Technical Memorandum 600.1

CSO Beach Projects

Green Infrastructure GIS Analysis

November 2009

King County

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Introduction

King County's Wastewater Treatment Division (WTD) plans to control all of its 38 combined sewer overflow (CSO) locations to an average of no more than one overflow per year by 2030. Projects are under way to control four CSOs at Puget Sound beach locations—the Barton Pump Station, Murray Pump Station, South Magnolia Overflow Weir, and North Beach Pump Station—all in the City of Seattle. Construction is scheduled to start on these projects in 2013.

In addition to storage and treatment options, demand management options are being investigated to control the Puget Sound beach CSOs. One such option is green infrastructure, an approach to wet-weather management that is cost-effective, sustainable, and environmentally friendly. Other communities have successfully applied green infrastructure to controlling CSOs and have garnered other benefits in the process. Recently, the U.S. Environmental Protection Agency issued guidance on employing green infrastructure for CSO control (EPA, 2008)[1] and has required inclusion of green infrastructure in long-term CSO control plans it has reviewed.

The first step in evaluating the potential of demand management options is to identify the sources of stormwater entering the combined sewer system (CSS). To do this, WTD conducted a geographic information system (GIS) analysis in 2008 to calculate the acreages in assessed properties and in rights-of-way (ROW) in the four Puget Sound beach CSO basins that contribute flow to the CSS.[2]

Information from the GIS analysis was used to identify the most promising areas for green infrastructure applications in these basins and to select one subbasin for further study. This technical memorandum briefly defines green infrastructure and then describes the study area and the approach, results, and recommendations of the green infrastructure analysis.

Green Infrastructure

The concept of green infrastructure originated in the strategic conservation planning field. In this context, large forests, wetlands, greenbelts, and so forth—all part of the *natural* environment—are viewed as infrastructure because they support essential ecosystem functions (Great City, 2009).[3] The term is increasingly being used to refer to *engineered* infrastructure at a smaller scale in relation to green stormwater management practices such as rain gardens and green roofs. These practices make use of soils and vegetation, in combination with other decentralized storage and infiltration approaches such as rain barrels and permeable pavement, to infiltrate, evaporate, capture, and reuse stormwater. Other names for green stormwater management include low impact development (LID), natural drainage, and water-sensitive design. This technical memorandum uses the term "green stormwater infrastructure" (GSI).

The U.S. Environmental Protection Agency says 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

[1] http://www.epa.gov/npdes/pubs/gi_action_strategy.pdf
[2] *Technical Memorandum 200.7, CSO Beach Project GIS Analysis.* September 2008.
[3] http://www.greatcity.org/campaigns/green-infrastructure/

hard infrastructure solutions" (EPA, 2007). In addition to helping to reduce sewer overflows and the amount of untreated stormwater that finds its way to surface waters, green infrastructure facilitates natural processes that recharge groundwater, preserve baseflow in streams, moderate impacts to water and air temperature, and protect hydrologic and hydraulic stability.

Stormwater Bioretention in a Residential Area

Green Roof on Chicago's City Hall

Study Area

The basins and subbains that drain to the four Puget Sound beach CSOs are shown in Figure 1 and Figure 2.[4] Figure 1 also shows the locations of other King County CSOs. Stormwater in these basins flows directly to the CSS, directly to the separate municipal storm sewer system (MS4), or overland to a receiving water body. Characteristics of the basins are as follows:

- The North Beach basin lies in the northwest corner of Seattle on a northwest facing slope. The basin is 863 acres and is divided into three subbasins: 439, 440, and 441.

- The South Magnolia basin lies between the Lake Washington Ship Canal and Elliott Bay on the west side of the city. The basin is 771 acres and is divided into four subbasins: 151, 152, 153, and 154.

- The Murray basin lies in West Seattle just north of Lincoln Park. The basin is 992 acres and is divided into four subbasins: 419, 420, 421, and 423.

- The Barton basin lies just south of both Lincoln Park and the Murray basin. At 863 acres, it is smaller than the Murray basin and is made up of five subbasins: 414, 415, 416, 417, and 418.

[4] Subbasins were delineated for flow monitoring and modeling conducted in 2006.

