# Technical Memorandum 810

# 2012 Comprehensive Combined Sewer Overflow Control Program Review

# Green Stormwater Infrastructure Alternatives

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King County
Department of Natural Resources and Parks
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# Acronyms

| | |
|---|---|
| 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 |
| MG | Million-gallon |
| 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 |
| SPU | Seattle Public Utilities |
| EPA | U.S. Environmental Protection Agency |
| WERF | Water Environment Research Foundation |
| WTD | King County Wastewater Treatment Division |

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# 1.0. INTRODUCTION

## 1.1 Background and Purpose

King County's *Combined Sewer Overflow (CSO) Control Plan* outlines measures for controlling CSO discharges to surface waters, in order to comply with federal and state water quality requirements. The CSO Control Plan is updated periodically as regulations evolve, new information becomes available, and the region experiences new development. To prepare for the next update, the CSO Control Program is undergoing a review—the *2012 CSO Control Program Review*, or "Program Review"—that will identify alternatives to control CSOs for King County's uncontrolled CSO sites. Alternatives will optimize and balance environmental, social, and financial goals to meet current needs.

The following CSO control approaches are considered in this Program Review:

- **Sewer separation**: Diverting stormwater flows from the existing combined sewer system to a separate storm drain system
- **Increased conveyance**: Increasing conveyance capacity of the combined sewer system
- **Offline Storage**: Using offline tanks, pipes, or tunnels to provide detention and reduce peak flows to the combined sewer system
- **Satellite Treatment**: Treating combined sewer overflows prior to discharge

In addition to the traditional CSO control solutions listed above, King County's Wastewater Treatment Division (WTD) is considering **Green Stormwater Infrastructure** (GSI) as a demand management approach to reduce the peak flows and volume of stormwater runoff to the combined sewer system (CSS).

GSI approaches can be implemented either alone or in combination with other traditional methods to achieve CSO control. This Program Review evaluates the GSI approach separately from traditional alternatives. The combined alternatives will be evaluated in future phases of work.

This technical memorandum presents the development and review process for planning-level GSI CSO control alternatives. This process consists of the following steps:

1. Select uncontrolled CSO basins for evaluation based on potential for GSI retrofit.
2. Generate estimates of impervious surface connected to the CSS using geographic information systems (GIS).
3. Perform initial GIS screening to estimate the portion of connected basins suitable for infiltration practices.

**What is Green Stormwater Infrastructure?**

Green stormwater infrastructure (GSI) is a decentralized approach for reducing runoff from developed areas by using infiltration, evapotranspiration, or stormwater reuse. Common techniques include bioretention (rain gardens), permeable pavements, vegetated swales, green roofs, and rainwater harvesting for re-use. Other names for GSI include low impact development (LID) and natural drainage systems.

4. Perform a more detailed GIS analysis to identify areas suitable for specific GSI practices.
5. Conduct targeted windshield surveys to validate GIS results and assess technical constraints to GSI implementation not captured in GIS evaluation, such as existing site improvements and infrastructure, available space in the right–of-way, and drainage patterns.
6. Calculate impervious basin areas likely manageable using GSI based on an assessment of technical constraints and anticipated participation.
7. Estimate total impervious area mitigated by GSI practices.
8. Evaluate runoff volume reduction benefits based on the areas mitigated by GSI and the effectiveness of the respective GSI practices.
9. Estimate life cycle cost of GSI retrofit alternative.

The remainder of this section discusses the regulatory drivers and technical approach for using GSI to control King County's CSOs.

## 1.2 Regulatory Context

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). Ecology requires that CSO sites average no more than one untreated discharge per year over a 20-year moving average (Washington Administrative Code 173-245-020). CSO sites that meet this requirement are classified as "controlled" and those that do not are classified as "uncontrolled". King County's combined sewer system includes 38 CSO sites, of which 14 are currently uncontrolled, with no projects underway to achieve control. King County's Wastewater Treatment Division (WTD) plans to control all of its 38 combined sewer overflow sites by 2030.

CSO control has traditionally relied upon centralized "grey" infrastructure approaches. However, 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, 2007a). In August of the same year, EPA's Office of Enforcement and Compliance Assurance (OECA) circulated another memorandum encouraging 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, 2007b). More recently, EPA issued another memorandum reiterating the goals of green stormwater infrastructure and outlining an agenda for EPA to continue to provide support to federal, state, tribal and local governments in implementing green stormwater infrastructure through NPDES permits (EPA, 2011). These memoranda are provided in Appendix A.

King County's wet-weather management programs were audited in January 2008 by the EPA OECA. While EPA has not yet made its findings public, recent audits of other wastewater utilities have resulted in consent decrees that require implementing green stormwater infrastructure and/or evaluating green stormwater infrastructure as a component of their long-

term CSO control plans. To support these enforcement activities, EPA has issued guidance on employing green stormwater infrastructure for CSO control (EPA, 2008).

## 1.3 Using GSI to Control CSOs

### 1.3.1 What is Green Stormwater Infrastructure?

GSI is a decentralized approach for reducing runoff from developed areas by using infiltration, evapotranspiration, or stormwater reuse. GSI practices are intended to be small-scale and distributed throughout a basin. Techniques include bioretention (rain gardens), permeable pavements, roof downspout disconnection, infiltration planters, vegetated swales, green roofs, trees, tree boxes, and pocket wetlands. GSI also includes decentralized harvesting approaches, such as the use of rain barrels and cisterns to capture, detain, and/or re-use stormwater for irrigation or flushing toilets.

GSI practices can attenuate peak flows, reduce runoff volumes, and provide water quality treatment. In combined sewer basins, GSI practices are used to intercept and manage stormwater before it reaches the CSS, thereby increasing capacity in the CSS and reducing the potential for CSOs.

In addition to helping reduce CSOs and providing treatment, GSI practices facilitate natural processes that recharge groundwater, preserve baseflow in streams, moderate impacts on water and air temperature, and protect hydrologic and hydraulic stability.

**Common GSI Practices**

**Bioretention** involves dispersed small scale landscape features designed to attenuate and treat stormwater. These features are typically vegetation-filled areas, such as rain gardens and swales, 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, limiting or removing the effects of the stormwater on the sewer system.

**Green Roofs** (ecoroofs) consist of shallow layers of growing medium, low-growing vegetation, subsurface drainage, and a waterproof membrane.

**Street trees** retain some rain in their canopies and take up a portion of the rain that infiltrates to the soil.

**Roof disconnection** removes water that flows from a roof through a downspout to a combined sewer and redirects it to some other location. It is not considered a GSI technique, but may be combined with "green" features such as rain gardens.

### 1.3.2 What is Required for GSI to Help Control CSOs?

Not all areas are well suited for GSI as a CSO control approach. Key factors that affect the potential success of GSI retrofit projects as they pertain to CSO control objectives are provided below:

- **Sufficient area of impervious surface connected to the CSS.** GSI practices are used in conjunction with disconnection strategies; areas that drain to the CSS are redirected to GSI practices, thereby increasing capacity in the CSS. Therefore, the potential benefits of GSI strategies are directly related to the amount of impervious surface which may be feasibly disconnected.
- **Space in the urban landscape for GSI retrofits.** Vegetated surface GSI techniques, such as bioretention, require sufficient open space. Siting opportunities include, but are

not limited to, existing planting strips, parking lots, and landscaped areas on private parcels.

- **Site suitability for infiltration practices.** Infiltrating GSI practices often provide the highest level of CSO control. Infiltration is not appropriate for areas near steep slopes or landslide hazard areas, areas underlain by high groundwater, or areas of contaminated soils or groundwater. Opportunities are highest where slopes are relatively flat and soils are permeable.
- **Re-infiltration of stormwater to the CSS**. For GSI practices that rely on infiltration of stormwater, it is crucial to understand the fate of the infiltrated water. If there is a potential for re-infiltration of this stormwater back into sewer laterals on private property or mainlines in the right-of-way, steps must be taken to eliminate these re-infiltration pathways. Methods can include pipe rehabilitation or replacement, trench water stops, and horizontal setbacks between infiltrating practices and sewer pipes.
- **Supporting conveyance infrastructure for large storm events**. In order to accommodate storms beyond design capacity, it is often necessary to direct excess flows into a separated stormwater system or back into the CSS.
- **Community support for GSI projects**. Community understanding of GSI projects and support for their implementation is critical to the success of this approach.

# 2.0. CSO BASINS EVALUATED

The 14 uncontrolled King County CSO sites for which no control projects are currently underway discharge CSOs to Elliott Bay, the Duwamish River, the Lake Washington Ship Canal, Lake Union, and the Montlake Cut. Each CSO site has an associated CSO outfall numbered by "Discharge Serial Number" (DSN) and a structure where overflows are diverted to the outfall from the CSS. Table 2-1 lists the CSO basins, the DSN for each CSO basin, and the name of the associated overflow diversion facility.

**Table 2-1. Uncontrolled CSO Basins and Facilities in King County**

| Area | Uncontrolled CSO Basin | DSN | Overflow Diversion Facility |
|---|---|---|---|
| Ship Canal | 11th Avenue NW | 004 | 11th Ave NW Overflow Structure |
| | 3rd Avenue W | 008 | 3rd Ave W Overflow Structure |
| | University | 015 | University Regulator Station |
| | Montlake | 014 | Montlake Regulator Station |
| Middle Elliott Bay Interceptor (EBI) | Hanford #2 | 032 | Hanford St Regulator Station |
| | Lander Street | 030 | Lander St Regulator Station |
| | Kingdome | 029 | Kingdome Regulator Station |
| | King Street | 028 | King St Regulator Station |
| Middle EBI | Hanford #1 | 031 | Hanford@Rainier, Bayview North and Bayview South Overflow Structures |
| South EBI | South Michigan Street | 039 | S Michigan St Regulator Station |
| | Brandon Street | 041 | Brandon St Regulator Station |
| West Duwamish | West Michigan Street | 042 | W Michigan St Regulator Station |
| | Terminal 115 | 038 | Terminal 115 Overflow Structure |
| | Chelan Avenue | 036 | Chelan Ave Regulator Station |

A high-level assessment was conducted for each of the uncontrolled basins to qualitatively rank the potential benefits of GSI for CSO control. Of the 14 basins, 4 basins were eliminated from further consideration, including the Lander Street, Kingdome, King Street and Terminal 115 basins. These basins were excluded due to predominant land use categorization (i.e., highly built-out areas with few retrofit opportunities) or degree of connection to the CSS (i.e., few opportunities for disconnection).

The nine CSO basins selected for further evaluation are shown in

Figure 2-1 and listed below. The Hanford #1 and #2 basins were evaluated as a single basin for GSI and are referred to as the "Hanford" basin.

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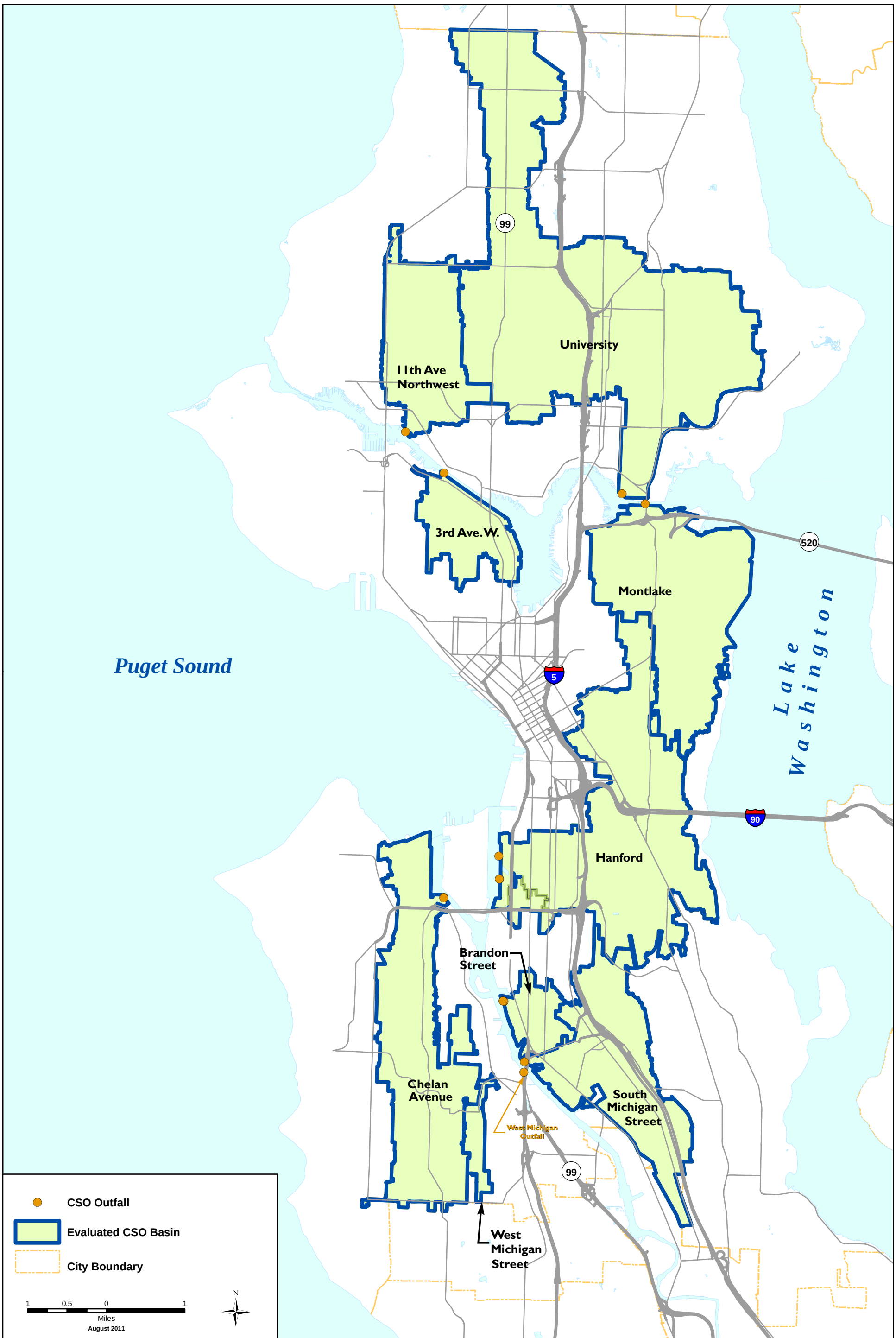


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**Figure 2-1**

**King County CSO Basins Evaluated for GSI**

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# 3.0. GSI PRACTICES EVALUATED

The GSI practices considered for CSO control vary by land use as shown in Table 3-1. Descriptions of the practices are provided below.

**Table 3-1. GSI Practices Evaluated by Land Use.**

| | Green Streets | | RainWise Programs | | |
|---|---|---|---|---|---|
| Land Use | Roadside Rain Garden | Permeable Pavement Alleys | Rain Garden | Cistern | Green Roof |
| Street Right-of-Way | X | | | | |
| Alley Right-of-Way | | X | | | |
| Residential Parcel | | | X | X | |
| Public Parcel | | | X | X | X |
| Commercial/Industrial Parcel | | | X | X | X |

## 3.1 Green Streets

The Green Street practices considered in this evaluation include roadside rain gardens and permeable pavement in alleyways in CSO basin rights-of-way as described below.

### 3.1.1 Roadside Rain Gardens

Roadside rain gardens are linear bioretention systems in the right-of-way designed to mitigate flows from roadways and sidewalks. The systems are shallow, vegetated depressions with a specialized soil mix, often paralleling the roadway, and designed to receive runoff from the adjacent impervious surfaces. Where possible, these systems are interconnected to provide conveyance as well as retention and infiltration of stormwater runoff. Where the existing planting strip width is not wide enough, curb extensions (curb bulbs) may be constructed at the end of each block to create space for the practice. Roadside rain gardens were considered for right-of-way areas suitable for infiltration.

### 3.1.2 Green Alleys

Green alleys consist of new or retrofitted permeable pavement to infiltrate rain falling on the alley areas and any adjacent runoff from improvements on private properties (e.g. driveways). Unimproved alleys may be improved by installing permeable pavement driving surface. Improved alleys, often designed as standard concrete V-shaped alleyways, may be retrofit by constructing a narrow permeable pavement strip in the center of existing alleys with checkdams in the subbase to maximize the storage and infiltration capabilities of the facility. Green alleys were considered for alley areas classified as suitable for infiltration.

## 3.2 RainWise Program

The Seattle RainWise program encourages private property owners to reduce the volume of stormwater that must be managed in public conveyance systems. This voluntary, incentive-style program offers rebates to reimburse residential property owners who implement GSI projects on their properties. A similar program targets GSI implementations at public school properties (called Green Schools). King County will partner with SPU to implement these programs in uncontrolled CSO basins. Further, King County intends to extend the RainWise program to commercial and industrial properties.

The RainWise practices considered in this evaluation include parcel-scale rain gardens and detention cisterns. Green roofs are also considered for commercial and industrial properties.

### 3.2.1 RainWise Rain Gardens

Parcel-scale rain gardens are bioretention systems that may be used to mitigate rooftop, private roadway, or parking lot runoff. Rain gardens were considered for residential, public and commercial/industrial parcels areas suitable for infiltration.

Rooftop, parking lot or driveway drainage that is currently conveyed directly to the combined sewer is disconnected and routed to a bioretention cell on private property. The cell is a small vegetated depression with a designed soil mix that retains rooftop runoff for subsequent infiltration or delayed release. These practices are only eligible in areas that are suitable for infiltration.

### 3.2.2 RainWise Cisterns

Detention cisterns are tanks designed to collect rooftop runoff and slowly meter it back into the CSS. The peak reduction performance will depend upon the contributing roof area, cistern height, and orifice size. Detention cisterns were considered for residential, public and commercial/industrial parcels.

Rooftop drainage that is currently conveyed directly to the combined sewer is stored in above-grade cisterns for alternate uses, principally irrigation of vegetation. Overflows from cisterns may be overland to the street collection system or directly back to the existing side sewer connection where overland overflow is infeasible. Cisterns are less effective for CSO control than rain gardens.

### 3.2.3 RainWise Green Roofs

Green roofs are areas of living vegetation installed on top of buildings to provide flow control via attenuation, soil storage, and losses to interception, evaporation, and transpiration. Green roofs are also known as ecoroofs, vegetated roofs, and roof gardens. Green roofs were considered for large public and commercial/industrial buildings.

# 4.0. DESKTOP GSI SUITABILITY ASSESSMENT

King County's WTD conducted a two-phase GIS analysis from 2008 to 2010 as part of their 2012 CSO Control Program Review. Phase 1 of the GIS assessment involved delineating pervious and impervious areas contributing stormwater runoff to the CSS. The results of this GIS screening assisted the County's modelers in determining the level of control required per basin to meet EPA's thresholds for CSOs. While this analysis provided adequate information for assessing grey infrastructure needs, the feasibility of GSI alternatives to reduce or eliminate grey facilities required a more detailed analysis. Phase 2 of the GIS assessment involved further characterization of land use designations and evaluation of GSI siting constraints (e.g., location of steep slopes, contaminated sites). This section includes a summary of the methods and results of both phases of the GIS analysis.

## 4.1 Characterization and Connectivity Assessment

### 4.1.1 Methodology

The first phase of GIS screening involved delineating land use designation (parcel and right-of-way) and land cover types (pervious and impervious) within each CSO basin and identifying basin areas that contribute stormwater runoff, or are "connected", to the CSS. The approach used was developed for the Puget Sound CSO Beach Projects in 2007 and more fully documented in King County TM 207.1, 2008 (King County 2010). The steps completed in the analysis are as follows:

1. Synthesize existing King County and City of Seattle data.
2. Delineate parcel and right-of-way areas by basin.
3. Identify land cover types (rooftop, pervious, and impervious).
4. Delineate parcel and right-of-way areas contributing to the CSS, municipal separate storm sewer system (MS4), and overland flow to a receiving water body.
5. Synthesize data from Steps 2 through 4 to develop tables of connectivity (i.e., runoff destination) by land use and land cover.

#### Parcel Characterization and Connectivity

Based on the existing King County and City of Seattle GIS land cover data, parcel areas were characterized as rooftop, impervious, or pervious area (Step 3). Rooftops and impervious areas were tallied separately to account for parcels that drain to both the MS4 and the CSS (e.g., rooftop area is connected to the CSS while surface pervious and impervious areas drain to the MS4). The connectivity of parcel areas was established based on evaluation of conveyance features identified in the GIS databases including infiltration pits, storm drain laterals, sewer laterals, catch basins, and downspouts. The connectivity of parcel rooftops and impervious/pervious areas were designated as one of the following (Step 4):

- Directly connected to the MS4
- Directly connected to the CSS
- Indirectly connected to the MS4 via overland flow to the right-of-way
- Indirectly connected to the CSS via overland flow to the right-of-way
- Connected to a receiving water body via overland flow

While these methods provide a basis for estimating parcel connectivity, there is inherent uncertainty due to inaccuracies and misinterpretations of the existing data. Some data inaccuracies can be remedied via field verification; however, some sources of error, such as modifications to parcel conveyance features post-data collection (or even post-field verification) are inevitable. An example of this would be the disconnection of a downspout by the property owner. The second source of error, data misinterpretation, is often a result of the number of assumptions required to infer parcel connectivity based on conveyance feature GIS data. An example of this would be the assumption that the presence of a downspout on a parcel and no MS4 system in the right-of-way indicates that the rooftop is contributing to the CSS.

To address these uncertainties, two sets of assumptions were used to estimate the possible extremes (high and low) in parcel connectivity to the CSS. Parcel connectivity scenarios A and B were evaluated for each land cover type (rooftop, impervious, or pervious) and potential flow destination (MS4, CSS, or receiving water body). For each scenario, parcels were subject to a set of additive criteria (provided in Appendix B) with conservative or favorable connectivity assumptions.

#### Right-of-way Characterization and Connectivity

A similar analysis was conducted for the right-of-way areas in each basin to determine the destination of stormwater runoff by land cover type. Area connectivity was evaluated based on existing basin topography and the location of CSS and MS4 structures (e.g., catch basin, curb and gutter, ditch). All runoff was assumed to flow via surface, ditch, or culvert conveyance to the first down-gradient inlet. The pervious and impervious areas of the right-of-way were categorized as (Step 4):

- Connected to the CSS
- Connected to the MS4
- Connected to a receiving water body via overland flow

### 4.1.2 Results

Based on initial GIS screening (Steps 1 and 2), each CSO basin was broken down by land use designation (i.e., right-of-way or parcel) and land cover (i.e., pervious or impervious). The results are tabulated in Table 4-1 below.

The connectivity analysis (Step 4) provided estimates of areas that contribute stormwater runoff to the CSS, the MS4, or a receiving water body for both connectivity scenarios (A and B). The results are tabulated by basin in Table 4-2 below.

**Table 4-1. Parcel and Right-of-way Areas by CSO Basin**

| CSO Basin | Right-of-way Area [1] (acres) | | | | Parcel Area (acres) [1,2] | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Impervious | Pervious | Other | Total | Impervious | Pervious | Rooftop | Other | Total | |
| 11th Avenue NW | 404 | 35 | 6 | 445 | 410 | 185 | 319 | 8 | 921 | 1,366 |
| University | 1,663 | 194 | 77 | 1,933 | 1,547 | 1,311 | 1,071 | 310 | 4,239 | 6,172 |
| 3rd Avenue W | 205 | 38 | 6 | 249 | 169 | 144 | 139 | 49 | 501 | 750 |
| Montlake | 483 | 139 | 69 | 691 | 423 | 596 | 362 | 141 | 1,522 | 2,212 |
| Hanford | 951 | 167 | 54 | 1,172 | 940 | 588 | 657 | 108 | 2,293 | 3,466 |
| Chelan Avenue | 338 | 78 | 97 | 514 | 550 | 574 | 258 | 695 | 2,076 | 2,590 |
| West Michigan Street | 43 | 13 | 3 | 59 | 43 | 68 | 30 | 2 | 144 | 203 |
| Brandon Street | 75 | 2 | 16 | 92 | 103 | 8 | 100 | 74 | 285 | 377 |
| South Michigan Street | 334 | 98 | 17 | 450 | 843 | 331 | 230 | 33 | 1,437 | 1,886 |

[1] Rounding of the values presented in this table may introduce discrepancies of up to one acre.
[2] Parcel-based impervious surfaces have been subdivided into rooftop area and other impervious surfaces (referred to as "impervious") to account for parcels where the rooftop and ground-level impervious surfaces have different runoff destinations (MS4, CSS, or receiving water body).

