SW
Existing Conditions

Appendix F
Surface Water Runoff on Streets in Barton Subbasin 416

Barton CSO
Subbasin 416
Green Stormwater System

Curb Extensions:
470 sq ft @ corners
350 sq ft x 2 @ midblock
65-70 Total = 33,750 sq ft

Green Alleys
approx. 10,000 sq ft each
x 8 Total = 76,000 sq ft



Appendix G

Survey of Utility Structures in Barton Subbasin 416

Barton CSO Subbasin 416
Green Stormwater Infrastructure

Sample Block Analysis:
Green areas indicate high potential for GSI installations: excavation in ROW without altering existing paving, pipes, or large trees

SW Cloverdale St

32nd Ave SW

31st Ave SW

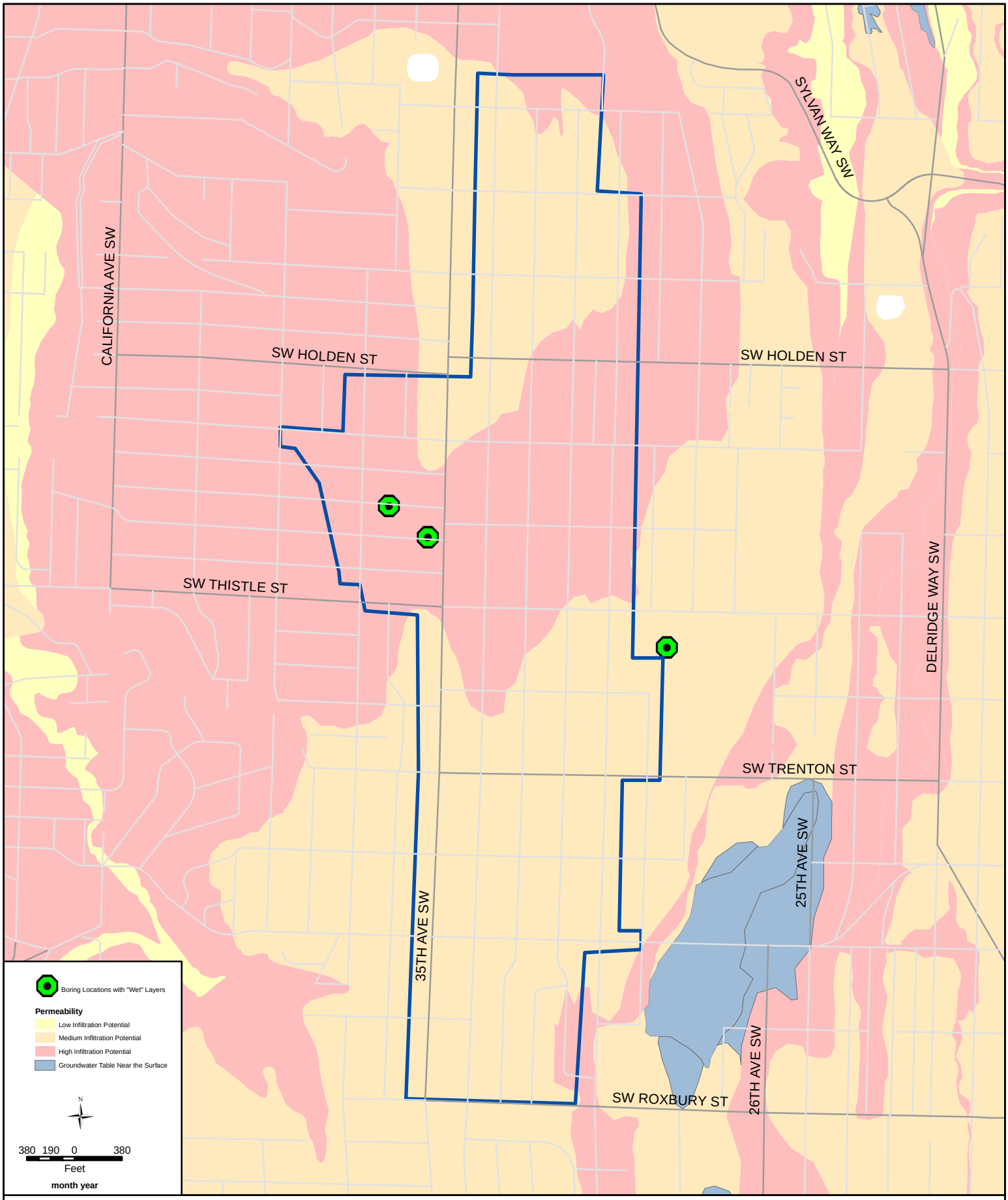
SW Trenton St

Legend

- Pavement edges
- Drainage lines to CSS
- Water lines
- Electrical lines (aerial)
- Parcel boundaries
- 2' contours
- Catch basins
- Fire hydrants
- Street lights

Appendix H

Soil Infiltration Rates in Barton Subbasin 416



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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Shaun O'Neil 20091120

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