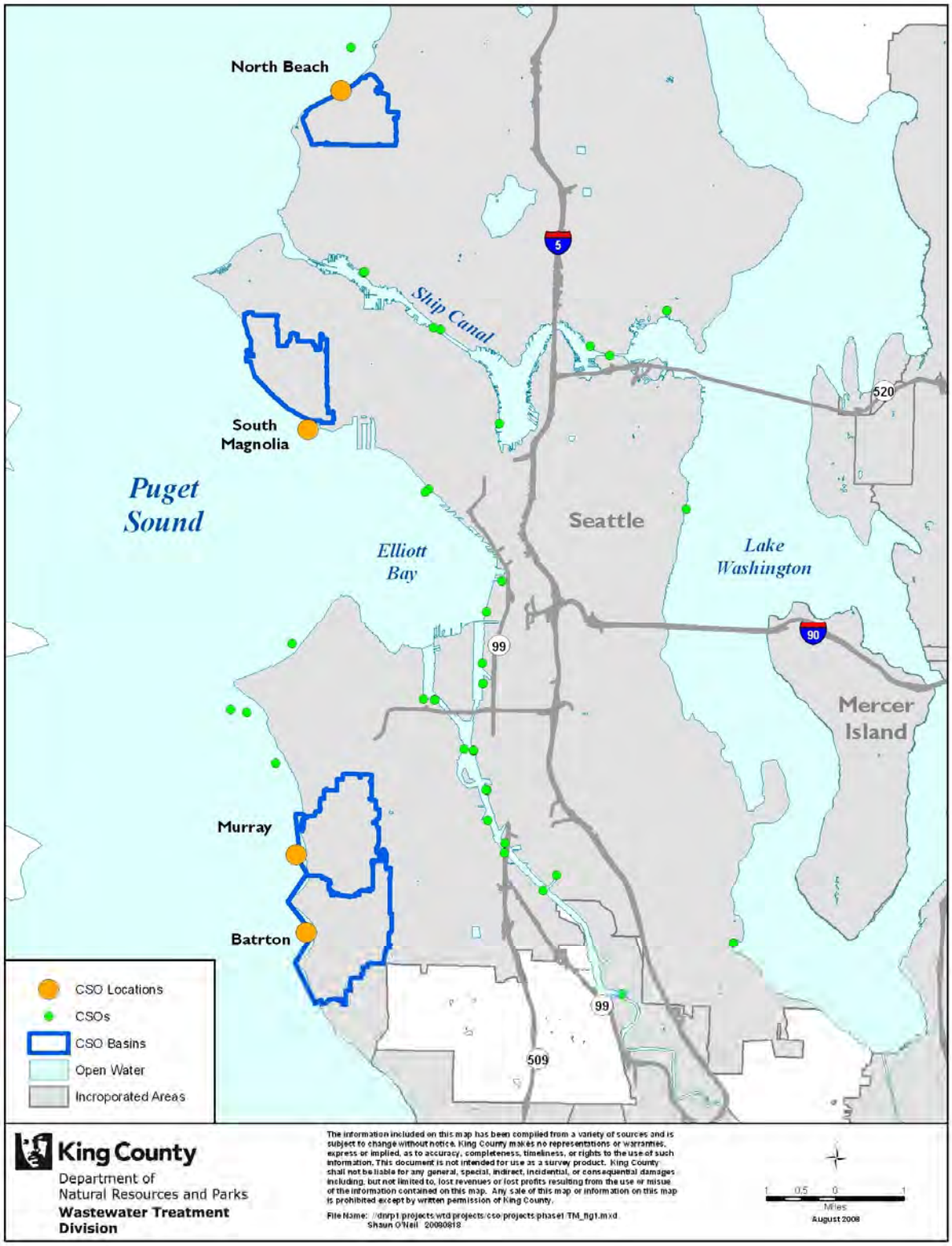

Figure 1. Location of Contributing Basins for Puget Sound Beach CSO Control Projects