**Table 4-2. Connectivity (Runoff Destination) by CSO Basin and Connectivity Scenario**

| CSO Basin | Land Use | Land Cover [1] | Runoff Area by Destination and Connectivity Scenario [2] (acres) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CSS | | | MS4 | | | Other [3] | | |
| | | | A[4] | B[4] | Difference[5] | A[4] | B[4] | Difference[5] | A[4] | B[4] | Difference[5] |
| 11th Avenue NW | ROW | Impervious | 206 | | - | 199 | | - | 5 | | - |
| | | Pervious | 17 | | - | 18 | | - | 0 | | - |
| | | **Total** | **222** | | **-** | **217** | | **-** | **6** | | **-** |
| | Parcel | Impervious | 240 | 247 | -8 | 170 | 160 | 10 | 4 | 7 | -3 |
| | | Pervious | 113 | 114 | -1 | 71 | 70 | 1 | 1 | 1 | 0 |
| | | Rooftop | 187 | 238 | -52 | 133 | 80 | 52 | 3 | 4 | -1 |
| | | **Total** | **539** | **600** | **-60** | **374** | **310** | **64** | **8** | **11** | **-4** |
| University | ROW | Impervious | 1058 | | - | 605 | | - | 54 | | - |
| | | Pervious | 116 | | - | 78 | | - | 23 | | - |
| | | **Total** | **1174** | | **-** | **682** | | **-** | **77** | | **-** |
| | Parcel | Impervious | 1075 | 1041 | 34 | 472 | 492 | -21 | 99 | 113 | -13 |
| | | Pervious | 868 | 823 | 45 | 444 | 458 | -14 | 142 | 173 | -30 |
| | | Rooftop | 743 | 863 | -121 | 329 | 217 | 111 | 68 | 59 | 9 |
| | | **Total** | **2686** | **2727** | **-42** | **1244** | **1168** | **76** | **310** | **344** | **-35** |
| 3rd Avenue W | ROW | Impervious | 181 | | - | 24 | | - | 6 | | - |
| | | Pervious | 32 | | - | 6 | | - | 0 | | - |
| | | **Total** | **213** | | **-** | **30** | | **-** | **6** | | **-** |
| | Parcel | Impervious | 164 | 164 | 1 | 5 | 6 | -1 | 12 | 12 | 0 |
| | | Pervious | 139 | 139 | 1 | 5 | 5 | 0 | 18 | 19 | 0 |
| | | Rooftop | 134 | 133 | 1 | 5 | 6 | -1 | 18 | 18 | 0 |
| | | **Total** | **438** | **435** | **3** | **15** | **17** | **-2** | **49** | **49** | **0** |
| Montlake | ROW | Impervious | 291 | | - | 192 | | - | 24 | | - |
| | | Pervious | 71 | | - | 68 | | - | 45 | | - |
| | | **Total** | **362** | | **-** | **259** | | **-** | **69** | | **-** |

**Table 4-2. Connectivity (Runoff Destination) by CSO Basin and Connectivity Scenario (continued)**

| CSO Basin | Land Use | Land Cover [1] | Runoff Area by Destination and Connectivity Scenario [2] (acres) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CSS | | | MS4 | | | Other [3] | | |
| | | | A[4] | B[4] | Difference[5] | A[4] | B[4] | Difference[5] | A[4] | B[4] | Difference[5] |
| Montlake (continued) | Parcel | Impervious | 288 | 273 | 14 | 135 | 144 | -8 | 31 | 37 | -6 |
| | | Pervious | 368 | 355 | 13 | 228 | 232 | -4 | 75 | 84 | -9 |
| | | Rooftop | 239 | 319 | -79 | 122 | 63 | 60 | 35 | 15 | 19 |
| | | **Total** | **895** | **947** | **-52** | **486** | **438** | **48** | **141** | **136** | **4** |
| Hanford | ROW | Impervious | 294 | | - | 657 | | - | 15 | | - |
| | | Pervious | 55 | | - | 112 | | - | 39 | | - |
| | | **Total** | **349** | | **-** | **769** | | **-** | **54** | | **-** |
| | Parcel | Impervious | 495 | 467 | 28 | 446 | 468 | -23 | 32 | 38 | -6 |
| | | Pervious | 340 | 322 | 18 | 247 | 263 | -16 | 54 | 57 | -2 |
| | | Rooftop | 327 | 368 | -41 | 330 | 294 | 36 | 22 | 17 | 4 |
| | | **Total** | **1162** | **1157** | **5** | **1023** | **1025** | **-2** | **108** | **112** | **-3** |
| Chelan | ROW | Impervious | 265 | | - | 73 | | - | 54 | | - |
| | | Pervious | 68 | | - | 11 | | - | 43 | | - |
| | | **Total** | **333** | | **-** | **84** | | **-** | **97** | | **-** |
| | Parcel | Impervious | 131 | 115 | 17 | 419 | 394 | 25 | 216 | 258 | -42 |
| | | Pervious | 154 | 130 | 24 | 420 | 345 | 76 | 450 | 549 | -100 |
| | | Rooftop | 109 | 98 | 11 | 149 | 150 | -1 | 29 | 39 | -10 |
| | | **Total** | **394** | **343** | **51** | **988** | **889** | **99** | **695** | **846** | **-151** |
| West Michigan Street | ROW | Impervious | 6 | | - | 37 | | - | 1 | | - |
| | | Pervious | 2 | | - | 11 | | - | 3 | | - |
| | | **Total** | **8** | | **-** | **48** | | **-** | **3** | | **-** |
| | Parcel | Impervious | 10 | 8 | 2 | 33 | 35 | -2 | 1 | 1 | 0 |
| | | Pervious | 17 | 16 | 1 | 51 | 52 | -1 | 1 | 1 | 0 |
| | | Rooftop | 12 | 15 | -3 | 18 | 15 | 3 | 0 | 1 | 0 |
| | | **Total** | **39** | **38** | **1** | **102** | **103** | **-1** | **2** | **3** | **0** |

**Table 4-2. Connectivity (Runoff Destination) by CSO Basin and Connectivity Scenario (continued)**

| CSO Basin | Land Use | Land Cover [1] | Runoff Area by Destination and Connectivity Scenario [2] (acres) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CSS | | | MS4 | | | Other [3] | | |
| | | | A[4] | B[4] | Difference[5] | A[4] | B[4] | Difference[5] | A[4] | B[4] | Difference[5] |
| Brandon Street | ROW | Impervious | 63 | | - | 12 | | - | 15 | | - |
| | | Pervious | 2 | | - | 0 | | - | 0 | | - |
| | | **Total** | **64** | | **-** | **12** | | **-** | **16** | | **-** |
| | Parcel | Impervious | 86 | 65 | 21 | 17 | 6 | 12 | 41 | 74 | -32 |
| | | Pervious | 8 | 4 | 3 | 0 | 0 | 0 | 5 | 8 | -3 |
| | | Rooftop | 98 | 85 | 14 | 2 | 7 | -5 | 28 | 36 | -9 |
| | | **Total** | **192** | **154** | **38** | **19** | **13** | **6** | **74** | **118** | **-44** |
| South Michigan Street | ROW | Impervious | 203 | | - | 132 | | - | 15 | | - |
| | | Pervious | 27 | | - | 71 | | - | 2 | | - |
| | | **Total** | **230** | | **-** | **202** | | **-** | **17** | | **-** |
| | Parcel | Impervious | 370 | 364 | 6 | 473 | 473 | -1 | 18 | 23 | -5 |
| | | Pervious | 196 | 191 | 4 | 135 | 138 | -2 | 7 | 9 | -2 |
| | | Rooftop | 188 | 190 | -3 | 43 | 41 | 2 | 8 | 7 | 1 |
| | | **Total** | **753** | **746** | **8** | **651** | **652** | **-2** | **33** | **39** | **-6** |

ROW - right-of-way

[1] Parcel impervious surfaces have been subdivided into rooftop area and ground-level impervious surfaces (referred to as "impervious") to account for parcels where the rooftop and ground-level impervious areas have different runoff destinations (MS4, CSS, or receiving water body).

[2] Rounding of the values presented in this table may introduce discrepancies of up to one acre.

[3] Area classified as having a flow destination of "other" includes areas directly contributing runoff to a receiving water body, areas from which runoff exits the basin via overland flow before entering the CSS or MS4, and any errors in calculation that may have occurred during the analysis (typically less than 2 acres).

[4] Scenarios A and B represent two distinct estimates of parcel connectivity. The connectivity criteria applied for each scenario are provided in Appendix B.

[5] Difference in connectivity estimates (runoff area connected per Scenario A – runoff area connected per Scenario B). Note that neither scenario consistently results in higher or lower values.

## 4.2 GSI Suitability Assessment

### 4.2.1 Methodology

Once the parcels and right-of-way areas connected to the CSS were estimated (Phase 1), a high-level GSI suitability analysis was conducted to assess the applicability of GSI for CSO control, or "mitigation", in the connected areas of each basin. This analysis included the subdivision of land use designations to include parcel type (public, residential, and commercial/industrial) as well as the identification of unsuitable parcels and right-of-way areas based on siting hazards. Methods were based on the SPU GSI feasibility protocol (Seattle 2010) with modifications to meet the needs of this analysis. The steps completed in this assessment are as follows:

1. Classification of parcels by land use designation (public, residential, or commercial/industrial)
2. Identification of areas suitable for infiltration facilities (parcel and right-of-way)
3. Identification of parcels suitable for green roofs
4. Identification of parcels suitable for cisterns
5. Development of suitability tables and CSO basin suitability maps

#### Parcel Suitability

The suitability of parcel-based GSI was evaluated for both infiltrating facilities (bioretention and permeable pavement) and non-infiltrating facilities (cisterns and green roofs). Since the suitability criteria for rain gardens and permeable pavement are very similar, these facilities have been lumped into a single estimate of infiltrating facility suitability. Cisterns and green roofs are evaluated separately since the criteria for suitability and the stormwater benefits are vastly different. Public, commercial, and industrial parcels were evaluated for all three facility types: infiltrating facilities, cisterns, and green roofs. Residential parcels were only evaluated for infiltrating facilities and cisterns. Infiltration facilities are the most effective measures for reducing flows to the CSS (relative to the non-infiltrating practices evaluated in this analysis). As a result, these facilities have been prioritized first for implementation on both public and private parcels.

The only criteria for cistern suitability is that the parcel has been classified as connected to the CSS per the connectivity assessment (Phase 1), described above. Infiltration facilities and green roofs were subject to additional suitability criteria as explained below.

Based on the GIS databases from King County and the City of Seattle, parcels were classified as suitable for infiltration facilities if they met the following criteria (based on parcel centroid location):

- Parcel is not within 300 feet of a steep slope (as identified in slide.shp)
- Parcel is not within 300 feet of a landslide prone area (as identified in slide.shp)
- Parcel is not within 100 feet of a contaminated site (as identified in carto_haz_cscs_pt.shp)

- Parcel is not within 100 feet of an abandoned landfill (as identified in landfill.shp)
- Parcel is not within 100 feet of a known underground storage tank (as identified in carto_haz_lust_pt.shp)
- Parcel falls within a high or medium infiltration area (as identified in Perm_Assessment.shp)

Parcels were deemed suitable for green roofs if they met the following criteria:

- Parcel is identified as a public or commercial/industrial land use
- Roof area is greater than 5,000 square feet

While the criteria used for identification of green roof suitability do not capture all of the design constraints, the intent was to identify a class of rooftops most likely to meet the criteria for siting of these facilities. Some of these design constraints include roof slopes (generally must be less than 20 percent) and capacity of the structure to support additional loads. By eliminating residential areas (where approximately 75 percent of roofs do not meet the slope criteria), and establishing a minimum roof area, the remaining structures are likely to be suitable for a green roof retrofit.

#### Right-of-way Suitability

The suitability of right-of-way-based GSI (including roadways and alleyways) was evaluated only for infiltrating facilities, including rain gardens and permeable pavement. The basin topography was used to determine longitudinal roadway slopes, allowing for the classification of right-of-way area as one of the following:

- Suitable (less than or equal to 6 percent slope)
- Moderately Suitable (greater than 6 percent and less than 15 percent slope)
- Not Suitable (greater than or equal to 15 percent slope or not connected to the CSS)

The infiltration criteria for parcel-based infiltrating facilities (including steep slope critical area and contaminated site setbacks, and infiltration constraints) were not applied to right-of-way areas. This decision was made so as to not eliminate right-of way areas in unfavorable infiltration areas where runoff could be routed to nearby areas where conditions are more suitable for infitrlation.

### 4.2.2 Results

The areas suitable for GSI practices are provided by basin in Table 4-3. Figures 4-1 through 4-10 illustrate the results of this analysis by CSO basin. The total suitable areas for each land use designation and facility type were used as the basis of the feasibility analysis, described in Section 5 of this memorandum.

**Table 4-3. GSI Suitability by Basin**

| CSO Basin | Land Use | Total Area (acres) | Suitable Area by GSI Practice [1] (acres) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Infiltration Facilities | | Cisterns [2] | | Green Roofs [3] | | Total [4] | |
| | | | High | Low | High | Low | High | Low | High | Low |
| 11th Avenue NW | Street & Alley ROW | | 193 | 95 | | | | | 193 | 95 |
| | Public Parcel | 57 | 15 | 15 | 11 | 11 | 8 | 8 | 27 | 26 |
| | Residential Parcel | 614 | 230 | 227 | 61 | 58 | | | 291 | 284 |
| | Com./Industrial Parcel | 250 | 83 | 70 | 22 | 16 | 21 | 18 | 104 | 86 |
| | Total | 1,366 | 520 | 407 | 94 | 85 | 29 | 25 | 615 | 492 |
| | | | 38% | 30% | 7% | 6% | 2% | 2% | 45% | 36% |
| University | Street & Alley ROW | 1,932 | 955 | 428 | | | | | 955 | 428 |
| | Public Parcel | 701 | 124 | 121 | 128 | 117 | 51 | 51 | 252 | 238 |
| | Residential Parcel | 2,483 | 564 | 552 | 494 | 496 | | | 1058 | 1047 |
| | Com./Industrial Parcel | 1,055 | 246 | 234 | 256 | 250 | 117 | 117 | 502 | 484 |
| | Total | 6,172 | 1889 | 1334 | 878 | 863 | 168 | 168 | 2767 | 2197 |
| | | | 31% | 22% | 14% | 14% | 3% | 3% | 45% | 36% |
| 3rd Avenue W | Street & Alley ROW | 249 | 139 | 58 | | | | | 139 | 58 |
| | Public Parcel | 89 | 1 | 1 | 25 | 23 | 7 | 7 | 27 | 24 |
| | Residential Parcel | 219 | 15 | 5 | 17 | 7 | | | 33 | 12 |
| | Com./Industrial Parcel | 193 | 8 | 5 | 56 | 34 | 19 | 13 | 64 | 39 |
| | Total | 750 | 163 | 69 | 98 | 64 | 27 | 20 | 262 | 133 |
| | | | 22% | 9% | 13% | 9% | 4% | 3% | 35% | 18% |
| Montlake | Street & Alley ROW | 691 | 177 | 72 | | | | | 177 | 72 |
| | Public Parcel | 256 | 33 | 32 | 28 | 26 | 14 | 15 | 60 | 58 |
| | Residential Parcel | 998 | 111 | 103 | 269 | 256 | | | 380 | 359 |
| | Com./Industrial Parcel | 268 | 36 | 34 | 53 | 50 | 14 | 13 | 88 | 84 |
| | Total | 2,212 | 357 | 241 | 349 | 332 | 28 | 28 | 706 | 574 |
| | | | 16% | 11% | 16% | 15% | 1% | 1% | 32% | 26% |

**Table 4-3. GSI Suitability by Basin (continued)**

| CSO Basin | Land Use | Total Area (acres) | Suitable Area by GSI Practice [1] (acres) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Infiltration Facilities | | Cisterns [2] | | Green Roofs [3] | | Total [4] | |
| | | | High | Low | High | Low | High | Low | High | Low |
| Hanford | Street & Alley ROW | 1,172 | 260 | 130 | | | | | 260 | 130 |
| | Public Parcel | 566 | 15 | 10 | 193 | 176 | 49 | 42 | 208 | 186 |
| | Residential Parcel | 772 | 15 | 11 | 107 | 95 | | | 122 | 106 |
| | Com./Industrial Parcel | 955 | 52 | 45 | 389 | 348 | 163 | 141 | 441 | 393 |
| | **Total** | **3,466** | **342** | **196** | **689** | **619** | **212** | **182** | **1030** | **815** |
| | | | **10%** | **6%** | **20%** | **18%** | **6%** | **5%** | **30%** | **24%** |
| Chelan Avenue | Street & Alley ROW | 514 | 86 | 44 | | | | | 86 | 44 |
| | Public Parcel | 809 | 5 | 5 | 10 | 5 | 3 | 3 | 15 | 10 |
| | Residential Parcel | 670 | 60 | 57 | 100 | 85 | | | 160 | 142 |
| | Com./Industrial Parcel | 597 | 22 | 21 | 39 | 28 | 16 | 10 | 61 | 49 |
| | **Total** | **2,590** | **174** | **127** | **149** | **118** | **20** | **13** | **323** | **245** |
| | | | **7%** | **5%** | **6%** | **5%** | **1%** | **0%** | **12%** | **9%** |
| West Michigan Street | Street & Alley ROW | 59 | 5 | 3 | | | | | 5 | 3 |
| | Public Parcel | 28 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| | Residential Parcel | 92 | 11 | 8 | 6 | 5 | | | 16 | 13 |
| | Com./Industrial Parcel | 24 | 2 | 2 | 2 | 2 | 1 | 1 | 4 | 4 |
| | **Total** | **203** | **18** | **13** | **9** | **8** | **1** | **1** | **27** | **21** |
| | | | **9%** | **6%** | **5%** | **4%** | **0%** | **0%** | **13%** | **10%** |
| Brandon Street | Street & Alley ROW | 92 | 62 | 45 | | | | | 62 | 45 |
| | Public Parcel | 49 | 3 | 2 | 8 | 8 | 2 | 2 | 11 | 10 |
| | Residential Parcel | 6 | 4 | 4 | 0 | 0 | | | 4 | 4 |
| | Com./Industrial Parcel | 230 | 108 | 88 | 61 | 47 | 91 | 77 | 169 | 135 |
| | **Total** | **377** | **176** | **138** | **70** | **56** | **93** | **79** | **246** | **194** |
| | | | **47%** | **37%** | **19%** | **15%** | **25%** | **21%** | **65%** | **52%** |

**Table 4-3. GSI Suitability by Basin (continued)**

| CSO Basin | Land Use | Total Area (acres) | Suitable Area by GSI Practice [1] (acres) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Infiltration Facilities | | Cisterns [2] | | Green Roofs [3] | | Total [4] | |
| | | | High | Low | High | Low | High | Low | High | Low |
| South Michigan Street | Street & Alley ROW | 450 | 187 | 106 | | | | | 187 | 106 |
| | Public Parcel | 859 | 23 | 23 | 121 | 121 | 14 | 14 | 144 | 144 |
| | Residential Parcel | 333 | 89 | 87 | 107 | 104 | | | 195 | 192 |
| | Com./Industrial Parcel | 244 | 108 | 104 | 93 | 91 | 78 | 77 | 200 | 195 |
| | Total | 1,884 | 407 | 321 | 320 | 316 | 91 | 91 | 727 | 637 |
| | | | 22% | 17% | 17% | 17% | 5% | 5% | 39% | 34% |

ROW - right-of-way
Com. - Commercial
[1] Rounding of the values presented in this table may introduce discrepancies of up to one acre.
[2] Any parcel identified as suitable for infiltrating facilities and/or green roofs is also suitable for cisterns.
[3] The suitability of green roofs relative to the other facilities evaluated is not mutually exclusive (i.e., in areas suitable for green roofs, cisterns or infiltration facilities could be substituted).
[4] Total suitable area is sum of infiltration and cistern areas.

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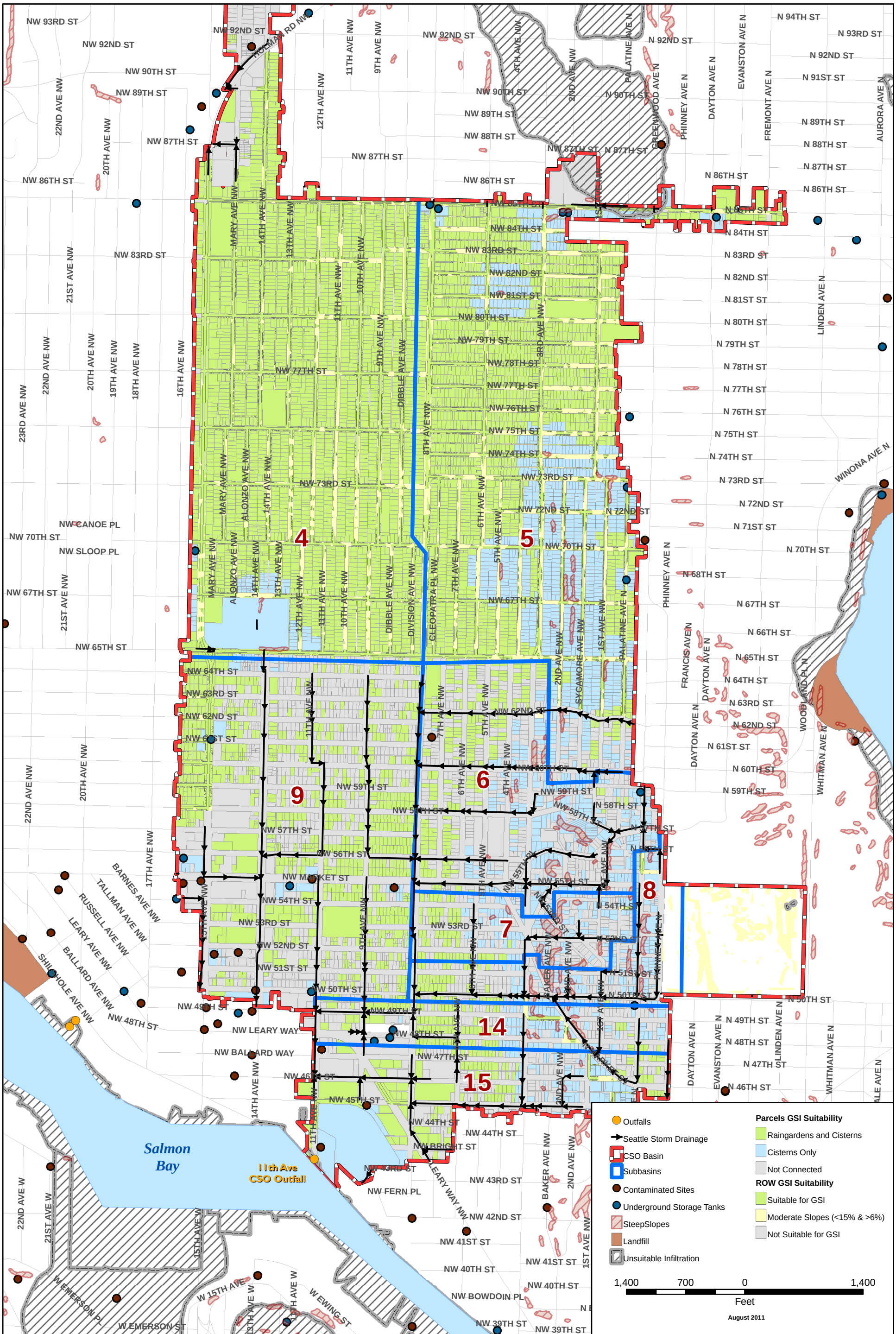