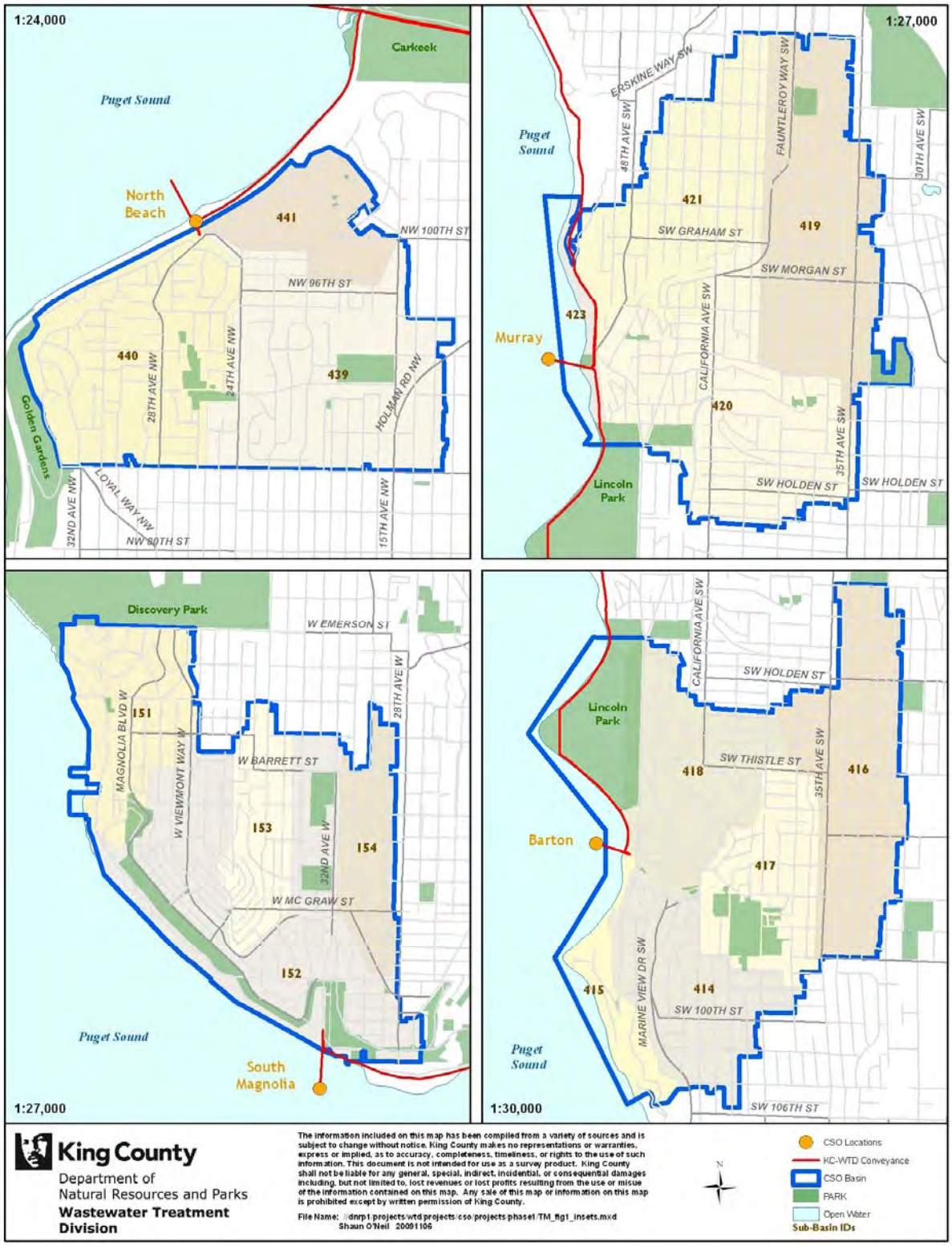

Figure 2. Location of Subbasins for Puget Sound Beach CSO Control Projects

Methodology

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

San Francisco's Approach

San Francisco conducted a literature review and case studies, reviewed existing San Francisco programs that could complement or support GSI, conducted a GIS spatial analysis of potential GSI implementation, modeled GSI scenarios in the collection system model, and conducted a cost-benefit analysis. The GIS spatial analysis relied on a set of criteria developed to help identify suitable locations for each of five GSI techniques:

- **Ecoroofs.** Also called green roofs, ecoroofs consist of shallow layers of growing medium, low-growing vegetation, subsurface drainage, and a waterproof membrane.
- **Roof disconnection.** A type of rainwater harvesting, roof disconnection refers to the practice of removing water that flows from a roof through a downspout to a CSS and redirecting it to some other location.
- **Street trees.** Each tree can intercept approximately 1,000 gallons of stormwater annually that would otherwise enter the conveyance system (Kennedy et al., 2007). Trees retain some of the rain in their canopies and uptake a portion of the rain that infiltrates to the soil via their root structures. Street trees are different from tree boxes and do not filter runoff from streets and other impervious surfaces.
- **Bioretention.** Bioretention involves dispersed small-scale landscape features designed to attenuate and treat stormwater (Kennedy et al., 2007). These features are typically vegetation-filled areas with a drainage mechanism, often located in parking lots, median strips, or streets.
- **Permeable pavement.** Permeable pavement allows rainfall to penetrate the pavement into a porous material that retains stormwater before it enters a combined sewer, thereby attenuating or removing the effects of the stormwater on the sewer. Permeable pavement is not suited for high-traffic areas.

King County's Approach

The analysis described in this technical memorandum is analogous to San Francisco's GIS spatial analysis of potential areas for GSI implementation. King County's approach to the analysis was as follows:

- Developed criteria to identify areas suitable for the five GSI techniques, starting with the San Francisco criteria and modifying them to accommodate data available for the City of Seattle (Table 1).

- Identified suitable areas and acreages in the 16 subbasins for implementation of each GSI technique by applying the criteria using the datasets listed in Table 2 in the areas identified in the earlier GIS analysis as flowing to the CSS (King County, 2008).

- Identified one subbasin that holds the most promise for implementation of GSI techniques to help reduce the scale of CSO control projects.

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

The sections that follow Tables 1 and 2 describe how areas were identified for each GSI technique.

Table 1. Criteria Used to Identify Areas Suitable for Green Stormwater Infrastructure Techniques

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

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

Table 2. List of GIS Datasets Used in the Green Stormwater Infrastructure Analysis

Feature Class Name	Description	Important Features	Field of Note
King County			
CSOBasin	CSO basin	Basin extents	
CSOBSN	Modeling subbasins	Monitored sub-basins	Basin_num
Parcel	Parcels	Address	
ROW	Rights-of-way		
lndcov_imp	Impervious areas		
DGM_TIN	Triangulated Irregular Network (TIN) of ground elevation from Light Detection and Ranging (LIDAR) data.	Elevation	
DSM_TIN	TIN of surface elevation from LIDAR	Elevation	
St_Address	Street network	Street classifications	KC_FCC
City of Seattle			
DWUMNL	Mainline conveyance	CSS, MS4, sewer designation	prble_flow
DWUMLAT	Lateral and side sewer conveyance	Sewer and storm drain designation	prble_flow
DWULATPT	Lateral line points	Storm drains, downspouts, infiltration pits	Ntype
CB_GPS	Storm drains in right-of-way	Storm drains	
BldgFtPt	Building footprints/rooftops		
ctr002	2-foot contours		
Ditches	Ditches	Culverts, ditches, curbs, tiled drains	Type
Arterial	Arterials	Arterials	
StTree	Street trees	Tree type	Genus, species

Ecoroofs

Structures suitable for ecoroofs were identified using the City of Seattle building footprint dataset. The analysis looked at buildings and garages with roofs that were greater than 5,000 square feet, that had slopes between 5 and 20 degrees, and that were connected to the CSS.

The San Francisco analysis found that only large ecoroofs offer enough benefit for stormwater management. The 5,000-square-foot cutoff represents a natural break between the area of a typical residential rooftop and that of a typical commercial/industrial rooftop. This criterion also is in line with the City of Seattle's design considerations for demand management solutions for CSO control. Further, it was assumed that most smaller roofs would have too great a slope to sustain an ecoroof. Only buildings and garages were included in the analysis because structures such as decks and patios are not suitable for ecoroof implementation.

Roof Disconnection

Stormwater flowing through roof downspouts to the CSS can be redirected to cisterns, the MS4, or some other non-CSS destination. King County's 2008 GIS analysis identified all structures in the four CSO basins that were directly connected to the CSS and that might be targeted for disconnection.

Roof disconnection is not necessarily a green stormwater infrastructure solution, but rather an alternative to be considered for reducing flows to the CSS. While the direct runoff from roofs is not a serious water quality issue, the ultimate destination of the runoff would need to be determined and appropriate methods to reduce water quality impacts would need to be undertaken.

Street Trees

Both private (parcel) and public (ROW) areas currently occupied by a tree or a building were identified by using the City of Seattle building footprint dataset and LIDAR (Light Detection and Ranging) images. An analysis of the difference in elevation between the ground and surface heights generated through the use of LIDAR data identified areas that as of 2001, had trees between 5 and 25 feet and areas that had trees greater than 25 feet. It was assumed in analyzing the LIDAR images that objects of less than 5 feet were not trees.

The remaining pervious areas were identified as being available for additional tree planting. Only pervious areas in the ROW were considered. It was assumed that private property owners may not be willing to plant trees for stormwater control purposes.