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**Figure 4-1**

**GSI Suitability for 11th Avenue NW CSO Basin**

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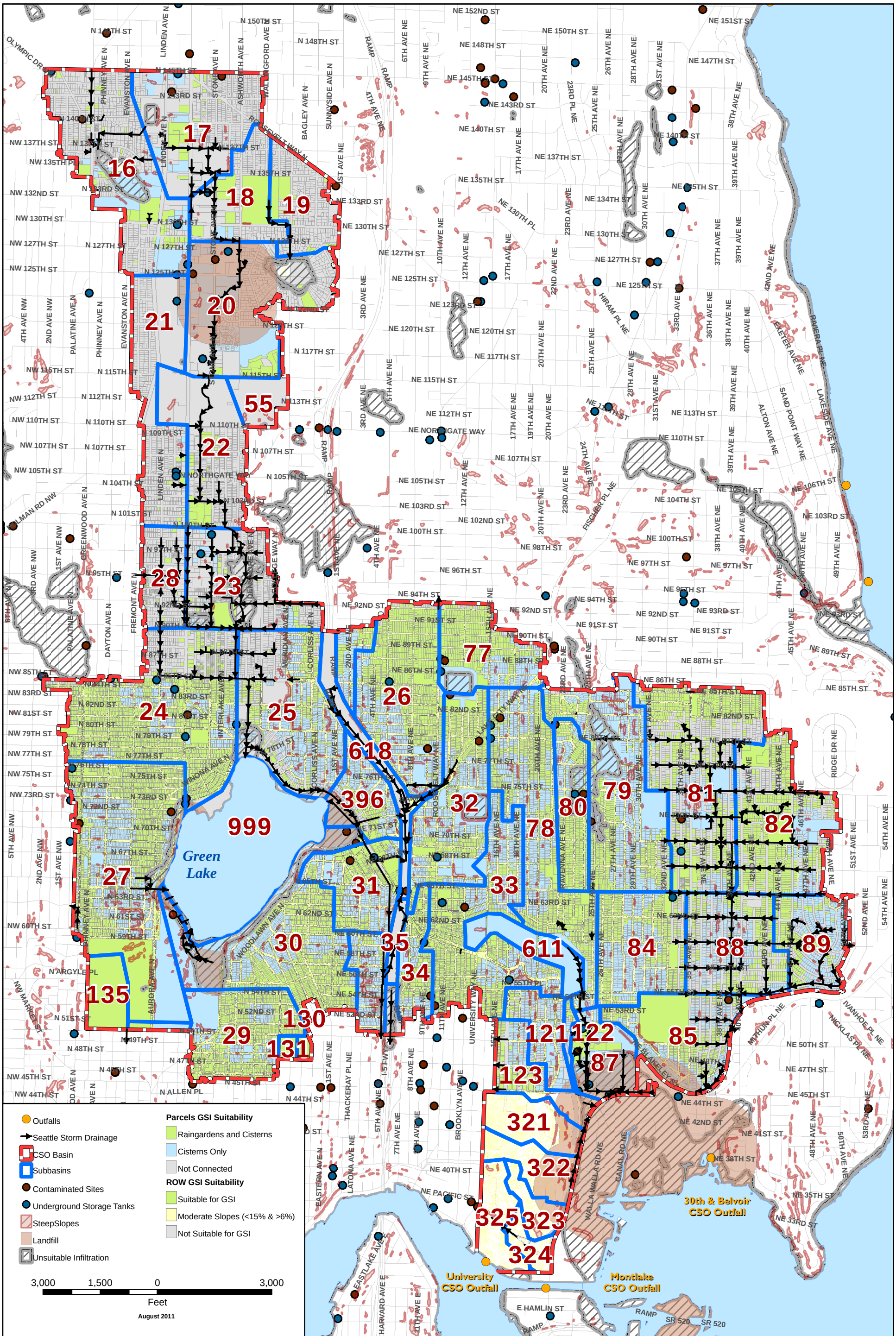


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**Figure 4-2**

**GSI Suitability for University CSO Basin**

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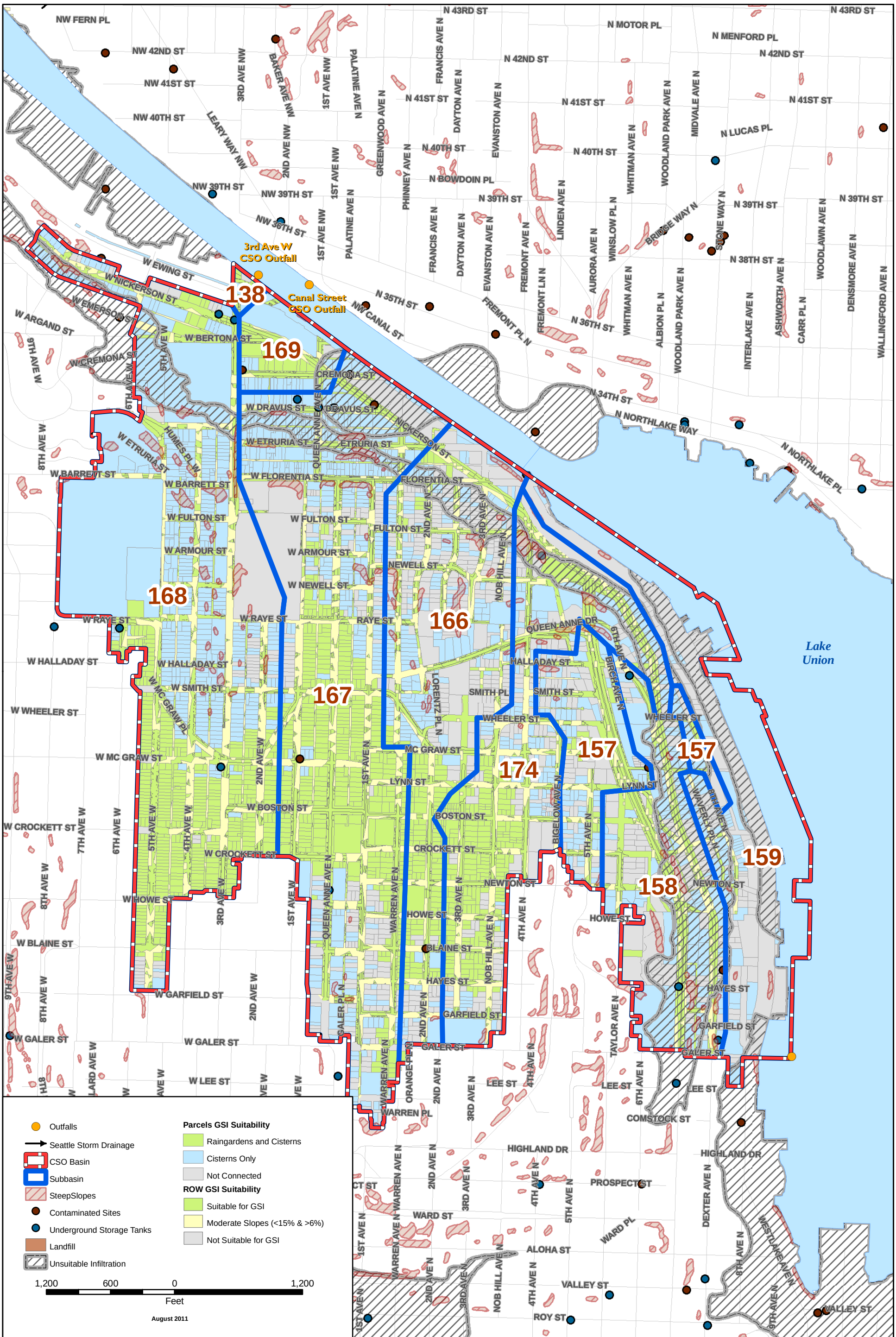


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**Figure 4-3**

**GSI Suitability for 3rd Avenue W CSO Basin**

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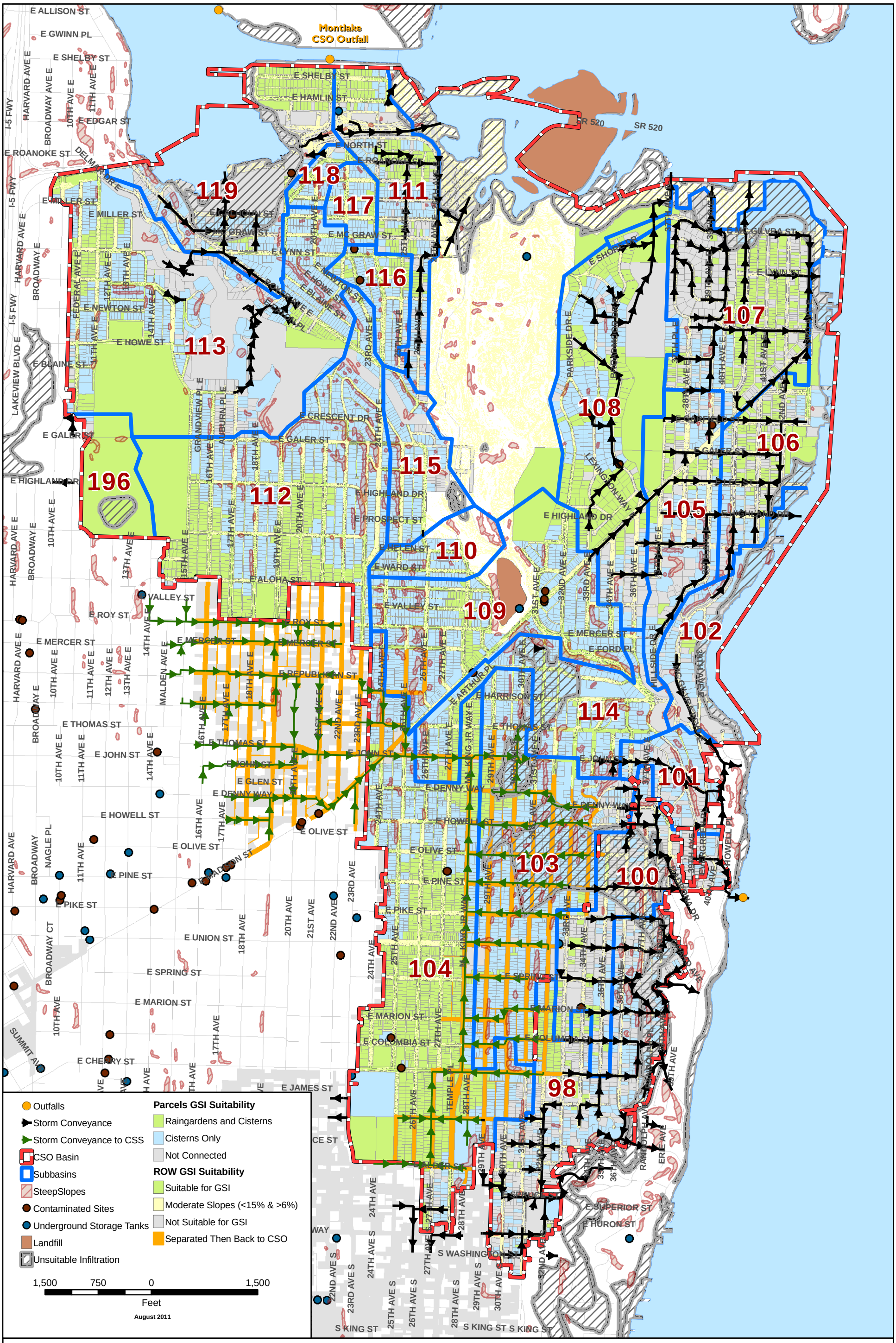


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**Figure 4-4**

**GSI Suitability for Montlake CSO Basin**

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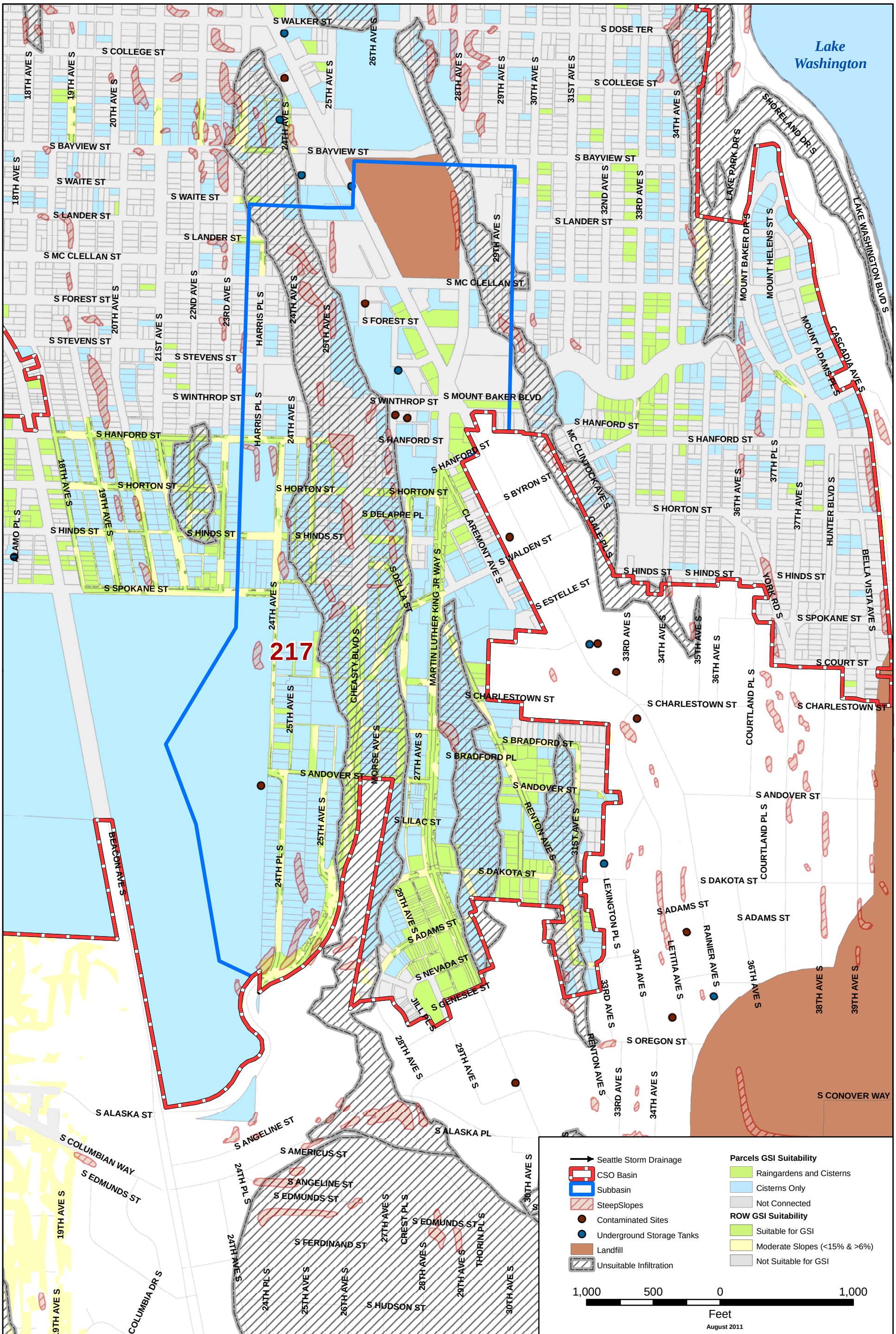


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**Figure 4-5**

**GSI Suitability for Hanford CSO Basin Southeast**

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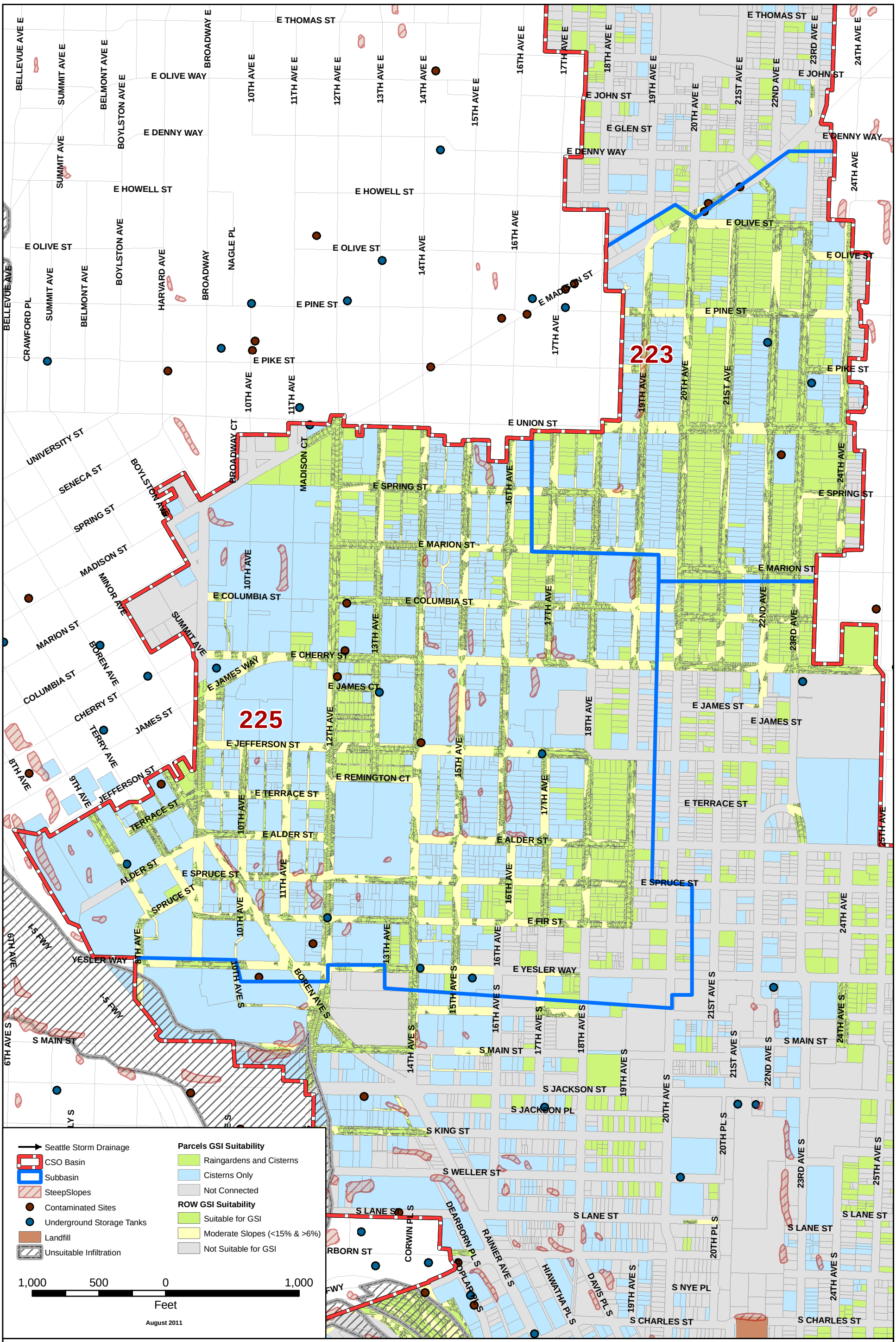


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**Figure 4-6**

**GSI Suitability for Hanford CSO Basin North**

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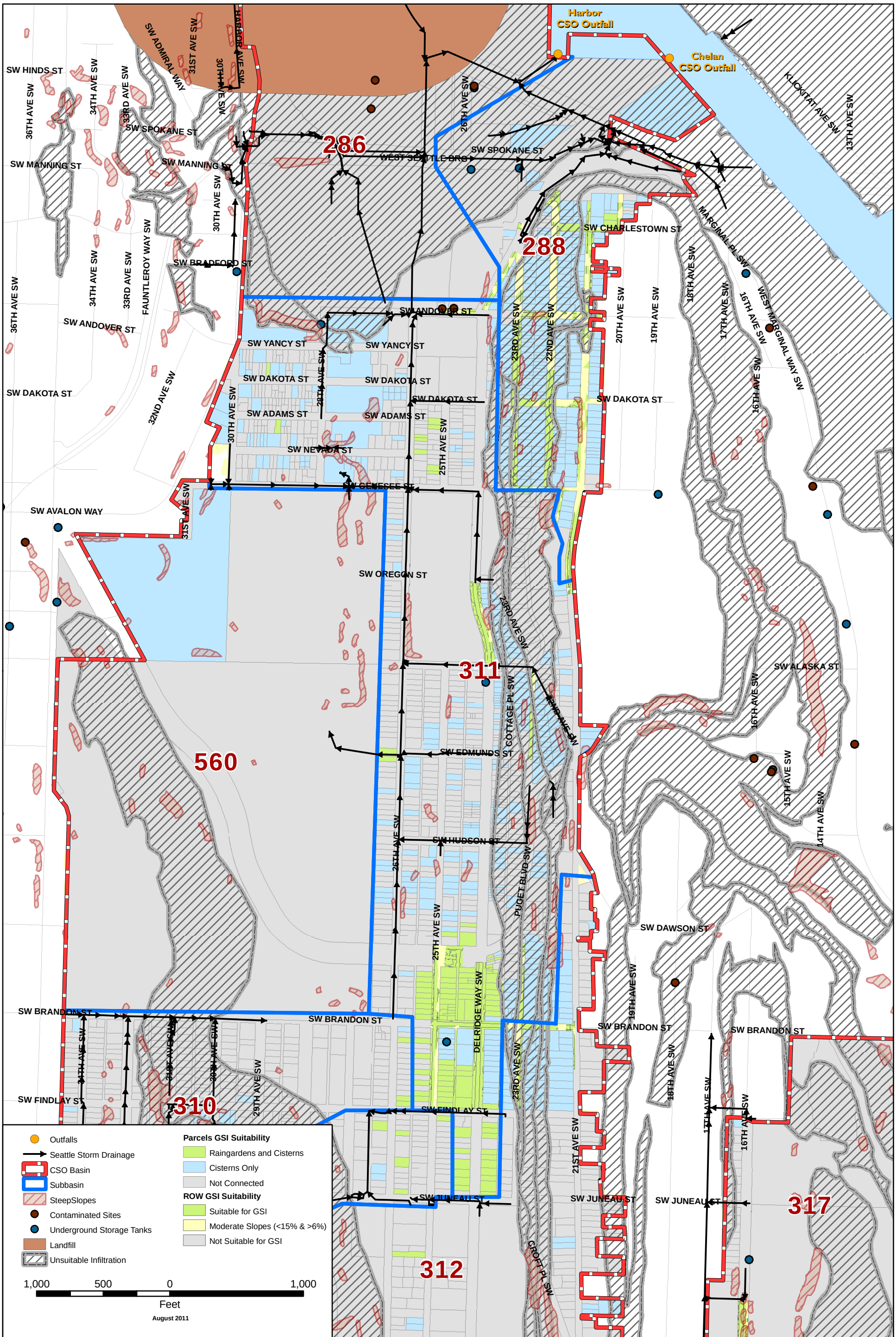


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**Figure 4-7**

**GSI Suitability for Chelan Avenue CSO Basin**

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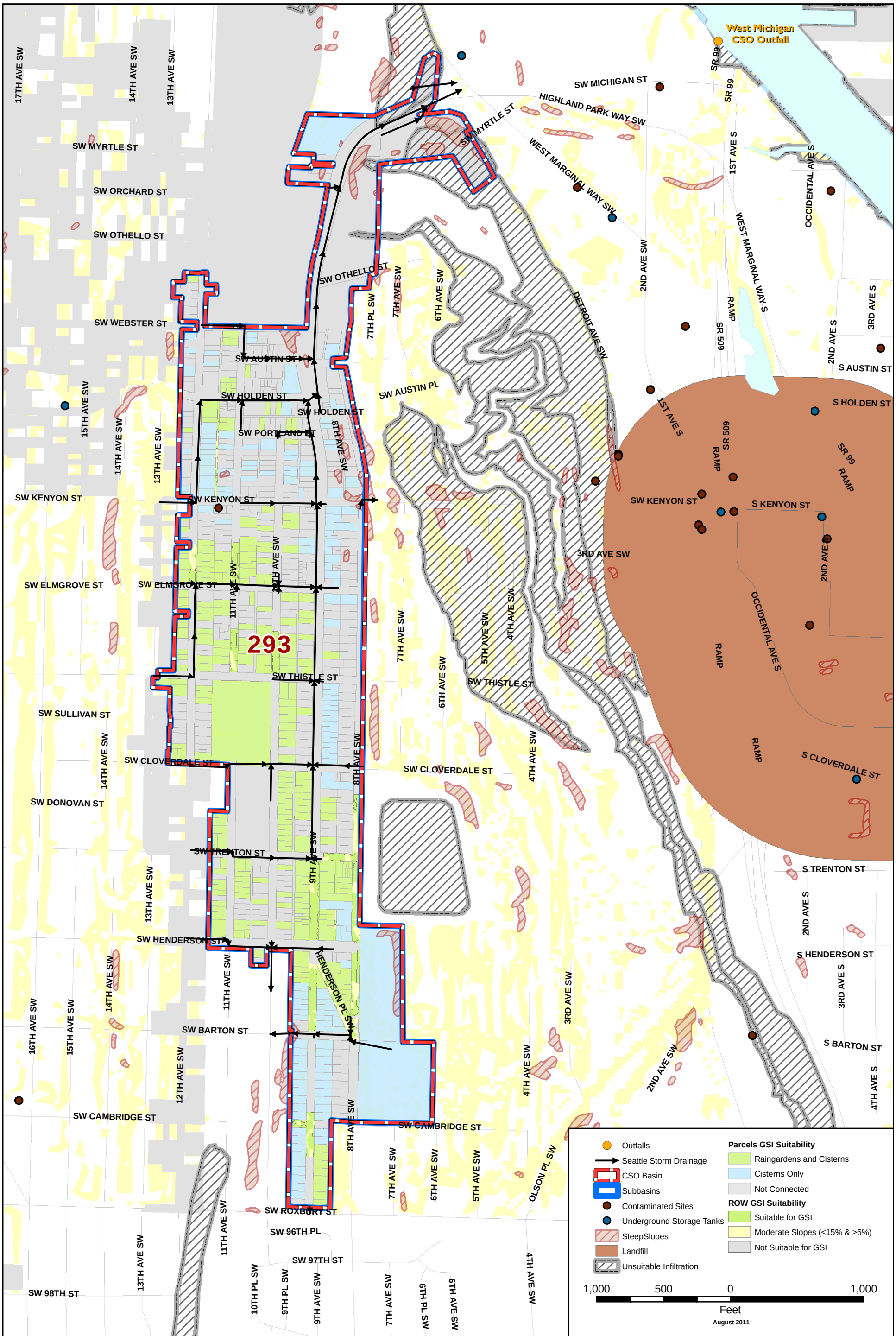