The extent other factors on the amount of street-tree GSI potential was not evaluated in this analysis. Property ownership considerations, utility interference, and other constraints such as type of tree could reduce the amount of the street-tree potential. For example, deciduous trees do not retain a canopy suitable for intercepting rainfall in the fall and winter months when Seattle experiences peak rainfall events. Conversely, tree canopies that overhang impervious areas adjacent to the identified pervious planting areas could increase the benefit of tree plantings. Also, identification of underused impervious areas (median strips, mid-block center turn lanes, and paved planting strips) may provide significant increases in the area that could be controlled by street trees.

A more robust analysis of potential benefits from street trees could be performed; however, the probability of using this technique for CSO control for the CSO beach projects is low. The time necessary for an evergreen tree to grow to maturity is too long, and waiting to realize the potential of this technique would put the King County CSO Control Program out of compliance.

Bioretention

Only areas in each subbasin with slopes of less than 5 percent were included in the identification of areas suitable for bioretention. Steeper slopes greatly reduce or eliminate retention effectiveness. Flows from any impermeable surface other than the rooftops were included. LIDAR data were used to identify basin slopes, and King County impervious area data were used to identify the impermeable surfaces.

Infiltration rates were not included in this analysis because of the low resolution of the available data. Variability in infiltration rates from block to block necessitates site-specific information, which will be considered in the design phase.

Permeable Pavement

As with the bioretention analysis, infiltration rates were not considered and only surface areas of less than 5 percent slope were included as candidates for permeable pavement. Low-traffic roads,

parking lots greater than 10,000 square feet, and alleys were included. Roads were identified using GIS street data and the “minor” feature class code of the Arterial dataset. The 10,000-square-foot limit on parking lots was based on an evaluation of impervious areas in each basin. This evaluation identified a natural break between parking lots and smaller non-parking lot areas, such as patios and driveways, at approximately 10,000 square feet.

Results

In the county’s 2008 GIS analysis conducted to determine the acreages that contribute stormwater flows to the CSS, assumptions were developed to compensate for inaccurate or insubstantial GIS data and to help model storm drain, downspout, and conveyance locations and conductivity. Acreages were calculated for two scenarios, designated as Scenarios A and B, to provide a minimum and maximum value for areas that contribute to the CSS. Both scenarios are considered valid for estimating surface area that could potentially be diverted from the CSS.

Each GSI technique was evaluated for both Scenarios A and B. The results are shown in Table 3. All of the criteria for a given scenario and source of flow—rooftop, impervious, or pervious—had to be met in order for that area to be considered as a source of flow for GSI techniques. Acreages identified for one GSI technique may also be included for another technique. For example, the acres under ecoroofs for a subbasin are also included in acres under roof disconnection for the same subbasin.

The analysis indicates that Subbasin 416 in the Barton CSO basin holds the highest potential for stormwater diversion/attenuation across all GSI techniques. This finding does not, however, imply that other subbasins could not benefit from GSI techniques nor that GSI techniques applied in Subbasin 416 will provide enough reduction in flows to the CSS to eliminate the need for additional CSO control.

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

Subbasin	Total acres (impervious/ rooftop)	Ecoroofs		Roof Disconnection		Street Trees		Bioretention		Permeable Pavement	
		Scenario									
		A	B	A	B	A	B	A	B	A	B
Barton											
414	234 (135)	0.8	1.2	3.6	7.2	0.1	0.1	0.9	0.4	0.1	0.1
415	115 (38)	1.0	0.8	2.5	2.2	0.0	0.1	1.5	0.8	1.2	0.4
416	314 (217)	5.1	5.4	37.8	48.6	10.0	10.9	40.1	40.1	26.3	26.3
417	200 (100)	1.2	1.6	2.9	18	0.3	0.3	1.4	1.4	2.5	2.9
418	249 (152)	1.2	4.1	5.6	28.2	0.0	0.0	2.8	2.3	2.7	2.7
Murray											
419	306 (184)	3.2	3.0	6.9	16.3	2.8	2.8	10.6	10.3	8.4	8.4
420	370 (215)	1.2	0.6	3.2	5.3	0.0	0.0	1.2	0.7	0.3	0.6
421	274 (171)	2.9	5.2	4.6	13.2	0.1	0.1	3.5	3.2	1.9	3.2
423	42 (5)	0.3	0.2	0.3	0.2	0.0	0.0	0.1	0.1	0.3	0.3
South Magnolia											
151	174 (94)	2.0	5.1	0.0	0.0	0.9	0.9	3.0	2.4	1.7	0.5
152	382 (262)	1.8	8.7	4.5	48.6	0.0	0.0	2.6	1.6	0.7	0.4
153	112 (82)	0.4	1.1	1.1	18.2	0.0	0.0	0.3	0.1	0.0	0.0
154	106 (76)	0.8	2.4	1.4	15.1	0.0	0.0	0.7	0.6	0.0	0.0
North Beach											
439	284 (208)	2.8	4.4	6.9	5.2	0.0	0.0	3.4	5.4	3.8	3.8
440	252 (140)	0.7	0.9	3.7	3.1	0.0	0.0	0.2	0.9	0.2	0.2
441	97 (59)	0.5	1.0	2.5	1.5	0.0	0.0	1.0	1.0	3.3	3.3