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Shaun O'Neil 20110810

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**Figure 4-8**

**GSI Suitability for West Michigan Street CSO Basin**

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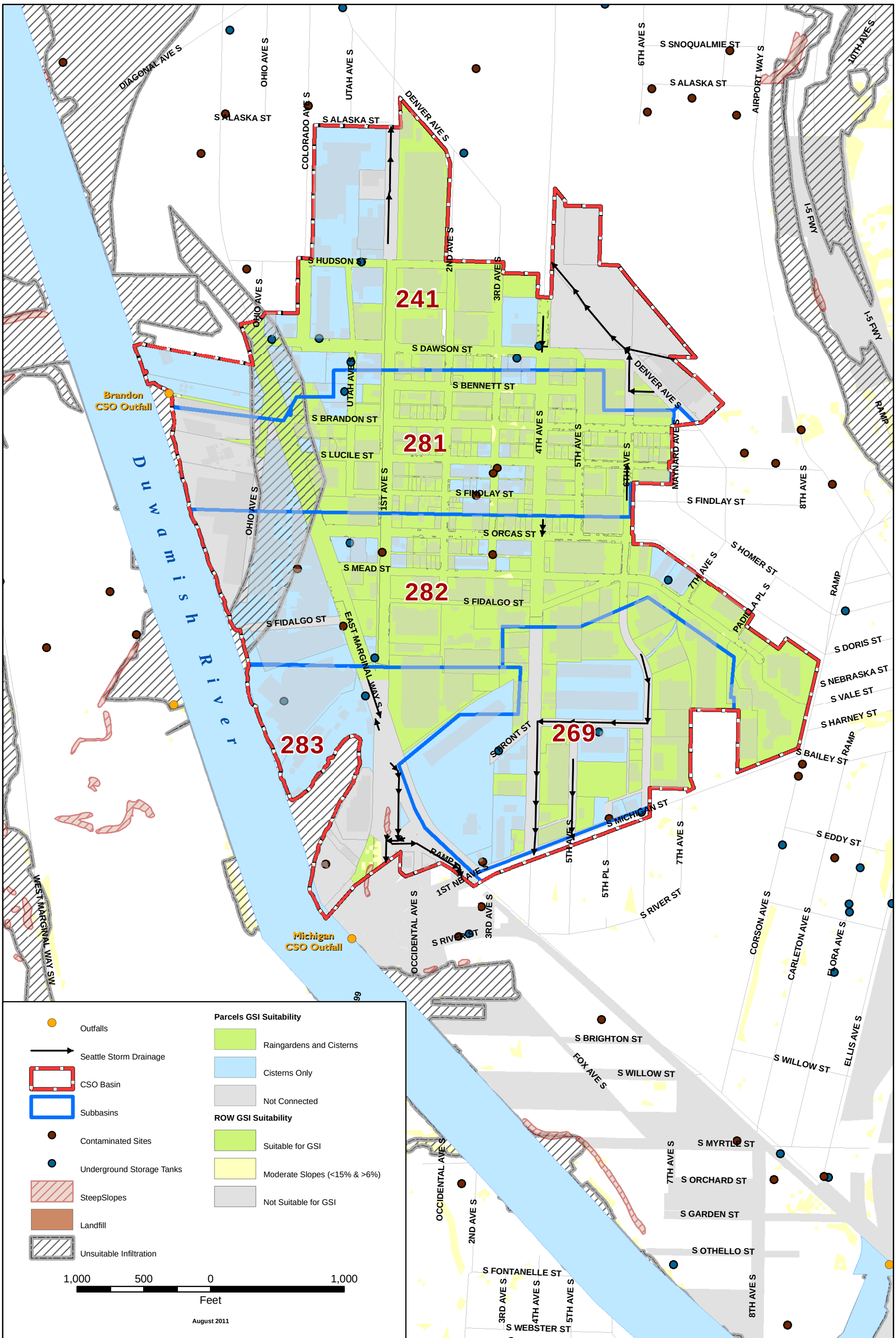


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Shaun O'Neil 20110818

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**Figure 4-9**

**GSI Suitability for Brandon Street CSO Basin**

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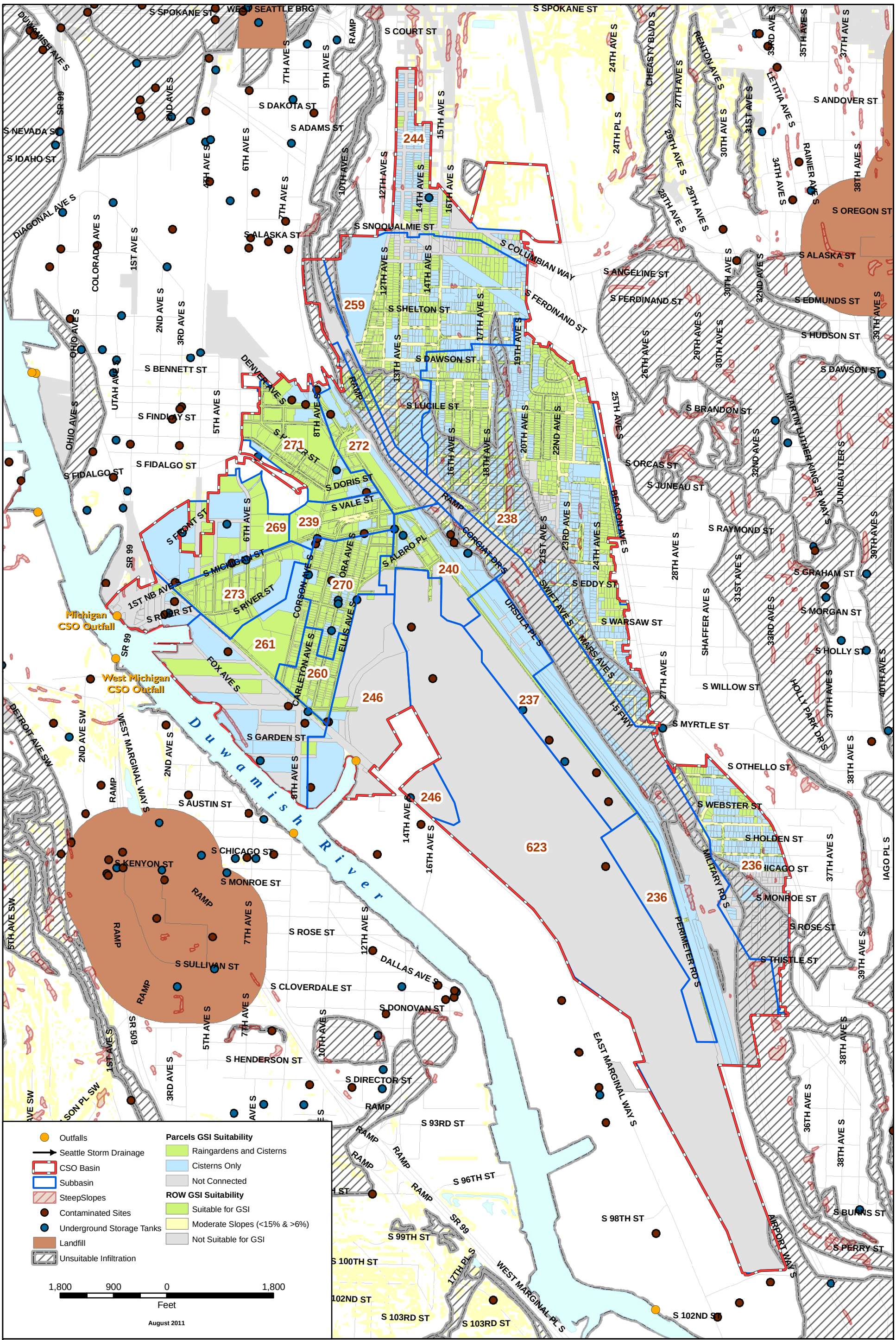


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Shaun O'Neil 20110825

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**Figure 4-10**

**GSI Suitability for South Michigan Street CSO Basin**

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# 5.0. GSI FEASIBILITY ASSESSMENT

## 5.1 Windshield Surveys

Windshield surveys were completed for each basin to further evaluate the feasibility of GSI techniques for CSO mitigation. These surveys focused on basin characteristics and technical constraints to GSI implementation that were not captured in the GIS evaluation such as existing site improvements and infrastructure, available space in the right-of-way, and positive drainage for parcel-scale facility overflows to a safe discharge point.

Surveys were conducted as a series of three field assessments:

- July 9, 2010 – 11th Avenue NW and 3rd Avenue W CSO basins
- August 6, 2010 – Brandon Street, South Michigan Street and Hanford CSO basins
- October 15, 2010 – University, Montlake, West Michigan Street, and Chelan Avenue CSO basins

Windshield survey methods and criteria were based on the SPU GSI feasibility protocol (Seattle 2010), with simplifications to match the resolution of the County's planning level effort. Rather than parcel- or block-level evaluations, windshield surveys consisted of a general assessment for GSI suitability over broader areas with a focus on pre-screened regions identified as feasible based on GIS analysis. Pre-screened areas included subbasins in which a significant portion of the right-of-way and parcel areas are connected to the CSS and meet the suitability criteria outlined in Section 4 of this memorandum (Desktop GSI Suitability Assessment). Figure 5-1 identifies these targeted subbasins.

### 5.1.1 Feasibility Criteria

High-level windshield surveys were conducted for selected pre-screened areas with a focus on the feasibility considerations listed below by GSI practice. Evaluation was based on visual observations; limited physical measurements were made.

#### Green Alley Feasibility Considerations

- Existing alley condition and material
- Alley right-of-way width
- Land uses (e.g., heavy truck traffic, parking)
- Likely run-on from adjacent impervious surfaces (driveways, rooftops, etc.)

#### Roadside Rain Garden Feasibility Considerations

- Adequate space in right-of-way for roadside rain gardens, including planting strip, excess parking width or wide driving lanes or sidewalks
- Percent planting strip occupied by established trees or high-value ornamental vegetation

- Existing downgradient rockeries, retaining walls, or reverse-sloped drives on adjacent parcels

#### Parcel Rain Garden Feasibility Considerations

- Adequate low-slope space for rain garden
- Minimal rockery or retaining walls down-gradient of potential facility location
- Positive drainage away from existing structure
- Sufficient grade and unobstructed area available for conveyance to rain garden from downspout and from the overflow point of the rain garden to a safe discharge point

#### Green Roof Feasibility Considerations

- Large, low-slope roof

#### Cistern Feasibility Considerations

- Adequate area available
- Degree of required gutter reconfigurations

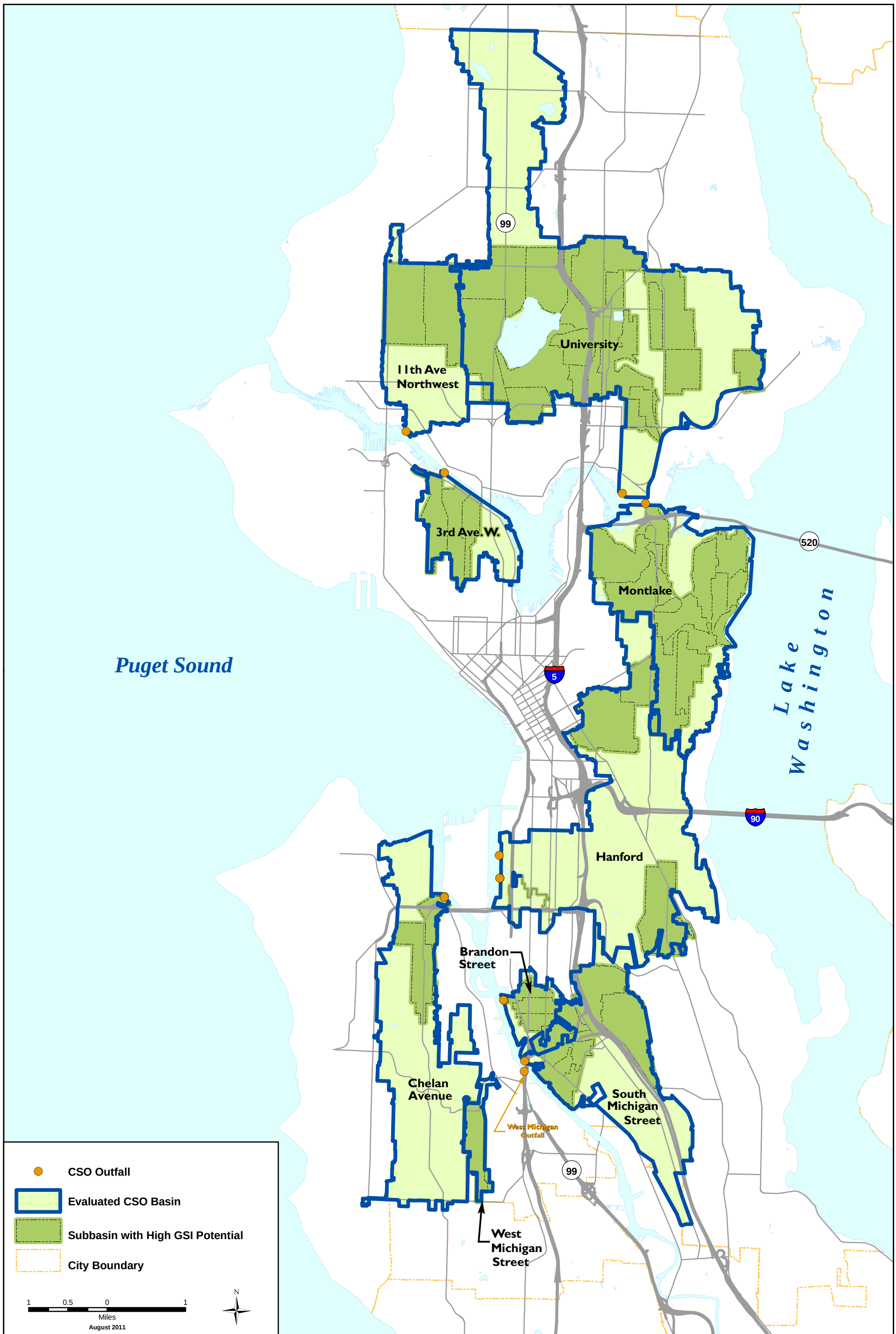
A series of photos taken while conducting the windshield surveys are provided in Figures 5-2 through 5-5. Each photo has been selected to illustrate some of the criteria considered while in the field. The GSI feasibility classifications in the photo captions (high, moderate, low) are based on the field assessment criteria. It is important to note that most of the areas visited in the field and shown here were already designated as suitable areas for GSI (based on the GIS analysis).

### 5.1.2 Windshield Survey Results

A summary of results are provided below by basin. A photo log is provided in Appendix C. The "key opportunities" listed below by basin were identified based on a limited survey effort; additional opportunities will likely be identified during future project phases.

#### 11th Avenue NW

The connected portion of the 11th Avenue NW CSO basin is comprised of flat to moderately sloping right-of-ways and parcels with several localized steep slopes (and their respective buffers). Based on Phase 2 of the GIS analysis, the basin has adequate infiltration capacity and minimal contaminated sites. The area is predominately residential with some commercial development on the arterial roads (NW 65th Street, 8th Avenue NW, etc.).

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Shaun O'Neil 20110919

**Figure 5-1**

**King County CSO Basins Targeted for Windshield Survey Assessment**

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The right-of-way shown on the left has a moderate to high potential for roadside rain gardens. Feasibility designation is based on the existing condition of the right-of-way (sufficiently wide with unimproved drainage) and existing topography (low site slopes).

This right-of-way shown on the right has minimal potential for roadside rain gardens as a retrofit to the existing planter strip due to the relatively high density of existing, well established trees in an improved section of right-of-way (existing curb and gutter). However, there is some potential for curb bulb rain garden retrofits due to the existing driving lane width.

**Figure 5-2. Residential Right-of-way Example GSI Feasibility Considerations**

The section of industrial right-of-way shown on the left has a moderate to high potential for roadside rain gardens to convert and mitigate the existing heavily impervious right-of-way. This designation is based on the sufficiently sized right-of-way width and the assumed typical roadway use (light to moderate daily traffic loads).

The section of industrial right-of-way shown on the right is likely a low opportunity area for right-of-way GSI due to likely heavy industrial uses including the potential for pollutant spills.

**Figure 5-3. Industrial Right-of-way Example GSI Feasibility Considerations**

The two alleyways pictured here represent areas of high (left) and low (right) potential for green alley retrofits (permeable pavement or subsurface infiltration). The site on the left is a moderately sloped, unimproved alley, making it a prime candidate for GSI. The site on the right, while also unimproved, is located up gradient of most of the adjacent structures, making this alley less feasible for retrofits.

**Figure 5-4. Green Alley Example GSI Feasibility Considerations**

The residential lot pictured to the left was classified as a low opportunity area for GSI due to the presence of a reverse-sloped driveway, retaining wall, and minimal available land to accommodate a facility.

**Figure 5-5. Residential Parcel Example GSI Feasibility Considerations**

The majority of the basin has a standard curb and gutter drainage system, parallel street parking, vegetated planter strips, and pedestrian paths present in the right-of-way. Many of the planter strips and/or driving lanes are sufficiently wide to accommodate roadside rain garden retrofits. Many of the residential lots are also adequately sized to accommodate stormwater retrofits including rain gardens, cisterns, or permeable pavements. These lots are characterized by minimally sloped lawns and positive drainage to the right-of-way. Key opportunities include:

- Right-of-way GSI within the 3rd Avenue NW corridor from NW 65th to 85th Street. This includes adequate planting strips for roadside rain garden retrofits along much of 3rd Avenue NW and several intersecting residential streets (including NW 83rd Street)
- A potential green alley project in the residential corridor bound by 3rd and 8th Avenue NW on the East and West and NW 80th and NW 85th Street on the South and North, respectively
- Roadside rain gardens on 6th Avenue NW from NW 80th Street to NW 85th Street
- High potential for residential retrofits (rain gardens, cisterns, permeable pavement) basin-wide, north of NW 65th Street

### University

The University CSO basin is the largest basin (in terms of total area connected to the CSS) under consideration for GSI retrofits in this study. Several areas within the basin have already been identified by the City of Seattle as potential for GSI projects.

Portions of the basin are affected by steep slopes and their setbacks, however, many of the steep slopes represented on the GIS maps were identified in the field as localized steep topography that may not warrant a steep slope setback for infiltration practices. Based on the GIS analysis, several areas of the basin have been deemed unsuitable for infiltration due to site soils,

contaminated sites, or the presence of underground storage tanks. The unsuitable infiltration areas (based on data provided by the City of Seattle in November 2009) are restricted primarily to the area immediately surrounding Green Lake and the Green Lake and Maple Leaf Reservoirs. The area is predominately residential with some commercial development on the arterial roads (namely Roosevelt Way NE and Aurora Avenue N). There are also a number of schools in the basin that could provide educational and other community outreach opportunities. The majority of the basin rights-of-way are characterized by a standard curb and gutter drainage system, parallel street parking, vegetated planter strips, and pedestrian pathways. Narrow roadways and existing planting strips, moderate longitudinal slopes, and reverse sloped drives or adjacent parcels below road grade will likely hinder a broad application of right-of-way GSI basin-wide. Key opportunities include:

- The potential for commercial GSI (permeable parking areas, rain garden retrofits, etc.) within the basin including PCC Natural Markets on Winona Avenue N at Stone Avenue N, and Safeway at 8th Avenue NE and NE 75th Street
- High potential for public and private parcel GSI through collaboration with local schools (e.g., Daniel Bagley Elementary School, Eckstein Middle School, Thornton Creek School)
- Possible collaboration with City of Seattle to expand their potential RainWise initiative in the east portion of the basin
- Some potential for roadside rain garden retrofits along NE 80th Street between Ashworth Avenue N and 1st Avenue NE and along Fremont Avenue N from North 73rd to North 80th Street
- Green Alley potential between 70th and 80th streets to the south and north and Dayton and Linden avenues to the west and east
- Some potential for commercial GSI in the South East portion of the basin in the area bound by NE Blakeley Street to the west, north, and east, and NE 45th Street to the south. Portions of this area are, however, designated as unsuitable for infiltration and in close proximity to a landfill.

### 3rd Avenue W

The connected portion of the 3rd Avenue W CSO basin is comprised of moderate to steep sloping rights-of-way and moderate to steeply sloped parcels (and their respective buffers). A significant portion of the basin has been deemed unsuitable for infiltration based on the GIS analysis. The basin has a minimal number of contaminated sites. The area is predominately residential with some commercial development on the arterial roads (namely Queen Anne Avenue N). There may be some opportunities in the northwest portion of the basin on the campus of Seattle Pacific University. However, this area is also characterized by steeper slopes and areas unsuitable for infiltration.

The majority of the basin has a standard curb and gutter drainage system, parallel street parking, vegetated planter strips, and pedestrian paths present in the right-of-way. However, many of the planter strips are narrow or landscaped with large established trees. Driving lanes on many of the residential streets tend to be narrower, making retrofits within the right-of-way infeasible. While many of the streets within the basin are not ideal for roadside rain garden retrofits, there are

opportunities scattered throughout the basin. As a result, sites should be evaluated on a case-by-case basis rather than an assumed blanket applicability. A significant portion of the residential lots were deemed unsuitable for infiltrating GSI facilities due to siting constraints (e.g., available space, positive drainage to the right-of-way) and steep slope setbacks. Key opportunities include:

- Right-of-way GSI including roadside rain gardens on 1st Avenue W between W Crockett Street and W McGraw Street and on W Crockett Street from 2nd Avenue W to Queen Anne Avenue N
- Some potential for roadside rain garden retrofits on north-south streets, west of 1st Avenue W (2nd, 3rd, 4th, and 5th Avenue W) and south of W Raye Street

### Montlake

The majority of the basin is affected by steep slopes and their setbacks. Based on the GIS analysis, several areas of the basin have been deemed unsuitable for infiltration due to site soils, contaminated sites, or the presence of underground storage tanks. The largest parcels in this basin are primarily designated green spaces including Volunteer Park, Interlaken Park, Washington Park Arboretum, and the Broadmoor Golf Club. The remainder of the basin is predominantly residential with some minor commercial development located on the arterial roads (e.g., E Union Street, E Cherry Street, and 34th Avenue). The majority of the basin right-of-way is characterized by a standard curb and gutter drainage system, parallel street parking, vegetated planter strips, and pedestrian pathways. Narrow roadways and existing planting strips coupled with moderate to steep longitudinal slopes could make right-of-way retrofits more difficult. Key opportunities include:

- Potential for GSI (permeable parking areas, rain garden retrofits, etc.) at St. Joseph's Parish and School
- Possible collaboration with City of Seattle to expand their potential RainWise initiative in the northeast portion of the basin
- Some potential for roadside rain garden retrofits along 26th Avenue between E Pine Street and E Marion Street and along E Columbia Street from 25th to 27th Avenue. This area in the southwest portion of the basin may be of particular interest due to the additional potential for green alley retrofits in the area.
- Full disconnection of the existing MS4 (by the City of Seattle or the County) that currently discharges back to the CSS (see GSI feasibility map). This applies to roughly half of the existing MS4 in the basin. There may also be some opportunity to disconnect some of the adjacent private parcels from the CSS.

### Hanford

The Hanford CSO basin is moderately sloped, with the north-south streets generally characterized as flat while the east-west streets are generally characterized as steeper (minimal potential for roadside rain gardens). The basin west of Interstate 5 is comprised of relatively flat industrial areas. The majority of the north end of the basin has a standard curb and gutter drainage system, parallel street parking, vegetated planter strips, and pedestrian paths present in the right-of-way.

Streets such as 19th and 23rd Ave between E Union and E Olive St are already narrow with minimal planter width, making GSI retrofits in this area challenging and most likely infeasible. Additionally, based on field investigation, there is minimal opportunity on 12th and 13th Ave and E Jefferson Street. Key opportunities include:

- Moderate to high potential for roadside rain gardens on 20th, 21st, and 22nd Ave between E Marion and Olive St. 21st Ave has existing wide planter strips along both sides of the street, suitable for retrofit rain gardens. 22nd Ave also provides some opportunity but approximately 20 percent of the roadway is lined with mature trees.
- A new P-Patch at the corner of 22nd Ave and E Union St that may provide potential for additional GSI or, at a minimum, educational signage for 22nd Ave improvements.
- Yesler Terrace – Seattle Housing Authority (SHA) project. Potential for disconnection of up to 20 acres. SHA is planning on disconnecting a large portion of the 20 acre site, but the County will consider collaborating in an effort to disconnect the entire site.
- Seattle University – The County is considering a collaborative project with the University to implement GSI on campus.
- A sizeable area of I-90 appears to contribute to the CSS in this basin and is a candidate for separation and/or a GSI solution.

### Chelan Avenue

Though the Chelan Avenue basin is relatively large, this study targets two smaller subbasins (County basins 288 and 311) for GSI retrofits. These basins are predominately residential with standard curb and gutter drainage, parallel street parking, vegetated planter strips, and pedestrian pathways in the rights-of-way. However, based on the GIS analysis, nearly all of basin 288 and approximately a quarter of basin 311 were deemed unsuitable for infiltration. In addition, most of the remaining rights-of-way and parcels in basin 311 are serviced by an existing MS4. Key opportunities include:

- SPU is considering GSI in the highly connected areas of the Delridge Neighborhood.

### West Michigan Street

The West Michigan Street CSO basin is the smallest basin (in terms of total area connected to the CSS) under consideration for GSI retrofits in this study. The area is predominately residential with standard curb and gutter drainage, parallel street parking, vegetated planter strips, and pedestrian pathways in the right-of-way. However, the majority of the basin (right-of-way and parcel) already flows to an existing MS4. Key opportunities include:

- Potential for roadside rain garden retrofits on 9th Avenue SW from SW Barton to SW Trenton Street.
- High potential for collaboration with Highland Park Elementary School and neighboring park north of SW Cloverdale Street. Based on GIS analysis, the school is not connected to the CSS, but the overall connectivity of the parcel should be confirmed. Potential retrofits include rain gardens and/or permeable pavement to mitigate parking, roof and other onsite impervious surfaces (e.g., tennis court).

### Brandon Street

The Brandon Street CSO basin is characterized by flat parcels and right-of-way with several intermittent contaminated sites. The majority of the basin has adequate infiltration capacity and minimal MS4 connectivity. It is a predominantly industrial area with moderate to heavy truck traffic.

Land cover in the basin is predominantly impervious including large industrial buildings, paved roadways, and paved and gravel parking areas. A large portion of the roads are in fair to poor condition, providing an excellent opportunity for GSI retrofits in collaboration with roadway improvement projects. Large gravel areas adjacent to roadways constitute a significant portion of parking in the basin. This non-structured strategy could be streamlined to allow for GSI integration without compromising parking volume. Key opportunities include:

- Pervious parking or other retrofit GSI for commercial areas (S Michigan St, west of Corson Ave S)
- Potential for roadside rain garden retrofits to the existing planting strips on west side of 6th Ave S from S Michigan St to S Mead St. These facilities could potentially mitigate runoff from adjacent parking areas. Connectivity of parcels should be confirmed since roadway is connected to the MS4.
- Seattle Design Center (S Orcas St and 6th Ave S)
- Potential pilot projects for Eco-Industrial work
- Right-of-way GSI is possible on majority of main roads in basin (includes S Orcas St, 4th and 5th Ave between S Orcas St and S Dawson St, 3rd Ave S between S Orcas St and S Hudson St as well as other areas. Roads such as 1st Ave S may be difficult to retrofit within the right-of-way due to narrow existing planting strips and existing multi-lane, multi-directional roadway.
- Streets in poor condition (such as Utah Ave S) that would benefit from GSI integration into the necessary roadway improvement projects
- Residential RainWise in Georgetown neighborhood including cistern considerations if soils are deemed unsuitable for infiltration due to known or suspected contamination

### South Michigan Street

The South Michigan Street CSO basin is characterized by flat parcels and rights-of-way with a moderate number of contaminated sites and areas deemed unsuitable for infiltration. King County International Airport (Boeing Field) dominates a large portion of the site and has its own MS4. The remaining area is predominantly residential with some commercial/industrial use in the northwest corner of the basin.

The residential areas in the basin are typically smaller roads with street parking on both sides and traffic calming devices, such as traffic circles at intersecting roadways, already in place. These neighborhoods appear to be interested in further traffic calming device implementation based on current signage observed in the field and existing plans for the narrowing of Ellis Ave S to reduce traffic volume and speed. Key opportunities include:

- The P-Patch and surrounding area at Oxbow Park between Carleton Ave S and Corson Ave S, and Orcas St., North of S Warsaw St. This site could serve as a high visibility

demonstration park for GSI (coupled with roadway integration of GSI on Carleton Ave S)

- High potential for roadside rain gardens and other GSI along Carleton Ave S due to wide rights-of-way and minimal observed roadway congestion
- Flora Ave S which provides some of the same opportunities for roadside GSI as Carleton Ave S including moderately sized existing planting strips (potential for retrofit of existing planting strips as well as mid-block curb bulbs)
- Incorporation of GSI at the South Seattle Community College campus
- Incorporation of GSI into existing plan for Ellis Ave S road narrowing
- Some potential for roadside rain gardens on the west side of Airport Way, south of S Hardy St.
- Residential RainWise in Georgetown neighborhood (cisterns and/or rain gardens)
- Collaboration with the arts community in Georgetown to develop innovative cistern designs
- Industrial green roofs, pervious parking areas, and parcel-based rain gardens

## 5.2 Technical and Social Feasibility Constraints

The GIS analysis documented in Section 4 provides an estimate of the basin areas that are potentially suitable for GSI retrofits based on a range of physical site characteristics including connectivity to the CSS, slopes, etc. This section addresses additional constraints that further limit implementation of GSI practices including 1) technical site constraints and 2) social feasibility constraints (i.e., participation and social acceptance). These constraints are quantified as "Technical Factors" and "Participation Factors" and are used to estimate the total area that can be feasibly managed using GSI as shown in Figure 5-6.

### 5.2.1 Technical Factors

To quantify the feasibility constraints observed in the windshield surveys, technical feasibility factors were developed based on field observations and professional judgment. These factors represent the estimated percent of the suitable area (estimated using GIS analysis) that is likely feasible for a GSI retrofit. "High" and "low" factors were developed for each basin by land use and GSI technique (i.e. infiltration facilities, cisterns, and green roofs). The range of technical factors applied are provided for right-of-way areas and private property in Table 5-1.

**Table 5-1. Technical Factors**

| Land Use | Technical Factors | | |
|---|---|---|---|
| | Infiltration Facilities | Cisterns | Green Roofs |
| Street & Alley Right-of-way | 20-80% | NA | NA |
| Public Parcel | 40-70% | 40-70% | 20-60% |
| Residential Parcel | 10-50% | 20-50% | NA |
| Commercial/ Industrial Parcel | 10-70% | 10-70% | 10-50% |

NA – Not Applicable

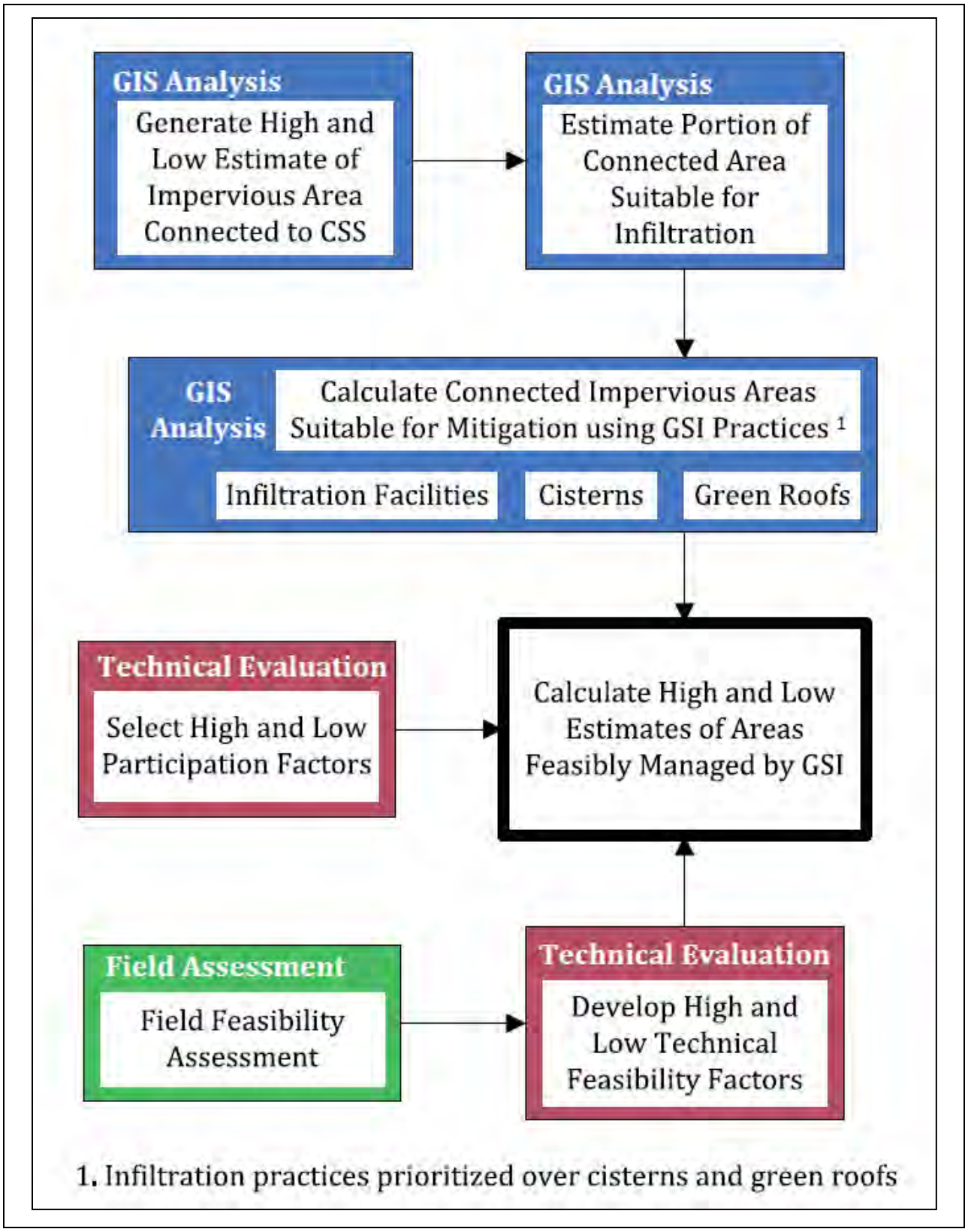


**Figure 5-6. Process Used to Develop Estimates of Basin Areas Where GSI Is Feasible**

### 5.2.2 Participation Factors

The feasibility of GSI projects is further constrained by public acceptance and the willingness of private property owners to participate in retrofit efforts. To account for this, participation factors were developed to estimate the percent of street and alley right-of-way projects that will be accepted by project neighbors and stakeholders, and the percent of private properties likely to participate in the RainWise program. SPU has developed high and low estimates of participation based on experience with GSI retrofit projects in Seattle. These factors are provided for right-of-way areas and private property in Table 5-2. Note that 100 percent participation is assumed for public parcels. These factors were used for all basins evaluated.

**Table 5-2. Participation Factors**

| Land Use | Participation Factors | |
|---|---|---|
| | High | Low |
| Street & Alley Right-of-way | 70% | 40% |
| Public Parcel | 100% | 100% |
| Residential Parcel | 35% | 10% |
| Commercial/Industrial Parcel | 20% | 5% |

Source: Unpublished data from SPU

### 5.2.3 Feasible Area Estimation

For each basin, the potential impervious area mitigated by GSI practice was calculated as:

*Suitable Area x Technical Factor x Participation Factor* where:

*Suitable Area*: Impervious portion of basin that is connected to the CSS and where GSI practices are potentially suitable (based in GIS evaluation)

*Technical Factor:* Percent of suitable area that is likely feasible for GSI retrofit (based on windshield surveys)

*Participation Factor:* Percent of suitable area that is likely socially feasible for GSI retrofit

## 5.3 Results

A summary of the GSI feasibility assessment results are presented by basin in Table 5-3. This table includes basin-wide estimates of the "suitable" area for GSI, the area-weighted technical and participation factors, and the total feasible area for GSI by practice (i.e., infiltration facilities, cisterns and green roofs). These results are broken down by land use in Appendix D.

**Table 5-3. Feasible impervious area managed by basin and GSI practice**

| CSO Basin | Total Area (ac) | Feasible Impervious Area Managed by GSI Practice [1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Infiltration Facilities | | Cisterns | | Green Roofs[5] | | Total[6] | |
| | | | | High | Low | High | Low | High | Low | High | Low |
| 11th Avenue NW | 1,366 | Total Suitable Area [2] | (ac) | 520 | 407 | 94 | 85 | 29 | 25 | 615 | 492 |
| | | Feasibility Factors [3] | (%) | 31% | 5% | 21% | 7% | 19% | 7% | 30% | 6% |
| | | Total Feasible Area [4] | (ac) | 162 | 22 | 20 | 6 | 6 | 2 | 182 | 28 |
| University | 6,172 | Total Suitable Area [2] | (ac) | 1,889 | 1,334 | 878 | 863 | 168 | 168 | 2,767 | 2,197 |
| | | Feasibility Factors [3] | (%) | 27% | 7% | 22% | 7% | 21% | 6% | 25% | 7% |
| | | Total Feasible Area [4] | (ac) | 510 | 89 | 191 | 58 | 35 | 11 | 701 | 147 |
| 3rd Avenue W | 750 | Total Suitable Area [2] | (ac) | 163 | 69 | 98 | 64 | 27 | 20 | 262 | 133 |
| | | Feasibility Factors [3] | (%) | 32% | 7% | 25% | 15% | 20% | 7% | 29% | 11% |
| | | Total Feasible Area [4] | (ac) | 52 | 5 | 24 | 10 | 5 | 1 | 77 | 15 |
| Montlake | 2,212 | Total Suitable Area [2] | (ac) | 357 | 241 | 349 | 332 | 28 | 28 | 706 | 574 |
| | | Feasibility Factors [3] | (%) | 29% | 8% | 20% | 5% | 32% | 11% | 24% | 6% |
| | | Total Feasible Area [4] | (ac) | 102 | 20 | 69 | 16 | 9 | 3 | 171 | 36 |
| Hanford | 3,466 | Total Suitable Area [2] | (ac) | 342 | 196 | 689 | 619 | 212 | 182 | 1,030 | 815 |
| | | Feasibility Factors [3] | (%) | 32% | 8% | 29% | 12% | 19% | 5% | 30% | 11% |
| | | Total Feasible Area [4] | (ac) | 110 | 15 | 200 | 76 | 39 | 9 | 310 | 91 |
| Chelan Avenue | 2,590 | Total Suitable Area [2] | (ac) | 174 | 127 | 149 | 118 | 20 | 13 | 323 | 245 |
| | | Feasibility Factors [3] | (%) | 26% | 5% | 18% | 3% | 14% | 4% | 22% | 4% |
| | | Total Feasible Area [4] | (ac) | 45 | 7 | 27 | 4 | 3 | 1 | 72 | 10 |
| West Michigan Street | 203 | Total Suitable Area [2] | (ac) | 18 | 13 | 9 | 8 | 1 | 1 | 27 | 21 |
| | | Feasibility Factors [3] | (%) | 25% | 3% | 22% | 8% | 18% | 5% | 24% | 5% |
| | | Total Feasible Area [4] | (ac) | 5 | 0 | 2 | 1 | 0 | 0 | 7 | 1 |
| Brandon Street | 377 | Total Suitable Area [2] | (ac) | 176 | 138 | 70 | 56 | 93 | 79 | 246 | 194 |
| | | Feasibility Factors [3] | (%) | 30% | 5% | 21% | 7% | 11% | 2% | 27% | 6% |
| | | Total Feasible Area [4] | (ac) | 52 | 7 | 14 | 4 | 11 | 1 | 67 | 11 |

**Table 5-3. Feasible impervious area managed by basin and GSI practice (continued)**

| CSO Basin | Total Area (ac) | Feasible Impervious Area Managed by GSI Practice [1] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Infiltration Facilities | | Cisterns | | Green Roofs[5] | | Total[6] | |
| | | | | High | Low | High | Low | High | Low | High | Low |
| South Michigan Street | 1,884 | Total Suitable Area [2] | (ac) | 407 | 321 | 320 | 316 | 91 | 91 | 727 | 637 |
| | | Feasibility Factors [3] | (%) | 37% | 8% | 36% | 16% | 17% | 4% | 37% | 12% |
| | | Total Feasible Area [4] | (ac) | 151 | 25 | 116 | 52 | 16 | 4 | 268 | 77 |
| Total | 19,019 | Total Suitable Area [2] | (ac) | 4,045 | 2,848 | 2,657 | 2,460 | 669 | 607 | 6,702 | 5,308 |
| | | Feasibility Factors [3] | (%) | 29% | 7% | 25% | 9% | 18% | 5% | 28% | 8% |
| | | Total Feasible Area [4] | (ac) | 1,189 | 191 | 665 | 225 | 124 | 31 | 1,854 | 416 |

ac - acres

[1] Rounding of the values presented in this table may introduce discrepancies of up to one acre.

[2] "Total Suitable Area" was generated using GIS (see Section 4).

[3] "Feasibility Factors" are the technical and participation factors weighted by area (see Appendix D).

[4] "Total Feasible Area" is calculated as the "Total Suitable Area" multiplied by the "Feasibility Factors".

[5] The suitability of green roofs relative to the other facilities evaluated is not mutually exclusive (i.e., in areas suitable for green roofs, cisterns or infiltration facilities could be substituted).

[6] Total suitable and feasible area is sum of infiltration and cistern areas.

# 6.0. GSI BENEFITS

Regulatory requirements mandate that CSO sites average no more than one untreated discharge per year. This goal can be achieved by 1) managing the CSO control volume (overflow volume with 1-year recurrence frequency) using sewer separation, increased conveyance, or storage strategies, or 2) treating the CSO peak flow rate (overflow rate with 1-year recurrence frequency) prior to discharge to the receiving water. Basin-wide GSI retrofits can reduce the required size of traditional CSO control facilities by reducing the volume of stormwater contributing to overflows or reducing the flow rates that require treatment prior to discharge. In some cases GSI may eliminate the need for traditional control strategies altogether.

To quantify the potential control volume and peak flow rate reduction achieved using GSI techniques, more in-basin monitoring and modeling needs to be completed. Ultimately, computer models that account for basin hydrology, system hydraulics, and flow routing will be developed to estimate these reductions. In the interim, the effects of GSI on stormwater runoff volume during the 1-year recurrence interval storm were evaluated as described below.

For each basin, stormwater runoff volumes routed to the CSS during the 1-year storm were estimated for the existing (unmitigated) basin conditions and the potential "low" and "high" GSI mitigation scenarios. The Soil Conservation Service (SCS) Curve Number (CN) method was applied to the existing land use classifications (i.e., impervious and pervious surfaces) to estimate runoff volumes. Impervious areas were represented by a CN of 98 (the default Natural Resources Conservation Service [NRCS] classification for impervious surfaces) and pervious surfaces were represented by a CN of 80 (corresponding to pervious areas in good condition on NRCS type D soil or pervious areas in fair condition on NRCS type C soil). The analysis assumed a 1-year, 24-hour rainfall depth of 1.4 inches to be consistent with other WTD CSO modeling efforts.

The resulting 1-year storm runoff depth for impervious and pervious surfaces in Seattle is 1.18 and 0.24 inches, respectively. For the existing condition, these runoff depths were applied over the total connected basin area (see Table 6-1) to estimate the unmitigated 1-year storm runoff volume. These volumes are presented by basin in Table 6-2.

For the low and high GSI scenarios, the benefits of GSI were estimated by effectively "disconnecting" the impervious areas considered feasible[1] for mitigation. The impervious areas fully mitigated for the 1-year storm were calculated for each facility type based on the following assumptions (see Table 6-1):

- Impervious areas deemed feasible for mitigation via infiltration facilities (rain gardens and permeable pavement) are fully mitigated. It is assumed that infiltration facilities are sized to infiltrate the entire 1-year storm volume for the contributing impervious runoff and the facility footprint.
- Impervious areas deemed feasible for mitigation via green roofs are credited for fully mitigating the runoff from 23.3 percent of the roof area. This credit is based on modeling performed to develop Seattle GSI flow control credits (Seattle 2009 and Seattle 2011).

[1] Impervious areas deemed feasible for mitigation via GSI include areas estimated as suitable from the GIS analysis, screened to reflect estimates of participation and other technical factors (per the analysis described in Section 5 of this memorandum and summarized in Table 5-3).

- Impervious areas deemed feasible for mitigation via cisterns are not given any credit in this analysis since these facilities are not capable of reducing flow volumes. The benefits of detention and peak attenuation will be evaluated in future phases of the project.

The impervious areas considered fully mitigated based on the above criteria were assumed to contribute no runoff to the CSS during the 1-year storm. Therefore, these areas were subtracted from the connected impervious area (see Table 6-1) and the runoff volumes were recalculated. The estimated reduction in runoff volume for GSI scenarios is presented by basin in Table 6-2. Based on this analysis, basin-wide GSI retrofits could reduce runoff during the 1-year storm by as much as 15 percent, as shown for the Brandon Street basin.

While these results quantify the potential 1-year runoff volume reduction associated with GSI strategies, they cannot be directly translated to reductions in CSO control volume because this preliminary analysis neglects flow routing. An understanding of the flow routing regime in the basin is critical for determining the spatial origins of runoff contributing to CSOs, particularly in larger basins. While the entire connected basin area contributes some quantity of flow to the CSS, in some basins, only a portion of the connected area directly contributes to the CSO event (i.e., flows from some portions of the basin may not contribute to the hydrograph during the period a CSO is discharging). To address this issue, a hydrologic and hydraulic model with a flow routing component is required. Future phases of this project will include modeling efforts that account for basin hydrology, system hydraulics, and flow routing. Such modeling efforts can quantify the control volume and peak flow reduction benefits of basin-wide GSI retrofits. Modeling will also enable identification of basin areas contributing to CSOs that can be targeted for GSI, maximizing storage where it is most needed in the basin.