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

Recommendations and Next Steps

Two actions are recommended:

- Select Subbasin 416 as the pilot basin to be evaluated for GSI techniques for the Puget Sound CSO beach projects.
- Consider a roof disconnection program in Subbasin 152 to take advantage of the large potential there.

King County will work with the City of Seattle to develop a refined list of GSI solutions and will conduct an analysis to identify the amount of flow that could be removed from the CSS in Subbasin 416. The results of this analysis will contribute to the overall alternatives analysis for the Puget Sound CSO beach projects and will be used to further refine King County's procedure for evaluating GSI for CSO control projects. The refined procedure will be used in the preparation of the county's 2011 CSO control program review to identify GSI contributions for the remaining CSO control projects.

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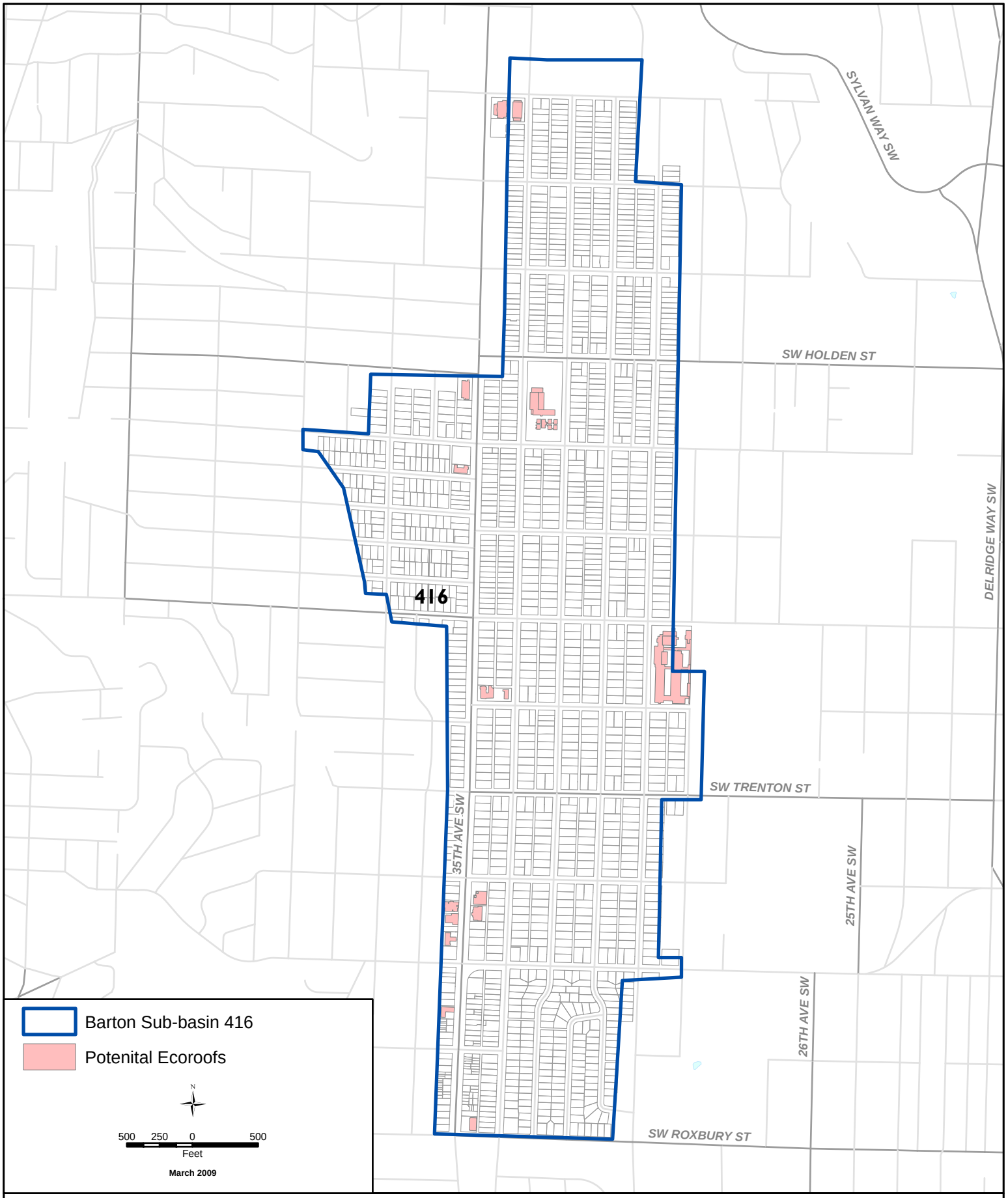