**Table 6-1. Unmitigated and Mitigated Basin Areas (in order of percent impervious area mitigated)**

| CSO Basin | Connected Basin Area [1] (acres) | | | | Connected Impervious Areas Mitigated by GSI [1] (acres) | | | | | | | GSI Benefits | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Infiltration Facility | | Cistern | | Green Roof | | Connected Impervious Area Mitigated for the 1-Year Storm | |
| | Connectivity Level[2] | Pervious | Impervious | Total | GSI Scenario | Feasible Area [3] | Area Fully Mitigated [4] | Feasible Area [3] | Area Fully Mitigated [5] | Feasible Area [3] | Area Fully Mitigated [6] | (acres) | (%) |
| 11th Avenue NW | High | 131 | 691 | 822 | High | 162 | 162 | 20 | 0 | 6 | 1 | **163** | **24%** |
| | Low | 130 | 632 | 762 | Low | 22 | 22 | 6 | 0 | 2 | 0 | **23** | **4%** |
| Brandon Street | High | 9 | 247 | 256 | High | 52 | 52 | 14 | 0 | 11 | 2 | **54** | **22%** |
| | Low | 6 | 212 | 218 | Low | 7 | 7 | 4 | 0 | 1 | 0 | **8** | **4%** |
| South Michigan Street | High | 223 | 761 | 983 | High | 151 | 151 | 116 | 0 | 16 | 4 | **155** | **20%** |
| | Low | 218 | 757 | 976 | Low | 25 | 25 | 52 | 0 | 4 | 1 | **26** | **3%** |
| University | High | 939 | 2,963 | 3,901 | High | 510 | 510 | 191 | 0 | 35 | 8 | **518** | **17%** |
| | Low | 984 | 2,876 | 3,860 | Low | 89 | 89 | 58 | 0 | 11 | 3 | **92** | **3%** |
| West Michigan Street | High | 19 | 28 | 47 | High | 5 | 5 | 2 | 0 | 0 | 0 | **5** | **16%** |
| | Low | 18 | 28 | 46 | Low | 0 | 0 | 1 | 0 | 0 | 0 | **0** | **2%** |
| Montlake | High | 426 | 883 | 1,309 | High | 102 | 102 | 69 | 0 | 9 | 2 | **104** | **12%** |
| | Low | 439 | 819 | 1,257 | Low | 20 | 20 | 16 | 0 | 3 | 1 | **21** | **3%** |
| Hanford | High | 395 | 1,116 | 1,511 | High | 110 | 110 | 200 | 0 | 39 | 9 | **119** | **11%** |
| | Low | 377 | 1,129 | 1,506 | Low | 15 | 15 | 76 | 0 | 9 | 2 | **17** | **2%** |
| 3rd Avenue W | High | 172 | 479 | 651 | High | 52 | 52 | 24 | 0 | 5 | 1 | **54** | **11%** |
| | Low | 171 | 477 | 648 | Low | 5 | 5 | 10 | 0 | 1 | 0 | **5** | **1%** |
| Chelan Avenue | High | 221 | 506 | 727 | High | 45 | 45 | 27 | 0 | 3 | 1 | **46** | **9%** |
| | Low | 197 | 478 | 675 | Low | 7 | 7 | 4 | 0 | 1 | 0 | **7** | **1%** |

[1] Rounding of the values presented in this table may introduce discrepancies of up to one acre.
[2] Neither connectivity scenario evaluated (Scenario A and B) consistently results in higher or lower values. For each basin, the scenario resulting in the highest level of connected area is associated with "high" connectivity level.
[3] Estimate of feasible area for GSI (see Table 5-3).
[4] Assumes infiltration facilities (i.e., bioretention or permeable pavement) are sized to infiltrate the entire 1-year storm volume.
[5] Detention cisterns attenuate peak flows, but do not provide reductions in volume. Flow control benefits are neglected in this evaluation.
[6] Green roofs are credited with mitigation of 23.3 percent of the green roof area per Seattle GSI flow control credits.

**Table 6-2. Unmitigated and Mitigated Runoff Volumes to CSS (in order of percent runoff volume reduction by basin)**

| CSO Basin | Unmitigated 1-year Storm Runoff Volume to CSS 1 (MG) | | | | Mitigated 1-year Storm Runoff Volume to CSS1,2 (MG) | | | | GSI Benefits: Runoff Volume Reduction for 1-Year Storm | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Connectivity Level | Pervious | Impervious | Total | GSI Scenario | Pervious | Impervious | Total | (MG) | (% ) |
| Brandon Street | High | 0 | 8 | 8 | High | 0 | 6 | 6 | **1.7** | **15%** |
| | Low | 0 | 7 | 7 | Low | 0 | 7 | 7 | **0.2** | **2%** |
| 11th Avenue NW | High | 1 | 22 | 23 | High | 1 | 17 | 18 | **5.2** | **14%** |
| | Low | 1 | 20 | 21 | Low | 1 | 20 | 20 | **0.7** | **2%** |
| University | High | 6 | 95 | 101 | High | 6 | 78 | 85 | **16.6** | **10%** |
| | Low | 6 | 92 | 99 | Low | 6 | 89 | 96 | **2.9** | **2%** |
| South Michigan Street | High | 1 | 24 | 26 | High | 1 | 19 | 21 | **5.0** | **10%** |
| | Low | 1 | 24 | 26 | Low | 1 | 23 | 25 | **0.8** | **2%** |
| 3rd Avenue W | High | 1 | 15 | 16 | High | 1 | 14 | 15 | **1.7** | **8%** |
| | Low | 1 | 15 | 16 | Low | 1 | 15 | 16 | **0.2** | **1%** |
| Montlake | High | 3 | 28 | 31 | High | 3 | 25 | 28 | **3.3** | **6%** |
| | Low | 3 | 26 | 29 | Low | 3 | 26 | 28 | **0.7** | **1%** |
| Hanford | High | 3 | 36 | 38 | High | 3 | 32 | 35 | **3.8** | **4%** |
| | Low | 2 | 36 | 39 | Low | 2 | 36 | 38 | **0.6** | **1%** |
| Chelan Avenue | High | 1 | 16 | 18 | High | 1 | 15 | 16 | **1.5** | **3%** |
| | Low | 1 | 15 | 17 | Low | 1 | 15 | 16 | **0.2** | **0%** |
| West Michigan Street | High | 0 | 1 | 1 | High | 0 | 1 | 1 | **0.1** | **3%** |
| | Low | 0 | 1 | 1 | Low | 0 | 1 | 1 | **0.0** | **0%** |

MG – million gallons

[1] Rounding of the values presented in this table may introduce discrepancies of up to 1 MG.

[2] Assumes zero runoff from the area fully mitigated.

# 7.0. GSI COSTS

This section describes the methodology and assumptions used to develop life-cycle cost estimates for GSI CSO control strategies. The costs are planning-level and based on generic GSI concepts and, as such, represent an order-of-magnitude estimate in the range of –50 to +100 percent. Specific details of each project such as GSI facility siting, design configuration, and sizing are determined later during project predesign.

Unless otherwise noted, methods are consistent with those used for other Program Review cost estimating efforts as summarized in Technical Memorandum 620—Cost Estimating Methodology for CSO Control Facilities.

Planning-level construction, allied and operations and maintenance (O&M) cost estimates are presented below by GSI practice.

## 7.1 Construction Costs

Construction costs were estimated for each GSI practice (Green Streets, residential RainWise, commercial/industrial RainWise and Green Schools). The estimated costs are summarized in Table 7-1 as cost per area of impervious surface mitigated. The methods and assumptions used to develop these costs are provided below.

**Table 7-1. Summary of Estimated GSI Construction Costs**

| | Capital Cost | |
|---|---|---|
| **GSI Strategy** | **Cost per square foot mitigated** | **Cost Type** |
| Roadside Bioretention | $3.5 | Construction |
| Residential RainWise | $1.5 – $4 | Rebate |
| Commercial/Industrial RainWise | $4 – $6 | Rebate |
| Green Schools | $4 – $6 | Rebate |

### 7.1.1 Roadside Bioretention (Green Streets)

SPU and WTD agreed to use similar values in estimating construction costs. To develop these costs, data was collected from multiple cities including Chicago, Portland, and Seattle. The roadside bioretention project costs ranged widely, from $36.00 - $88.00 per square foot of facility, due to varying degrees of project complexity and different design bases. These costs were compared to the bids received for the Ballard Roadside Rain Garden project and the cost estimate from the Barton CSO GSI Project. The costs for these two projects were $44, $54, and $67 per square foot of facility (with an average cost of $55 per square foot of facility). This value is similar to the costs from the jurisdictional review and was used as the basis for roadside bioretention costs in this evaluation.

To translate this facility construction cost to a cost per impervious area mitigated, facility size estimates were needed. For this planning-level effort, it was assumed that bioretention areas are sized as 6 percent of the impervious surface area requiring mitigation. For example, a 60 square

foot facility would be required to mitigate 1,000 square feet of impervious area (for full infiltration of the 1-year storm). Based on this 6 percent "sizing factor", the cost was estimated at $3.50 per square foot of impervious area mitigated.

### 7.1.2 Residential RainWise

The SPU residential RainWise program offers rebates to property owners for the cost of installing cisterns and/or rain gardens on private properties in CSO basins. WTD intends to collaborate with SPU to extend this program to County CSO Basins. The current rebates range from $1.50 to $4.00 per square foot of impervious surface mitigated based on the GSI strategy employed and whether the property is within a combined or partially separated basin. The amount of the rebate was developed based on an estimated cost to mitigate the same stormwater runoff in the right-of-way. Rebates have not yet been made permanent and may be adjusted in the future.

### 7.1.3 Commercial/Industrial RainWise

Similar to residential RainWise, this program would offer rebates to commercial and industrial property owners for the cost of installing cisterns, permeable pavement, green roofs and/or rain gardens on private property in CSO basins. The rebates would range from $4.00 to $6.00 per square foot mitigated and depend on the GSI strategy employed and whether the property is within a combined or partially separated basin. The amount of the rebate was developed based on an estimated cost to mitigate the same stormwater runoff in the right-of-way.

### 7.1.4 Green Schools

This program would encourage both private and public schools to build and maintain rain gardens on site. It would be similar to the commercial and industrial RainWise program, but would also contain a community outreach and education component for teachers, students, and parents. The rebates would range from $4.00 to $6.00 per square foot mitigated and depend on the GSI strategy employed and whether the property is within a combined or partially separated basin. The amount of the rebate was based on an estimated cost to mitigate the same volume and peak flow in the right-of-way.

## 7.2 Allied Costs

Allied costs for GSI alternatives were estimated using a cost model by PRISM, which is based on King County data for projects that have already been constructed. The cost model is organized by type of construction (treatment, conveyance, or pump station) and the construction cost. The model includes allied costs such as engineering services, planning, and permitting support. For this evaluation, the costs associated with a "conveyance" project were used because these projects are typically of low complexity, consist of linear project sites, and involve work in the right-of-way (like Green Street projects). These allied costs were also applied to RainWise and Green Schools as a conservative estimate of WTD support and other miscellaneous program costs.

## 7.3 Operations and Maintenance Costs

### 7.3.1 Roadside Bioretention

Operations and maintenance costs for roadside bioretention were developed using the Water Environment Research Foundation (WERF) best management practice (BMP) and LID Life Costs Model Version 2.0 (WERF 2009). The model allows the user to input the square footage of facility and estimate the number of hours needed to complete maintenance tasks. Table 7-2 outlines the maintenance task and hours needed per year for vegetated GSI facilities.

**Table 7-2. GSI Maintenance Costs for Vegetated Facilities**

| | Time Between Events | Hours per Event [1] | Crew Size |
|---|---|---|---|
| **Regular Activities** | | | |
| Inspection, Reporting & Information Management | 24 months | 2 | 1 |
| Vegetation Management with Trash & Minor Debris Removal | 6 months | 2 | 2 |
| **Corrective and Infrequent Activities [2]** | | | |
| Till Soil | 4 years | 2 | 2 |
| Unclog Drain | 2 years | 2 | 1 |
| Replace Mulch | 2 years | 2 | 2 |

[1] Based on 2,500 sq. ft. facility
[2] Unplanned and/or more than 3 years between events

To translate these labor hours into operations and maintenance (O&M) costs, labor rates were estimated using RS Means for landscape and general labor. The value for landscape maintenance, inspection and reporting is $65/hour and for general labor is $31/hour. A sensitivity analysis was performed using County labor rates (highest in range) for a Senior Gardener ($29 per hour) and a Wastewater Utility Worker ($22 per hour) along with an overhead rate of 60.7 percent for WTD according to King County Finance. The analysis showed that in-house labor was comparable to the RS Means values. An additional $50 per hour was added for equipment use (e.g., transportation and landscape equipment).

The resulting annual O&M costs as shown in Table 7-3 are in line with current maintenance costs from privately maintained projects in the Seattle area. Note that a simplified cost per square foot was not used because these costs vary depending on the overall size (total area) of the project.

### 7.3.2 RainWise and Green Schools

Under the RainWise and Green School programs, property owners are responsible for facility operations and maintenance. However, according to analysis by SPU, ongoing funding is required to implement the programs and replace a certain number of facilities each year. It is assumed that approximately 2 percent of the facilities will fail each year. This failure rate includes facilities ceasing to perform and property owners removing facilities. To compensate for this loss, an annual rebate cost is assumed to replace these failed facilities.

**Table 7-3. GSI Alternative Cost Estimates**

| CSO Basin | GSI Scenario | Runoff Volume Reduction for 1-Year Storm (MG) | Green Streets | RainWise and Green Schools | Total Capital | Annual O&M Costs[1] | Life-Cycle Costs (2010 Dollars) |
|---|---|---|---|---|---|---|---|
| 11th Avenue NW | High | 5.2 | $19,000,000 | $400,000 | $19,400,000 | $43,130 | $21,019,000 |
| | Low | 0.7 | $2,000,000 | $20,000 | $2,020,000 | $5,630 | $2,234,700 |
| University | High | 16.6 | $58,000,000 | $3,000,000 | $61,000,000 | $131,260 | $65,927,000 |
| | Low | 2.9 | $5,000,000 | $900,000 | $5,900,000 | $14,630 | $6,433,700 |
| 3rd Avenue W | High | 1.7 | $19,000,000 | $400,000 | $19,400,000 | $19,880 | $20,958,800 |
| | Low | 0.2 | $2,000,000 | $200,000 | $2,200,000 | $3,380 | $2,420,900 |
| Montlake | High | 3.3 | $10,000,000 | $600,000 | $10,600,000 | $25,510 | $11,556,700 |
| | Low | 0.7 | $1,000,000 | $200,000 | $1,200,000 | $3,760 | $1,337,400 |
| Hanford [2] | High | 3.8 | | | | | |
| | Low | 0.6 | | | | | |
| Chelan Avenue | High | 1.5 | $5,000,000 | $200,000 | $5,200,000 | $13,130 | $5,691,200 |
| | Low | 0.2 | $700,000 | $50,000 | $750,000 | $3,010 | $855,500 |
| West Michigan Street | High | 0.1 | $1,000,000 | $200,000 | $1,200,000 | $2,630 | $1,299,400 |
| | Low | 0.0 | $500,000 | $60,000 | $560,000 | $1,880 | $625,700 |
| Brandon Street | High | 1.7 | $6,000,000 | $400,000 | $6,400,000 | $15,010 | $7,224,300 |
| | Low | 0.2 | $900,000 | $30,000 | $930,000 | $3,380 | $2,374,300 |
| South Michigan Street | High | 5.0 | $18,000,000 | $800,000 | $18,800,000 | $41,630 | $20,362,000 |
| | Low | 0.8 | $3,000,000 | $200,000 | $3,200,000 | $6,380 | $3,439,200 |

1. O&M costs include the costs for replacing or adding new properties to RainWise.
2. Costs for the Hanford basin were not developed because the CSO project will not include GSI elements in the near-term.

## 7.4 Life-Cycle Costs

The King County Life-Cycle Cost Model was used to estimate life-cycle costs for the GSI project alternatives. Project life-cycle costs combine capital and O&M costs to allow reasonable comparisons between alternatives with high capital costs and those with high O&M costs. The life-cycle cost is the project cost plus the present worth value of ongoing O&M costs over the expected lifetime of the project. A present worth factor is used to convert annual O&M costs to a present value:

$$P = A \times [(1 + i)^n - 1] / [i (1 + i)^n]$$

where:

P = Present worth of O&M cost (2010 dollars)

A = Annual O&M cost (2010 dollars)

I = Discount Rate (annual percentage rate)

n = Period of Analysis (years)

The discount rate, expressed as an annual percentage, accounts for future price changes to convert O&M costs over the project lifespan to dollars in the same year used for capital cost estimating. Consistent with the Program Review, a discount rate of 2.2 percent was chosen, which is based on the recent WTD borrowing costs of 3 percent net annual inflation. The period of analysis is chosen to approximate the life of the capital facilities to be compared in the economic analysis. For the Program Review, a planning period of 50 years was chosen.

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# 8.0. GSI ALTERNATIVE SUMMARY

Table 8-1 provides a summary of the potential benefits and costs of GSI strategies for CSO control by basin. Specifically, the following are provided:

- The recommended grey CSO control alterative (e.g., traditional storage, conveyance or treatment) per the Program Review
- The GSI alternative components by basin (e.g., Green Streets, RainWise, Green Schools, and other key opportunities)
- The basin-wide opportunities for GSI relative to all CSO basins considered in this evaluation
- The estimated percent of basin impervious surface connected to the CSS that could be managed by GSI (so that it contributes no flow to the CSS during the 1-year storm)
- The estimated reduction in runoff to the CSS during the 1-year storm due to GSI retrofit
- The planning-level construction and life-cycle costs for GSI alternatives
- King County will seek to collaborate with SPU, other agencies and institutions where possible. Examples of opportunities for collaboration are listed below: GSI projects to augment SHA disconnection project at Yesler Terrace in Hanford/Lander basin (potential for disconnection of up to 20 acres).
- GSI projects at Seattle Center in Dexter CSO Basin (38 acre connected area)
- GSI implementation on Seattle University campus in Hanford basin
- Bioretention and redevelopment projects at Woodland Park Zoo in the University Basin to reduce flow from zoo property
- GSI retrofits in northwest Georgetown in the Michigan and Brandon basins in collaboration with Georgetown Community Council
- Eco-industrial projects in collaboration with Seattle Department of Planning and Development
- Green corridor projects in collaboration with Seattle Department of Transportation

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**Table 8-1. GSI Alternative Summary Table**

| CSO Basin | Program Review Recommended Preferred Alternative | Key GSI Alternative Components | Relative GSI Potential | Total Area (acres) | GSI Scenario | Total Connected Impervious Area (acres) | GSI Feasibility: Connected Impervious Area Managed (acres) | GSI Feasibility: Connected Impervious Area Managed (%) | GSI Benefits: Runoff Volume Reduction to CSS for 1-Year Storm (MG) | GSI Benefits: Runoff Volume Reduction to CSS for 1-Year Storm (%) | GSI Costs: Total Construction | GSI Costs: Life-Cycle Costs (2010 Dollars) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11th Avenue NW | Increase conveyance capacity from the 11th Ave NW Overflow Structure to the Ballard Regulator Station | Residential RainWise, Green Schools, Green Streets, and green alleys. | High | 1,366 | High | 691 | 182 | 26% | 5.2 | 23% | $19,400,000 | $21,019,000 |
| | | | | | Low | 632 | 28 | 4% | 0.7 | 3% | $2,020,000 | $2,234,700 |
| University | 5.23-MG storage tank near the University Regulator Station (collaboration with SPU) | Residential RainWise, Green Schools, Green Streets, and green alleys. | High | 6,172 | High | 2963 | 701 | 24% | 16.6 | 16% | $61,000,000 | $65,927,000 |
| | | | | | Low | 2876 | 147 | 5% | 2.9 | 3% | $5,900,000 | $6,433,700 |
| 3rd Avenue W | 7.23-MG storage tank on the north side of the Ship Canal (collaboration with SPU) | Residential RainWise, Green Schools, Green Streets, and green alleys. Demonstration projects on the Seattle Pacific University campus are also being considered. | Low | 750 | High | 479 | 77 | 16% | 1.7 | 10% | $19,400,000 | $20,958,800 |
| | | | | | Low | 477 | 15 | 3% | 0.2 | 1% | $2,200,000 | $2,420,900 |
| Montlake | 7.87-MG storage tank near the Montlake Regulator Station (Collaboration with SPU) | Residential RainWise, Green Schools, Green Streets, and green alleys. | High | 2,212 | High | 883 | 171 | 19% | 3.3 | 11% | $10,600,000 | $11,556,700 |
| | | | | | Low | 819 | 36 | 4% | 0.7 | 2% | $1,200,000 | $1,337,400 |
| Hanford | 0.34-MG storage tank near the Bayview North Overflow Structure and conveyance improvements to use available capacity in the Bayview Tunnel | Residential RainWise, Green Schools, Green Streets, and green alleys. | High | 3,465 | High | 1116 | 310 | 28% | 3.8 | 10% | --[1] | --[1] |
| | | | | | Low | 1129 | 91 | 8% | 0.6 | 1% | --[1] | --[1] |
| Chelan Avenue | 3.85-MG storage tank near the Chelan Ave Regulator Station and modifications to the Alki Trunk | Commercial and residential RainWise. | Low | 2,590 | High | 506 | 72 | 14% | 1.5 | 8% | $5,200,000 | $5,691,200 |
| | | | | | Low | 478 | 10 | 2% | 0.2 | 1% | $750,000 | $855,500 |
| West Michigan Street | 0.32-MG storage pipe near the Terminal 115 Overflow Structure | Commercial and residential RainWise. This includes upstream work in the 8th Ave CSO basin. | High | 203 | High | 28 | 7 | 24% | 0.1 | 14% | $1,200,000 | $1,299,400 |
| | | | | | Low | 28 | 1 | 4% | 0.0 | 1% | $560,000 | $625,700 |
| Brandon Street | 66-MGD wet-weather treatment facility near the S Michigan St Regulator Station and new conveyance from the Brandon St Regulator Station to the new wet-weather treatment facility (same as S Michigan St Alternative) | Commercial and residential RainWise, Green Streets, and green alleys. Depth to groundwater and contamination is an issue for infiltration techniques in some areas. | High | 377 | High | 247 | 67 | 27% | 1.7 | 22% | $6,400,000 | $7,224,300 |
| | | | | | Low | 212 | 11 | 5% | 0.2 | 4% | $930,000 | $2,374,300 |
| South Michigan Street | 66-MGD wet-weather treatment facility near the S Michigan St Regulator Station and new conveyance from the Brandon St Regulator Station to the new wet-weather treatment facility (same as Brandon Alternative) | Commercial and residential RainWise, Green Streets, and green alleys. Depth to groundwater and contamination is an issue for infiltration techniques in some areas. | High | 1,886 | High | 761 | 268 | 35% | 5.0 | 19% | $18,800,000 | $20,362,000 |
| | | | | | Low | 757 | 77 | 10% | 0.8 | 3% | $3,200,000 | $3,439,200 |

[1] Costs for the Hanford basin were not developed because the CSO project will not include GSI elements in the near-term.

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# 9.0. GSI IMPLEMENTATION

The King County CSO Control Program initiates CSO control projects through a two-phased process including a conceptual planning phase and a problem definition phase. These phases are described below as they pertain to this project.

## 9.1 Conceptual Planning Phase

Under the conceptual planning phase, planning-level alternatives are developed with broad definition at a high level uncertainty. This memorandum documents the planning phase for this project wherein conceptual alternatives were developed for candidate basins.

- Basin-wide GSI suitability assessment (Section 4)
- Targeted feasibility assessment and concept development (Section 5)
- Planning-level concepts, benefit, and costs (Sections 6, 7 and 8)
- Preliminary plan to engage stakeholders and community (Appendix E)

This gives project planners enough information to begin the problem definition phase.

## 9.2 Problem Definition Phase

Problem definition is a newer concept to project management. This phase consists of refining the planning-level concepts to better define the feasible GSI retrofit areas, characterize basin soils, develop preliminary facility layout and estimate the potential CSO control benefits and costs of GSI alternatives. The problem definition phase for this project will include the following steps, which are consistent with the SPU approach to GSI projects.

### 9.2.1 Step 1: Field Feasibility and Site Assessment

Under this step the areas identified for implementing GSI are refined based on geotechnical investigations and thorough site assessments.

Geotechnical investigations are a key to evaluating the feasibility and potential performance of GSI infiltration strategies. Based on a review of the feasibility assessments performed during the conceptual planning phase, the basin characteristics effecting infiltration feasibility (e.g., steep slope buffer zones, surface geology, groundwater elevations) will be refined and targeted geotechnical testing will be performed, including pilot infiltration tests, soil borings and groundwater monitoring. This step will be conducted concurrent with early outreach efforts to the community described below.

Detailed feasibility assessments for projects in the right-of-way will be performed according to SPU GSI feasibility protocol (Seattle 2010). These assessments will be conducted on a parcel- or block-level to develop sufficiently detailed information to confirm feasibility and inform design.

### 9.2.2 Step 2: Identify Community Stakeholders and Develop Public Involvement Plan

GSI projects require the early and sustained engagement of stakeholders. For each neighborhood identified for GSI Green Street retrofits, stakeholders will be identified and a public involvement plan will be developed. These efforts will be coordinated with the education and outreach elements of the RainWise and Green School programs. A preliminary public involvement approach is included as Appendix E.