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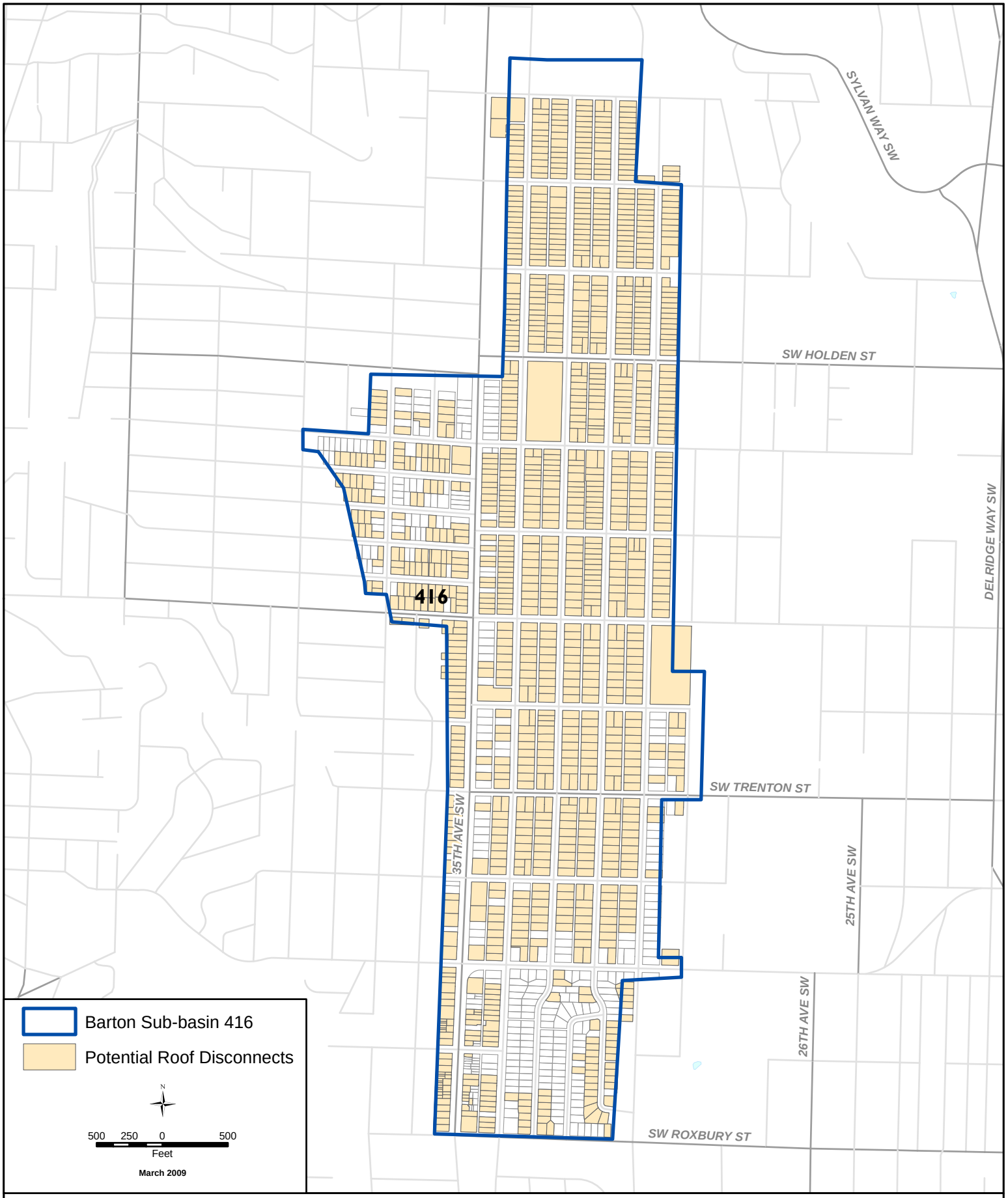
Barton CSO Basin
Sub-Basin 416
Structures with Ecoroof Potential