### 9.2.3 Step 3: GSI Modeling, Sizing and Initial Layout

Based on the geotechnical evaluations and site feasibility assessments conducted during step 1, mapping will be developed to illustrate which blocks are suitable for Green Streets. Hydrologic models will be developed and calibrated to estimate the control volume and peak flow reduction benefits of GSI alternatives (see Section 6) and re-size the grey infrastructure projects to meet CSO control goals. Cost estimates will be updated for these refined alternatives. These costs should include additional geotechnical work that will be needed to develop GSI designs.

### 9.2.4 Project Charter

The product of problem definition is the preliminary project charter, which includes the scope, schedule and budget for the project. The preliminary project charter will bring the project to 10 percent design; this will included all of the geotechnical and modeling information; the feasible blocks within a given area and the proposed street layouts. The preliminary project charter will allow the project team to meet the WTD Gate 1 requirements for project management.

# 10.0. REFERENCES

EPA. 2007a. *Use of Green Infrastructure in NPDES Permits and Enforcement.* Memorandum from Linda Boornazian, Director of Water Permits Division, and Mark Pollins, Director of Water Enforcement Division, to EPA regional water division directors, regional counsel/enforcement coordinators, and state NPDES directors. U.S. Environmental Protection Agency. August 16, 2007.

EPA. 2007b. *Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and Other Water Programs.* Memorandum from Benjamin H. Grumbles, Assistant Administrator, to EPA regional administrators. U.S. Environmental Protection Agency. March 5, 2007. http://msdgc.org/downloads/wetweather/greenreport/Files/Green_Report_Exhibit_B.pdf.

EPA. 2008. *Managing Wet Weather with Green Infrastructure, Action Strategy 2008.* Prepared in collaboration with Association of State and Interstate Water Pollution Control Administrators, National Association of Clean Water Agencies, Natural Resources Defense Council, and the Low Impact Development Center. U.S. Environmental Protection Agency. http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf.

EPA. 2011. *Protecting Water Quality with green Infrastructure in EPA Water permitting and Enforcement Programs.* Memorandum from Nancy Stoner, Acting Assistant Administrator of the Office of Water, and Cynthia Giles, Assistant Administrator of the Office of Enforcement and Compliance Assurance. U.S. Environmental Protection Agency. April 20, 2011.

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# APPENDIX A:

# EPA Memoranda Supporting GSI

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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.

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

APR 20 2011

MEMORANDUM

SUBJECT: Protecting Water Quality with Green Infrastructure in EPA Water Permitting and Enforcement Programs

FROM: Nancy Stoner
Acting Assistant Administrator
Office of Water (OW)

Cynthia Giles
Assistant Administrator
Office of Enforcement and Compliance Assurance (OECA)

TO: EPA Regional Administrators, OW & OECA Office & Division Directors

The United States Environmental Protection Agency (EPA) strongly encourages and supports the use of green infrastructure approaches to manage wet weather through infiltration, evapotranspiration, and rainwater harvesting. As stated in previous memoranda,[1] EPA recognizes that green infrastructure can be a cost-effective, flexible, and environmentally-sound approach to reduce stormwater runoff and sewer overflows and to meet Clean Water Act (CWA) requirements. Green infrastructure also provides a variety of community benefits including economic savings, green jobs, neighborhood enhancements and sustainable communities. The benefits of green infrastructure are particularly enhanced in urban and suburban areas where green space is limited and environmental damage may be more extensive. The Office of Water (OW) and the Office of Enforcement and Compliance Assurance (OECA) are committed to working with interested communities and water resource managers to successfully incorporate green infrastructure into National Pollutant Discharge Elimination System (NPDES) permits, as well as remedies designed to address non-compliance with the CWA, to better manage both stormwater runoff and sewer overflows.

Given the multiple benefits associated with green infrastructure, EPA encourages the use of green approaches to stormwater runoff and sewer overflow management to the maximum extent possible. Green practices reduce stormwater runoff, preventing it from entering combined and separate sanitary sewer systems and reducing the volume and occurrence of overflows.

[1] "Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and other Water Programs" signed by Benjamin Grumbles, Assistant Administrator, Office of Water, on March 5, 2007, and "Use of Green Infrastructure in NPDES Permits and Enforcement" signed by Linda Boornazian, Director, Water Permits Division and Mark Pollins, Director, Water Enforcement Division, on August 16, 2007.

Green practices also lower the amount of untreated stormwater discharging to surface waters. Green infrastructure provides additional green spaces and recreational opportunities, enhanced ecosystem services, improved air quality, increased property values, energy savings, economic development, reduced urban heat island effects, and job creation opportunities. In addition, green infrastructure can serve as both a climate change mitigation and adaptation strategy, through increased carbon sequestration from plants and soils, and flexibility in adjusting to potential changes in precipitation patterns. As a result of these benefits, communities around the country are increasingly incorporating green designs into wet weather controls through both NPDES permits and water enforcement agreements.

Tremendous progress has been made in recent years on models and technical approaches to assist communities with green infrastructure planning, making it easier for communities to demonstrate that green infrastructure solutions meet CWA requirements. CWA NPDES permits and enforcement agreements that incorporate green or gray infrastructure solutions require enforceable performance criteria, implementation schedules, monitoring plans and protocols, progress tracking and reporting, and operation and maintenance requirements. Regardless of the technology used, EPA looks for a demonstration of sound modeling and technical approaches as well as planning for overall wet weather control approaches to satisfy regulatory requirements. EPA will continue to increase its efforts to help interested communities ensure that green infrastructure meets CWA requirements as well as community goals and encourages communities to consider green infrastructure in all wet weather control plans.

In November 2010, EPA Deputy Administrator Bob Perciasepe formed a cross-agency green infrastructure Steering Committee and Work Group comprised of representatives of each region and every Assistant Administrator's office to further encourage and support the implementation of green infrastructure solutions. As part of this effort, EPA will continue to work with other federal agencies, state and local governments, tribes, municipalities, and the private sector to identify opportunities and provide technical assistance to communities implementing green approaches to control wet weather. EPA will also provide additional tools to encourage states and communities to leverage green infrastructure opportunities within other innovative environmental projects.

We encourage you and your staff to contact OW's Green Infrastructure Coordinator, Chris Kloss at kloss.christopher@epa.gov and OECA's Green Infrastructure Coordinator, Mahri Monson at monson.mahri@epa.gov with questions, comments and information on green infrastructure in permitting and enforcement. Attachment A to this memorandum contains some recent examples of successful incorporation of green infrastructure into NPDES permits and enforcement actions. Attachment B lists the green infrastructure regional liaisons for both the water and the enforcement programs.

Cc: Regional Permit and Enforcement Liaisons

Attachments

Attachment A

Recent Examples of Green Infrastructure in Permits and Enforcement Actions

**Stormwater Permitting Approaches with Green Infrastructure**

***California -*** Since May 2009, California Regional Water Quality Control Boards have adopted nine Phase I MS4 permits requiring that new development and redevelopment projects retain the 85th percentile storm event via infiltration, evapotranspiration, and rainwater harvest and reuse by utilizing green infrastructure practices. Within the individual permits, there are provisions that allow for off-site mitigation or payment of fees if retention and biofiltration are not technically feasible on site.

***Charles River Watershed, MA -*** The draft Residual Designated Discharge General Permit has been developed and noticed for the communities of Milford, Bellingham and Franklin, Massachusetts. The draft permit proposes stormwater control requirements to reduce phosphorus loading for properties with two or more acres of impervious area and the use of infiltration/recharge practices to achieve the required phosphorus load reduction for a property if it is determined that such practices are technically feasible.

***Massachusetts -*** EPA's draft small MS4 general permit for Massachusetts encourages the use of practices which capture (infiltrate, evapotranspire, and/or harvest and reuse rainwater) the 90th percentile storm event (1 inch storm). The draft permit also requires municipalities to examine existing guidelines and policies for their ability to support green infrastructure options in new development and redevelopment, identify impediments, and determine what changes need to be made.

***Santa Monica, CA -*** In July 2010, the City updated its Urban Runoff Pollution Ordinance to require that new development and redevelopment projects infiltrate, store for non-potable use, or evapotranspire the first ¾ inch of a storm, or pay an Urban Runoff Reduction fee that the City then uses for larger scale stormwater control projects. The ordinance promotes the use of green infrastructure for meeting the stormwater retention requirements.

***Washington, DC -*** The District's draft MS4 permit includes a development retention standard of 1.2 and 1.7 inches for non-federal and federal properties, respectively, along with numeric targets for green roofs (350,000 square feet over the permit cycle on District properties) and tree canopy (4,150 trees per year and 13,500 by 2014). The draft DC MS4 permit built off of a supplement to the previous permit that identified numeric targets for tree canopy, LID projects (17 by August 2009), rain gardens (50 by December 2009), rain barrels (125 by December 2009), and downspout disconnection (200 by December 2009).

**Enforcement Actions with Green Infrastructure**

***Cincinnati, OH -*** Cincinnati's 2004 consent decree (CD) to control sewer overflows was amended in 2010, providing opportunities to incorporate green infrastructure solutions by

substituting “green for grey” on a project by project basis. The city is currently evaluating potential green infrastructure projects and has a three year study and detailed design period to examine green solutions in the Lick Run Watershed, in Mill Creek Valley on the west side of Cincinnati. One promising project in the Lick Run drainage area, a corridor that includes an environmental justice community, would remove storm water flows from the combined sewer system and create a new above-ground drainage feature with surrounding park land. Cincinnati will be meeting with EPA throughout 2011 to discuss green infrastructure plans, and proposals for “green for grey” substitutions are likely to be submitted in 2012.

***Cleveland, OH -*** The 2010 Cleveland, OH, CD requires that green infrastructure be used to capture 44 million gallons of combined sewer overflow discharge in order to clean up Cleveland’s waters. The city agreed to spend at least $42 million on green infrastructure and will conduct a feasibility study to develop a green infrastructure plan to meet the 44 million gallon reduction requirement. The agreement allows Cleveland to submit plans for additional green infrastructure controls, based on the results of initial projects. The city will target the majority of its green infrastructure projects in low-income and minority concentrated neighborhoods, where there is an abundance of vacant land that can be utilized at a relatively low cost. The residents of Cleveland will benefit from reduction of sewer overflows and their associated health hazards, increased green space and recreational opportunities, increased property values and job opportunities.

***Kansas City, MO -*** EPA and Kansas City, Missouri signed a consent decree in May 2010 which requires the city to use green infrastructure to help control and eliminate sewer overflows. Kansas City will initially implement a green infrastructure plan to control wet weather flows in a 744-acre environmental justice neighborhood, with the option to expand green infrastructure programs throughout the city to help keep sewer overflows from polluting the community’s water. Green infrastructure technologies to be implemented include catch basin retrofits in road and street rights-of-way, curb extension swales, street trees, permeable pavement, green roofs and stormwater planters. Thanks to this agreement, the citizens of Kansas City will benefit from improvements in water quality, air quality, and new green spaces throughout the city.

***Louisville, KY -*** Through an agreement with EPA filed in 2005 and amended in 2009, Louisville, Kentucky is using green infrastructure to help solve the city’s sewer overflow problems. Louisville has committed to constructing 19 initial green infrastructure demonstration projects including green roofs, green streets, urban reforestation, and other green elements to keep polluted runoff from entering their waters. After a six-year study period to monitor demonstration projects, the sewer department may propose additional green infrastructure controls. Louisville’s sewer department has already distributed hundreds of rain barrels to residents throughout the city, providing citizens the opportunity to participate in cleaning up their waters. The community at large will continue to benefit from ongoing installment of rain gardens, permeable parking lots, and other green amenities throughout Louisville.

Attachment B

Regional Green Infrastructure Liaisons

| Region | Water Program<br>Green Infrastructure Liaisons | Enforcement and Compliance<br>Green Infrastructure Liaisons |
|---|---|---|
| **1** | Johanna Hunter | Joy Hilton<br>Jeff Kopf |
| **2** | Jeff Gratz | Murray Lantner |
| **3** | Dominique Lueckenhoff | Allison Graham |
| **4** | MaryAnn Gerber<br>Darryl Williams | Araceli Bonilla |
| **5** | Bob Newport | Jonathan Moody |
| **6** | Brent Larsen<br>Suzanna Perea | Diana McDonald |
| **7** | Kerry Herndon<br>Mandy Whitsitt | Jodi Bruno |
| **8** | Stacey Eriksen | David Gwisdalla |
| **9** | John Kemmerer | Michelle Moustakas |
| **10** | Krista Mendelman | Rob Grandinetti |

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# APPENDIX B:

## Connectivity Criteria for Parcels

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# APPENDIX B – CONNECTIVITY CRITERIA FOR PARCELS

| Land Cover Type | Scenario | Connectivity Criteria |
|---|---|---|
| **Directly to MS4** | | |
| Rooftop | A | 1. Parcel shown directly connected to MS4<br>2. AND a lateral identified as carrying storm drainage flow lies in the parcel |
| | B | 1. Parcel shown directly connected to MS4<br>2. AND a lateral identified as carrying storm drainage flow lies in the parcel<br>3. AND parcel contains a downspout |
| Impervious | A | 1. Parcel shown directly connected to MS4<br>2. AND a lateral identified as carrying storm drainage flow lies in the parcel |
| | B | 1. Parcel shown directly connected to MS4<br>2. AND a lateral identified as carrying storm drainage flow lies in the parcel<br>3. AND parcel contains no infiltration pit<br>4. AND parcel contains a catch basin |
| Pervious | A | 1. Parcel shown directly connected to MS4<br>2. AND a lateral identified as carrying storm drainage flow lies in the parcel |
| | B | 1. Parcel shown directly connected to MS4<br>2. AND a lateral identified as carrying storm drainage flow lies in the parcel<br>3. AND parcel contains no infiltration pit<br>4. AND parcel contains a catch basin |
| **To MS4 via ROW** | | |
| Rooftop | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow to ROW serviced by a MS4 |
| Impervious | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow to ROW serviced by a MS4 |
| Pervious | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow to ROW serviced by a MS4 |
| **Directly to CSS** | | |
| Rooftop | A | 1. Parcel not connected to MS4<br>2. AND parcel contains no infiltration pit<br>3. AND a lateral identified as carrying storm drainage flow lies in the parcel |

| Land Cover Type | Scenario | Connectivity Criteria |
|---|---|---|
| Rooftop (continued) | B | 1. Parcel not connected to MS4<br>2. AND parcel contains no infiltration pit<br>3. AND parcel contains a downspout |
| Impervious | A | 1. Parcel not connected to MS4<br>2. AND parcel contains no infiltration pit<br>3. AND a lateral identified as carrying storm drainage flow lies in the parcel |
| | B | 1. Parcel not connected to MS4<br>2. AND parcel contains no infiltration pit<br>3. AND parcel contains a catch basin |
| Pervious | A | 1. Parcel not connected to MS4<br>2. AND parcel contains no infiltration pit<br>3. AND a lateral identified as carrying storm drainage flow lies in the parcel |
| | B | 1. Parcel not connected to MS4<br>2. AND parcel contains no infiltration pit<br>3. AND parcel contains a catch basin |
| **To CSS via ROW** | | |
| Rooftop | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow to ROW serviced by a CSS |
| Impervious | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow ROW serviced by a CSS |
| Pervious | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow ROW serviced by a CSS |
| **Overland to Receiving Water Body** | | |
| Rooftop | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow to ROW not serviced by either a CSS or MS4 |
| Impervious | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow to ROW not serviced by either a CSS or MS4 |
| Pervious | A | 1. Flow not directly to CSS or MS4 |
| | B | 1. Terrain indicates runoff will flow to ROW not serviced by either a CSS or MS4 |

# APPENDIX C:

# Windshield Photo Logs

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# 3rd Avenue W CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | 1st Ave W @ Crockett St (North)<br>Right-of-way suitable for roadside raingardens. |
| 2 | 1st Ave N @ Crockett St (West ROW) (North)<br>Right-of-way planting strip and sidewalk draining to street. |
| 3 | Alley between 1st and 2nd Ave W, from W Boston St to Crockett St (South)<br>Green alley potential. |
| 4 | 5th Ave W @ W Blaine St (North)<br>Right-of-way suitable for roadside raingardens. |

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# 11th Avenue NW CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | NW 65th St @ Dibble Ave NW (East)<br>Minimal opportunities for roadside raingardens. |
| 2 | 3rd Ave NW @ NW 65th St (North)<br>Right-of-way suitable for roadside raingardens. |
| 3 | 3rd Ave NW @ NW 65th St (East ROW) (South)<br>Right-of-way planting strip and sidewalk draining to street. |
| 4 | 3rd Ave NW @ NW 65th St (East ROW) (North)<br>Right-of-way planting strip and sidewalk draining to street. |
| 5 | NW 83rd St @ 3rd Ave NW (West)<br>Side street with ROW potential for roadside raingardens. |
| 6 | 8th Ave NW @ NW 83rd St (West ROW) (North)<br>Small (approx. 1 foot wide) planter provides minimal opportunities for roadside raingardens. |
| 7 | Alley between NW 82nd and NW 83rd St East of 6th Ave NW (East)<br>Green alley potential. Flat alley, high potential. |
| 8 | 6th Ave NW @ NW 82nd St (South)<br>Wide ROW with moderately sized existing planting strips. High potential for roadside raingardens/curb bulbs. |
| 9 | 13th Ave NW @ NW 80th St (North)<br>ROW with potential for roadside raingardens |
| 10 | 13th Ave NW between NW 80th and NW 83rd St (East)<br>Sample reverse sloped driveway on East side of 13th Ave. |

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# Brandon Street CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | 3rd Ave S @ S Lucile St (South)<br>Typical gravel ROW parking. |
| 2 | Alley between S Brandon St and S Lucile St, West of 3rd Ave S (West)<br>Abandoned alley. Existing low area that collects water from adjacent right-of-way and parcel runoff. |
| 3 | 3rd Ave S @ S Brandon St (North)<br>Typical right-of-way cross-section with gravel parking on either side of street. Delivery vehicle access required. |
| 4 | 2nd Ave S @ S Hudson St (North)<br>Right-of-way cross-section. GIS maps indicate disconnected ROW, but parcels on the west side of 2nd Ave S are connected to CSS. Potential opportunity for GSI to mitigate parcel runoff. |
| 5 | 2nd Ave S @ S Dawson St (North)<br>Right-of-way cross-section. Potential for ROW and parcel-based GSI. |
| 6 | S Orcas St @ 2nd Ave S (East)<br>North right-of-way with adequate planting strip for roadside raingardens. |
| 7 | Utah Ave S @ S Lucile St (North)<br>Right-of-way with improvement needs and GSI opportunity. |

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# South Michigan Street CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | 8th Ave @ S Garden St (East)<br>Existing raingardens at Markey Machinery Company. |
| 2 | Flora Ave S @ S Eddy St (East ROW) (South)<br>Moderate opportunity for GSI. Potentially roadside raingardens (mid-block curb bulbs or utilize existing vegetated planting strip). |
| 3 | Carleton Ave S between S Willow St and S Warsaw St (North)<br>High potential for GSI. Wide Right-of-way may allow for roadside raingardens. |
| 4 | Airport Way S @ S Hardy St (South)<br>Moderate opportunity on West side of right-of-way. |

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# Hanford CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | 20th Ave @ E Union St (South)<br>Right-of-way opportunity for roadside raingardens. |
| 2 | 20th Ave @ E Union St (West ROW) (North)<br>Right-of-way opportunity for roadside raingardens. |

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# University CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | Winona Ave N @ Stone Ave N (South-West)<br>PCC Natural Markets. Possible permeable parking or raingarden retrofit. |
| 2 | Stone Ave N @ Winona Ave N (South-East)<br>ROW with adequate planting strips for roadside raingardens. |
| 3 | N 74th St @ Fremont Ave N (East)<br>ROW cross-section. High potential for roadside raingardens. |
| 4 | Alley between N 75th St and North 76th St, from Fremont Ave N to Linden Ave N (East)<br>Paved typical. High potential for green alley retrofit. |
| 5 | Aurora Ave N @ N 80th St (South)<br>Minimal potential for roadside raingardens. |
| 6 – 8 | N 80th St and Stone Ave N (varies)<br>Daniel Bagley Elementary School. Educational outreach opportunity. Some existing GSI onsite (e.g., bioswales in parking lot). Potential for retrofits elsewhere in parking facilities as well as mitigation of roof runoff and runoff from adjacent asphalt play area. |
| 9 | NE 91st St @ 8th Ave NE (East)<br>Reverse sloped drive. Deterrent for roadside raingardens. |
| 10 | NE 89th St @ 12th Ave NE (West)<br>Narrow planting strips provide minimal opportunity for roadside raingardens. |
| 11 | Ravenna Ave NE @ NE 75th St (South)<br>West planter strip has high potential for retrofit roadside raingarden. |
| 12 | Ravenna Ave NE @ NE 75th St (South)<br>East planter strip has low potential for retrofit roadside raingarden. |
| 13 | Ravenna Ave NE @ NE 75th St (E)<br>Houses East of Ravenna are below road grade (deterrent for roadside raingardens). |

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# Montlake CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | East Highland Dr @ 20th Ave E (East)<br>Typical wide planting strip. High potential for roadside raingardens. |
| 2 | 41st Ave E @ E Lynn St (South)<br>South of Lynn. Moderate to Minimal potential for roadside raingardens due to narrow planter strips and existing trees. |
| 3 | 26th Ave @ E Pine St (North)<br>Wide planter strip with high potential for roadside raingardens. |
| 4 | Alley between 26th and 27th Ave, from E Marion to E Columbia St (North)<br>Alley with moderate to minimal opportunities for greening due to existing connectivity and easterly property slopes (drain away from alley). |
| 5 | Alley between 26th and 27th Ave, from E Marion to E Columbia St (East)<br>Retaining wall and parcels draining away from ROW (East of alley) |
| 6, 7 | Alley between 25th and 26th Ave, from E Columbia to E Cherry St (varies)<br>Alley with monitoring wells adjacent to contaminated site. Minimal opportunity for greening. |

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# West Michigan Street CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | 9th Ave SW @ SW Trenton to SW Henderson St (North)<br>Wide ROW (~5' planting strips). High potential for roadside raingardens. |
| 2 | 9th Ave SW, south of SW Henderson St (South)<br>Some potential for natural drainage system. Would have to accommodate existing on-street parking. |
| 3 | 9th Ave SW, south of SW Henderson St (North)<br>Existing planting area downhill of moderately sized drainage area. High potential for GSI (roadside raingardens). |
| 4 | SW Cloverdale St and 10th Ave SW (varies)<br>Highland Park Elementary School. Potential parking lot retrofit and/or potential mitigation of roof runoff and onsite basketball courts. |

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# Chelan Avenue CSO Basin

| Photo Number | Photo Description |
|---|---|
| 1 | 25th Ave SW, north of SW Brandon St (North)<br>High potential for roadside raingardens. |
| 2 | 25th Ave SW, north of SW Brandon St (South)<br>High potential for roadside raingardens. |
| 3 | 25th Ave SW between SW Brandon and SW Findlay St (North)<br>Moderate potential for roadside raingardens/natural drainage systems, but would need to accommodate existing on-street parking. |

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# APPENDIX D:

# Feasible Area Managed by Basin, GSI Practice and Land Use

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**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| 11th Avenue NW | Street & Alley Right-of-Way | 445 | Suitable Impervious Area [a] | (ac) | 193 | 95 | | | | | 193 | 95 |
| | | | Technical Factor [b] | (%) | 80% | 30% | | | | | 80% | 30% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **108** | **11** | **0** | **0** | **0** | **0** | **108** | **11** |
| | | | | **(%)** | **24%** | **3%** | **0%** | **0%** | **0%** | **0%** | **24%** | **3%** |
| | Public Parcel | 57 | Suitable Impervious Area [a] | (ac) | 15 | 15 | 11 | 11 | 8 | 8 | 27 | 26 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **11** | **6** | **8** | **4** | **5** | **2** | **19** | **10** |
| | | | | **(%)** | **19%** | **10%** | **14%** | **8%** | **8%** | **3%** | **33%** | **18%** |
| | Residential Parcel | 614 | Suitable Impervious Area [a] | (ac) | 230 | 227 | 61 | 58 | | | 291 | 284 |
| | | | Technical Factor [b] | (%) | 50% | 20% | 50% | 20% | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **40** | **5** | **11** | **1** | **0** | **0** | **51** | **6** |
| | | | | **(%)** | **7%** | **1%** | **2%** | **0%** | **0%** | **0%** | **8%** | **1%** |
| | Commercial/ Industrial Parcel | 250 | Suitable Impervious Area [a] | (ac) | 83 | 70 | 22 | 16 | 21 | 18 | 104 | 86 |
| | | | Technical Factor [b] | (%) | 20% | 10% | 30% | 10% | 20% | 10% | 22% | 10% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **3** | **0** | **1** | **0** | **1** | **0** | **5** | **0** |
| | | | | **(%)** | **1%** | **0%** | **1%** | **0%** | **0%** | **0%** | **2%** | **0%** |
| | Total | 1,366 | Total Suitable Area [d] | (ac) | 520 | 407 | 94 | 85 | 29 | 25 | 615 | 492 |
| | | | Feasibility Factors [e] | (%) | 31% | 5% | 21% | 7% | 19% | 7% | 30% | 6% |
| | | | Total Feasible Area [f] | (ac) | 162 | 22 | 20 | 6 | 6 | 2 | 182 | 28 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| University | Street & Alley Right-of-Way | 1,932 | Suitable Impervious Area [a] | (ac) | 955 | 428 | | | | | 955 | 428 |
| | | | Technical Factor [b] | (%) | 50% | 20% | | | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **334** | **34** | **0** | **0** | **0** | **0** | **334** | **34** |
| | | | | **(%)** | **17%** | **2%** | **0%** | **0%** | **0%** | **0%** | **17%** | **2%** |
| | Public Parcel | 701 | Suitable Impervious Area [a] | (ac) | 124 | 121 | 128 | 117 | 51 | 51 | 252 | 238 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **87** | **48** | **90** | **47** | **31** | **10** | **176** | **95** |
| | | | | **(%)** | **12%** | **7%** | **13%** | **7%** | **4%** | **1%** | **25%** | **14%** |
| | Residential Parcel | 2,483 | Suitable Impervious Area [a] | (ac) | 564 | 552 | 494 | 496 | | | 1058 | 1047 |
| | | | Technical Factor [b] | (%) | 40% | 10% | 50% | 20% | | | 45% | 15% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **79** | **6** | **86** | **10** | **0** | **0** | **165** | **15** |
| | | | | **(%)** | **3%** | **0%** | **3%** | **0%** | **0%** | **0%** | **7%** | **1%** |
| | Commercial/ Industrial Parcel | 1,055 | Suitable Impervious Area [a] | (ac) | 246 | 234 | 256 | 250 | 117 | 117 | 502 | 484 |
| | | | Technical Factor [b] | (%) | 20% | 10% | 30% | 10% | 20% | 10% | 25% | 10% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **10** | **1** | **15** | **1** | **5** | **1** | **25** | **2** |
| | | | | **(%)** | **1%** | **0%** | **1%** | **0%** | **0%** | **0%** | **2%** | **0%** |
| | Total | 6,172 | Total Suitable Area [d] | (ac) | 1889 | 1334 | 878 | 863 | 168 | 168 | 2767 | 2197 |
| | | | Feasibility Factors [e] | (%) | 27% | 7% | 22% | 7% | 21% | 6% | 25% | 7% |
| | | | Total Feasible Area [f] | (ac) | 510 | 89 | 191 | 58 | 35 | 11 | 701 | 147 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| 3rd Avenue West | Street & Alley Right-of-Way | 249 | Suitable Impervious Area [a] | (ac) | 139 | 58 | | | | | 139 | 58 |
| | | | Technical Factor [b] | (%) | 50% | 20% | | | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **48** | **5** | **0** | **0** | **0** | **0** | **48** | **5** |
| | | | | **(%)** | **20%** | **2%** | **0%** | **0%** | **0%** | **0%** | **20%** | **2%** |
| | Public Parcel | 89 | Suitable Impervious Area [a] | (ac) | 1 | 1 | 25 | 23 | 7 | 7 | 27 | 24 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **1** | **0** | **18** | **9** | **4** | **1** | **19** | **9** |
| | | | | **(%)** | **1%** | **0%** | **20%** | **10%** | **5%** | **1%** | **21%** | **11%** |
| | Residential Parcel | 219 | Suitable Impervious Area [a] | (ac) | 15 | 5 | 17 | 7 | | | 33 | 12 |
| | | | Technical Factor [b] | (%) | 50% | 20% | 50% | 20% | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **3** | **0** | **3** | **0** | **0** | **0** | **6** | **0** |
| | | | | **(%)** | **1%** | **0%** | **1%** | **0%** | **0%** | **0%** | **3%** | **0%** |
| | Commercial/ Industrial Parcel | 193 | Suitable Impervious Area [a] | (ac) | 8 | 5 | 56 | 34 | 19 | 13 | 64 | 39 |
| | | | Technical Factor [b] | (%) | 20% | 10% | 30% | 10% | 20% | 10% | 29% | 10% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **0** | **0** | **3** | **0** | **1** | **0** | **4** | **0** |
| | | | | **(%)** | **0%** | **0%** | **2%** | **0%** | **0%** | **0%** | **2%** | **0%** |
| | Total | 750 | Total Suitable Area [d] | (ac) | 163 | 69 | 98 | 64 | 27 | 20 | 262 | 133 |
| | | | Feasibility Factors [e] | (%) | 32% | 7% | 25% | 15% | 20% | 7% | 29% | 11% |
| | | | Total Feasible Area [f] | (ac) | 52 | 5 | 24 | 10 | 5 | 1 | 77 | 15 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| Montlake | Street & Alley Right-of-Way | 691 | Suitable Impervious Area [a] | (ac) | 177 | 72 | | | | | 177 | 72 |
| | | | Technical Factor [b] | (%) | 50% | 20% | | | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **62** | **6** | **0** | **0** | **0** | **0** | **62** | **6** |
| | | | | **(%)** | **9%** | **1%** | **0%** | **0%** | **0%** | **0%** | **9%** | **1%** |
| | Public Parcel | 256 | Suitable Impervious Area [a] | (ac) | 33 | 32 | 28 | 26 | 14 | 15 | 60 | 58 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **23** | **13** | **19** | **10** | **8** | **3** | **42** | **23** |
| | | | | **(%)** | **9%** | **5%** | **8%** | **4%** | **3%** | **1%** | **16%** | **9%** |
| | Residential Parcel | 998 | Suitable Impervious Area [a] | (ac) | 111 | 103 | 269 | 256 | | | 380 | 359 |
| | | | Technical Factor [b] | (%) | 40% | 10% | 50% | 20% | | | 47% | 17% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **16** | **1** | **47** | **5** | **0** | **0** | **63** | **6** |
| | | | | **(%)** | **2%** | **0%** | **5%** | **1%** | **0%** | **0%** | **6%** | **1%** |
| | Commercial/ Industrial Parcel | 268 | Suitable Impervious Area [a] | (ac) | 36 | 34 | 53 | 50 | 14 | 13 | 88 | 84 |
| | | | Technical Factor [b] | (%) | 20% | 10% | 30% | 10% | 20% | 10% | 26% | 10% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **1** | **0** | **3** | **0** | **1** | **0** | **5** | **0** |
| | | | | **(%)** | **1%** | **0%** | **1%** | **0%** | **0%** | **0%** | **2%** | **0%** |
| | Total | 2,212 | Total Suitable Area [d] | (ac) | 357 | 241 | 349 | 332 | 28 | 28 | 706 | 574 |
| | | | Feasibility Factors [e] | (%) | 29% | 8% | 20% | 5% | 32% | 11% | 24% | 6% |
| | | | Total Feasible Area [f] | (ac) | 102 | 20 | 69 | 16 | 9 | 3 | 171 | 36 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| Hanford | Street & Alley Right-of-Way | 1,172 | Suitable Impervious Area [a] | (ac) | 260 | 130 | | | | | 260 | 130 |
| | | | Technical Factor [b] | (%) | 50% | 20% | | | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **91** | **10** | **0** | **0** | **0** | **0** | **91** | **10** |
| | | | | **(%)** | **8%** | **1%** | **0%** | **0%** | **0%** | **0%** | **8%** | **1%** |
| | Public Parcel | 566 | Suitable Impervious Area [a] | (ac) | 15 | 10 | 193 | 176 | 49 | 42 | 208 | 186 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **11** | **4** | **135** | **70** | **30** | **8** | **145** | **74** |
| | | | | **(%)** | **2%** | **1%** | **24%** | **12%** | **5%** | **1%** | **26%** | **13%** |
| | Residential Parcel | 772 | Suitable Impervious Area [a] | (ac) | 15 | 11 | 107 | 95 | | | 122 | 106 |
| | | | Technical Factor [b] | (%) | 40% | 10% | 50% | 20% | | | 49% | 19% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **2** | **0** | **19** | **2** | **0** | **0** | **21** | **2** |
| | | | | **(%)** | **0%** | **0%** | **2%** | **0%** | **0%** | **0%** | **3%** | **0%** |
| | Commercial/ Industrial Parcel | 955 | Suitable Impervious Area [a] | (ac) | 52 | 45 | 389 | 348 | 163 | 141 | 441 | 393 |
| | | | Technical Factor [b] | (%) | 60% | 20% | 60% | 20% | 30% | 10% | 60% | 20% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **6** | **0** | **47** | **3** | **10** | **1** | **53** | **4** |
| | | | | **(%)** | **1%** | **0%** | **5%** | **0%** | **1%** | **0%** | **6%** | **0%** |
| | Total | 3,465 | Total Suitable Area [d] | (ac) | 342 | 196 | 689 | 619 | 212 | 182 | 1030 | 815 |
| | | | Feasibility Factors [e] | (%) | 32% | 8% | 29% | 12% | 19% | 5% | 30% | 11% |
| | | | Total Feasible Area [f] | (ac) | 110 | 15 | 200 | 76 | 39 | 9 | 310 | 91 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| Chelan Avenue | Street & Alley Right-of-Way | 514 | Suitable Impervious Area [a] | (ac) | 86 | 44 | | | | | 86 | 44 |
| | | | Technical Factor [b] | (%) | 50% | 20% | | | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **30** | **4** | **0** | **0** | **0** | **0** | **30** | **4** |
| | | | | **(%)** | **6%** | **1%** | **0%** | **0%** | **0%** | **0%** | **6%** | **1%** |
| | Public Parcel | 809 | Suitable Impervious Area [a] | (ac) | 5 | 5 | 10 | 5 | 3 | 3 | 15 | 10 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **4** | **2** | **7** | **2** | **2** | **1** | **11** | **4** |
| | | | | **(%)** | **0%** | **0%** | **1%** | **0%** | **0%** | **0%** | **1%** | **0%** |
| | Residential Parcel | 670 | Suitable Impervious Area [a] | (ac) | 60 | 57 | 100 | 85 | | | 160 | 142 |
| | | | Technical Factor [b] | (%) | 50% | 20% | 50% | 20% | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **11** | **1** | **17** | **2** | **0** | **0** | **28** | **3** |
| | | | | **(%)** | **2%** | **0%** | **3%** | **0%** | **0%** | **0%** | **4%** | **0%** |
| | Commercial/ Industrial Parcel | 597 | Suitable Impervious Area [a] | (ac) | 22 | 21 | 39 | 28 | 16 | 10 | 61 | 49 |
| | | | Technical Factor [b] | (%) | 20% | 10% | 30% | 10% | 20% | 10% | 26% | 10% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **1** | **0** | **2** | **0** | **1** | **0** | **3** | **0** |
| | | | | **(%)** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **1%** | **0%** |
| | Total | 2,590 | Total Suitable Area [d] | (ac) | 174 | 127 | 149 | 118 | 20 | 13 | 323 | 245 |
| | | | Feasibility Factors [e] | (%) | 26% | 5% | 18% | 3% | 14% | 4% | 22% | 4% |
| | | | Total Feasible Area [f] | (ac) | 45 | 7 | 27 | 4 | 3 | 1 | 72 | 10 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| West Michigan Street | Street & Alley Right-of-Way | 59 | Suitable Impervious Area [a] | (ac) | 5 | 3 | | | | | 5 | 3 |
| | | | Technical Factor [b] | (%) | 80% | 30% | | | | | 80% | 30% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **3** | **0** | **0** | **0** | **0** | **0** | **3** | **0** |
| | | | | **(%)** | **5%** | **1%** | **0%** | **0%** | **0%** | **0%** | **5%** | **1%** |
| | Public Parcel | 28 | Suitable Impervious Area [a] | (ac) | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **0** | **0** | **1** | **1** | **0** | **0** | **1** | **1** |
| | | | | **(%)** | **0%** | **0%** | **3%** | **2%** | **0%** | **0%** | **4%** | **2%** |
| | Residential Parcel | 92 | Suitable Impervious Area [a] | (ac) | 11 | 8 | 6 | 5 | | | 16 | 13 |
| | | | Technical Factor [b] | (%) | 40% | 10% | 50% | 20% | | | 43% | 14% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **2** | **0** | **1** | **0** | **0** | **0** | **2** | **0** |
| | | | | **(%)** | **2%** | **0%** | **1%** | **0%** | **0%** | **0%** | **3%** | **0%** |
| | Commercial/ Industrial Parcel | 24 | Suitable Impervious Area [a] | (ac) | 2 | 2 | 2 | 2 | 1 | 1 | 4 | 4 |
| | | | Technical Factor [b] | (%) | 20% | 10% | 30% | 10% | 30% | 10% | 25% | 10% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| | | | | **(%)** | **0%** | **0%** | **1%** | **0%** | **0%** | **0%** | **1%** | **0%** |
| | Total | 203 | Total Suitable Area [d] | (ac) | 18 | 13 | 9 | 8 | 1 | 1 | 27 | 21 |
| | | | Feasibility Factors [e] | (%) | 25% | 3% | 22% | 8% | 18% | 5% | 24% | 5% |
| | | | Total Feasible Area [f] | (ac) | 5 | 0 | 2 | 1 | 0 | 0 | 7 | 1 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| Brandon Street | Street & Alley Right-of-Way | 92 | Suitable Impervious Area [a] | (ac) | 62 | 45 | | | | | 62 | 45 |
| | | | Technical Factor [b] | (%) | 80% | 30% | | | | | 80% | 30% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **35** | **5** | **0** | **0** | **0** | **0** | **35** | **5** |
| | | | | **(%)** | **38%** | **6%** | **0%** | **0%** | **0%** | **0%** | **38%** | **6%** |
| | Public Parcel | 49 | Suitable Impervious Area [a] | (ac) | 3 | 2 | 8 | 8 | 2 | 2 | 11 | 10 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **2** | **1** | **6** | **3** | **1** | **0** | **8** | **4** |
| | | | | **(%)** | **4%** | **1%** | **12%** | **7%** | **3%** | **1%** | **15%** | **8%** |
| | Residential Parcel | 6 | Suitable Impervious Area [a] | (ac) | 4 | 4 | 0 | 0 | | | 4 | 4 |
| | | | Technical Factor [b] | (%) | 50% | 20% | 50% | 20% | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **1** | **0** | **0** | **0** | **0** | **0** | **1** | **0** |
| | | | | **(%)** | **11%** | **1%** | **1%** | **0%** | **0%** | **0%** | **12%** | **1%** |
| | Commercial/ Industrial Parcel | 230 | Suitable Impervious Area [a] | (ac) | 108 | 88 | 61 | 47 | 91 | 77 | 169 | 135 |
| | | | Technical Factor [b] | (%) | 70% | 30% | 70% | 30% | 50% | 20% | 70% | 30% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **15** | **1** | **9** | **1** | **9** | **1** | **24** | **2** |
| | | | | **(%)** | **7%** | **1%** | **4%** | **0%** | **4%** | **0%** | **10%** | **1%** |
| | Total | 377 | Total Suitable Area [d] | (ac) | 176 | 138 | 70 | 56 | 93 | 79 | 246 | 194 |
| | | | Feasibility Factors [e] | (%) | 30% | 5% | 21% | 7% | 11% | 2% | 27% | 6% |
| | | | Total Feasible Area [f] | (ac) | 52 | 7 | 14 | 4 | 11 | 1 | 67 | 11 |

**GSI Feasibility Assessment by CSO Basin**

| CSO Basin | Land Use | Total Area (ac) | | | Feasible Impervious Area Managed by GSI Practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Infiltration Facilities | | Cisterns | | Green Roofs | | Total | |
| | | | | | High | Low | High | Low | High | Low | High | Low |
| South Michigan Street | Street & Alley Right-of-Way | 450 | Suitable Impervious Area [a] | (ac) | 187 | 106 | | | | | 187 | 106 |
| | | | Technical Factor [b] | (%) | 80% | 30% | | | | | 80% | 30% |
| | | | Participation Factor [c] | (%) | 70% | 40% | | | | | 70% | 40% |
| | | | **Total** | **(ac)** | **104** | **13** | **0** | **0** | **0** | **0** | **104** | **13** |
| | | | | **(%)** | **23%** | **3%** | **0%** | **0%** | **0%** | **0%** | **23%** | **3%** |
| | Public Parcel | 859 | Suitable Impervious Area [a] | (ac) | 23 | 23 | 121 | 121 | 14 | 14 | 144 | 144 |
| | | | Technical Factor [b] | (%) | 70% | 40% | 70% | 40% | 60% | 20% | 70% | 40% |
| | | | **Total** | **(ac)** | **16** | **9** | **85** | **48** | **8** | **3** | **101** | **58** |
| | | | | **(%)** | **2%** | **1%** | **10%** | **6%** | **1%** | **0%** | **12%** | **7%** |
| | Residential Parcel | 333 | Suitable Impervious Area [a] | (ac) | 89 | 87 | 107 | 104 | | | 195 | 192 |
| | | | Technical Factor [b] | (%) | 50% | 20% | 50% | 20% | | | 50% | 20% |
| | | | Participation Factor [c] | (%) | 35% | 10% | 35% | 10% | | | 35% | 10% |
| | | | **Total** | **(ac)** | **16** | **2** | **19** | **2** | **0** | **0** | **34** | **4** |
| | | | | **(%)** | **5%** | **1%** | **6%** | **1%** | **0%** | **0%** | **10%** | **1%** |
| | Commercial/ Industrial Parcel | 244 | Suitable Impervious Area [a] | (ac) | 108 | 104 | 93 | 91 | 78 | 77 | 200 | 195 |
| | | | Technical Factor [b] | (%) | 70% | 30% | 70% | 30% | 50% | 20% | 70% | 30% |
| | | | Participation Factor [c] | (%) | 20% | 5% | 20% | 5% | 20% | 5% | 20% | 5% |
| | | | **Total** | **(ac)** | **15** | **2** | **13** | **1** | **8** | **1** | **28** | **3** |
| | | | | **(%)** | **6%** | **1%** | **5%** | **1%** | **3%** | **0%** | **12%** | **1%** |
| | Total | 1,886 | Total Suitable Area [d] | (ac) | 407 | 321 | 320 | 316 | 91 | 91 | 727 | 637 |
| | | | Feasibility Factors [e] | (%) | 37% | 8% | 36% | 16% | 17% | 4% | 37% | 12% |
| | | | Total Feasible Area [f] | (ac) | 151 | 25 | 116 | 52 | 16 | 4 | 268 | 77 |

*a.* "Suitable Impervious Area" is the impervious portion of basin that is connected to the CCS and where GSI practices meet the criteria defined in the GIS analysis (see Section 4).

*b.* The "Technical Factor" represents the percent of suitable area that is likely feasible for GSI retrofit (based on windshield surveys, see Section 5).

*c.* The "Participation Factor" represents the percent of suitable area that is likely socially feasible for GSI retrofit.

*d.* "Total Suitable Area" is the summation of suitable impervious areas by land use designation.

*e.* "Feasibility Factors" are the technical and participation factors weighted by area.

*f.* "Total Feasible Area" is calculated as the "Total Suitable Area" multiplied by the "Feasibility Factors".

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# APPENDIX E:

# Preliminary Public Involvement Approach

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# APPENDIX E – PRELIMINARY PUBLIC INVOLVEMENT PLAN

This document outlines a preliminary public involvement approach to support King County's Combined Sewer Overflow (CSO) Control Program's planned effort to reduce peak flows of stormwater into the sewer system by constructing GSI throughout CSO basins – all within the City of Seattle. The estimated number of projects (70,000-100,000) indicates a considerable impact on Seattle neighborhoods including:

- A Residential RainWise program by King County and City of Seattle would include an estimated 30,0000 households (with City of Seattle offering funding to 9,000 of these households in late 2011)
- Approximately 10,000 Seattle city blocks will be considered for above-ground natural drainage projects located on rights-of-way (planting strips) by King County and Seattle (with a King County project currently in the pre-design stage in West Seattle)
- Up to 20,000 commercial/ industrial /institutional GSI projects would be considered (with King County grant-funded projects underway in the Duwamish area)

Managing public involvement for GSI, with its highly visible rain gardens, swales and plantings, is a process of managing permanent change to the character of a given neighborhood where construction of GSI will take place.

## Approaches for Public Education and Outreach

King County is launching a large-scale program utilizing stormwater control methods new to much of the public. People are bound to have many questions about this work as they decide whether to take advantage of rebates to build rain gardens or anticipate swales being built in front of their residences.

With tens of thousands of successful interactions with Seattle residents and businesses required to get the work done, gaining public understanding and approval is imperative to achieve the maximum amount of GSI possible to reduce stormwater flows and the capacity of the gray infrastructure that will be built next.

Even a large-scale, relatively neutral response of "wait and see" by those unfamiliar with the method could decrease the adoption and speed of the County's GSI program. Wide-spread understanding and approval of the benefits of GSI and the ability of the County to successfully implement these solutions would greatly increase program efficacy.

## Expressing Benefits of GSI

To help gain public understanding and approval, the benefits of GSI must be communicated, including:

- GSI will reduce extent of gray infrastructure needed; helping reduce expenditures and use of land throughout Seattle.
- King County is responding to EPA encouragement to use GSI approaches when feasible.

- Many stakeholder groups of the CSO Control Program are major proponents of GSI as a more sustainable approach to reducing stormwater flows and helping prevent pollution to the areas water bodies. The County's implementation of as much GSI as possible is an indicator that we have heard these stakeholders.

## Potential Public Concerns

These new methodologies that will occur within Seattle neighborhoods will be above ground and permanently visible. A significant portion of the GSI program is based upon the public acceptance – either through volunteering to build stormwater-absorbing rain gardens on properties or the acceptance of neighborhoods to be forever changed by the swales and plantings in the public right-of-way in front of their homes (their parking strips).

The public may be concerned about:

- Resulting decreases in parking spaces on certain streets
- The ability of plantings to shelter scavenging urban animals and swales to breed mosquitoes
- The aesthetics of the plantings
- Drainage – of swales and/or risk of overall ground saturation
- Whether neighbors' rain gardens could negatively impact their property values or cause basement flooding

The County also needs to have conversations with the many non-profit organizations already enthusiastic about GSI to share an understanding of the limits of GSI so that they can be knowledgeable stewards of the GSI process. This understanding includes limits to the feasibility of GSI (such as in areas with steep slopes) and its applicability (GSI alone cannot handle the enormous flows that happen during a large storm) – i.e., gray infrastructure has its place in the overall solution.

## Implementation Strategies

Strategies should be proposed to provide a wide range of opportunities for stakeholders and the public to be involved. Far-reaching strategies can provide information and opportunities for a large number of people to participate in the process. These would include public education; consistent messaging; providing many opportunities for input, coordinated outreach with other Wastewater Treatment Division projects and with the City of Seattle.

In-depth engagement can provide information and opportunities for those with a high level of interest, with a range of stakeholders and interested parties that will include environmental organizations, especially those focused on water quality issues.

The program can use a wide range of tools for in-depth engagement, including interviews, workshops and public meetings to involve the public. The program can demonstrate that the County is listening to concerns, and working to balance a variety of interests with current regulatory, technical and fiscal realities.

## Partnerships

The County's GSI project is uniquely characterized by its growing number of partnerships:

- Seattle's RainWise Program: The County's collaboration with Seattle in CSO Control projects demonstrates a concern for cost-effective approaches. This collaboration could include partnership with Seattle's RainWise Program that provides vouchers to Seattle property owners wising to build Rain Gardens on their properties. Joining this already-developed program provides the County with a public platform providing education and information for those seeking to collaborate with its efforts, saving resources that would be spent on a parallel program.
- County/institutional partnerships: are underway (including Seattle University with its award-winning GSI project; Seattle Center and Woodland Park Zoo). Not only do successful institutional projects reduce stormwater run-off, but they show the public what GSI is and demonstrate that it works.
- An impressive number of non-profit organization GSI projects: are underway. The CSO Control Program benefits by the portion done in Seattle, and is seeking to partner in both education and technical standards.
- Other jurisdictions: Other regional and national jurisdictions that have already completed major GSI projects offer a wealth of outreach models, insights and materials that inform the County's public involvement planning.

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