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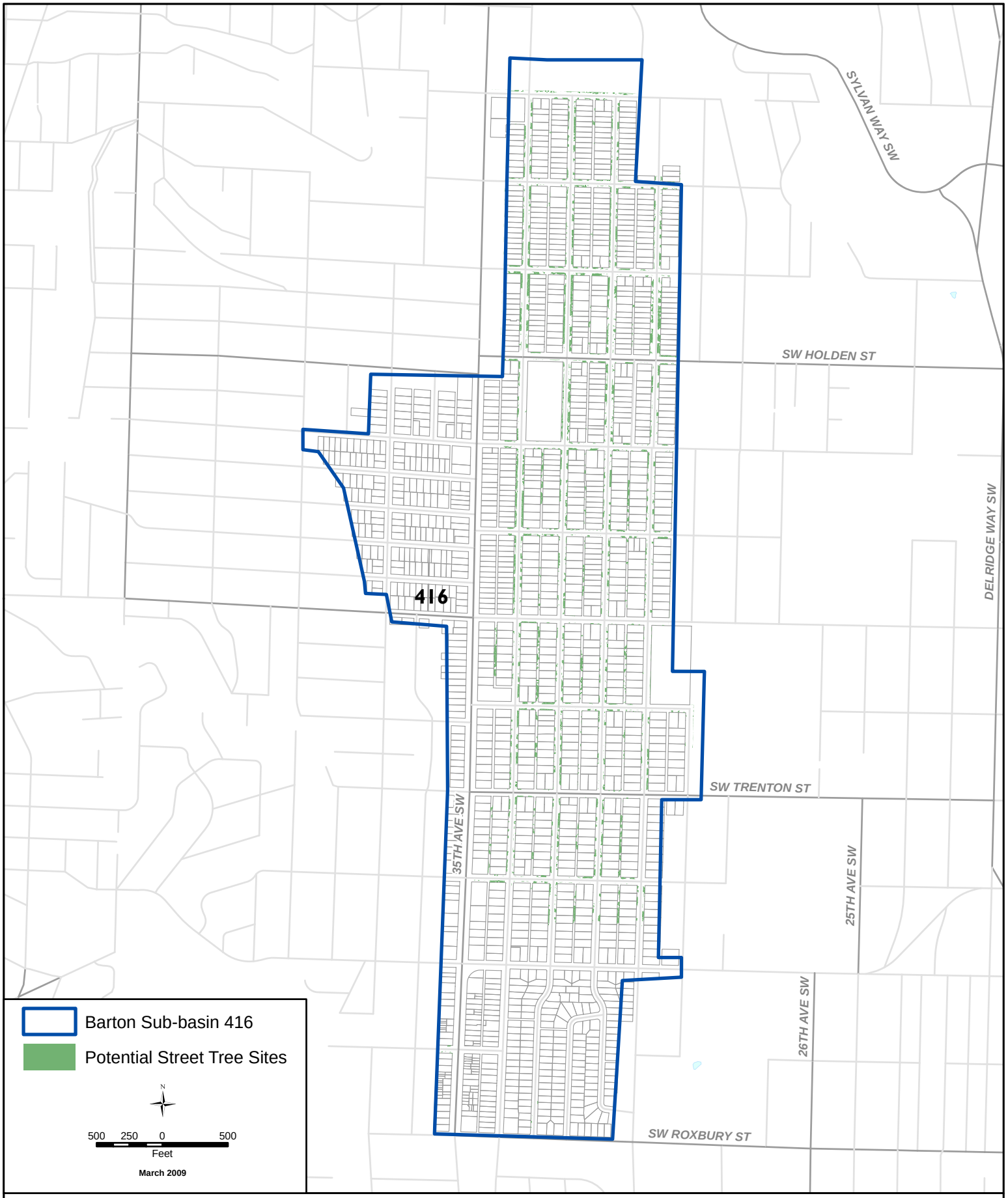
Barton CSO Basin
Sub-Basin 416
Structures with Roof Disconnection Potential



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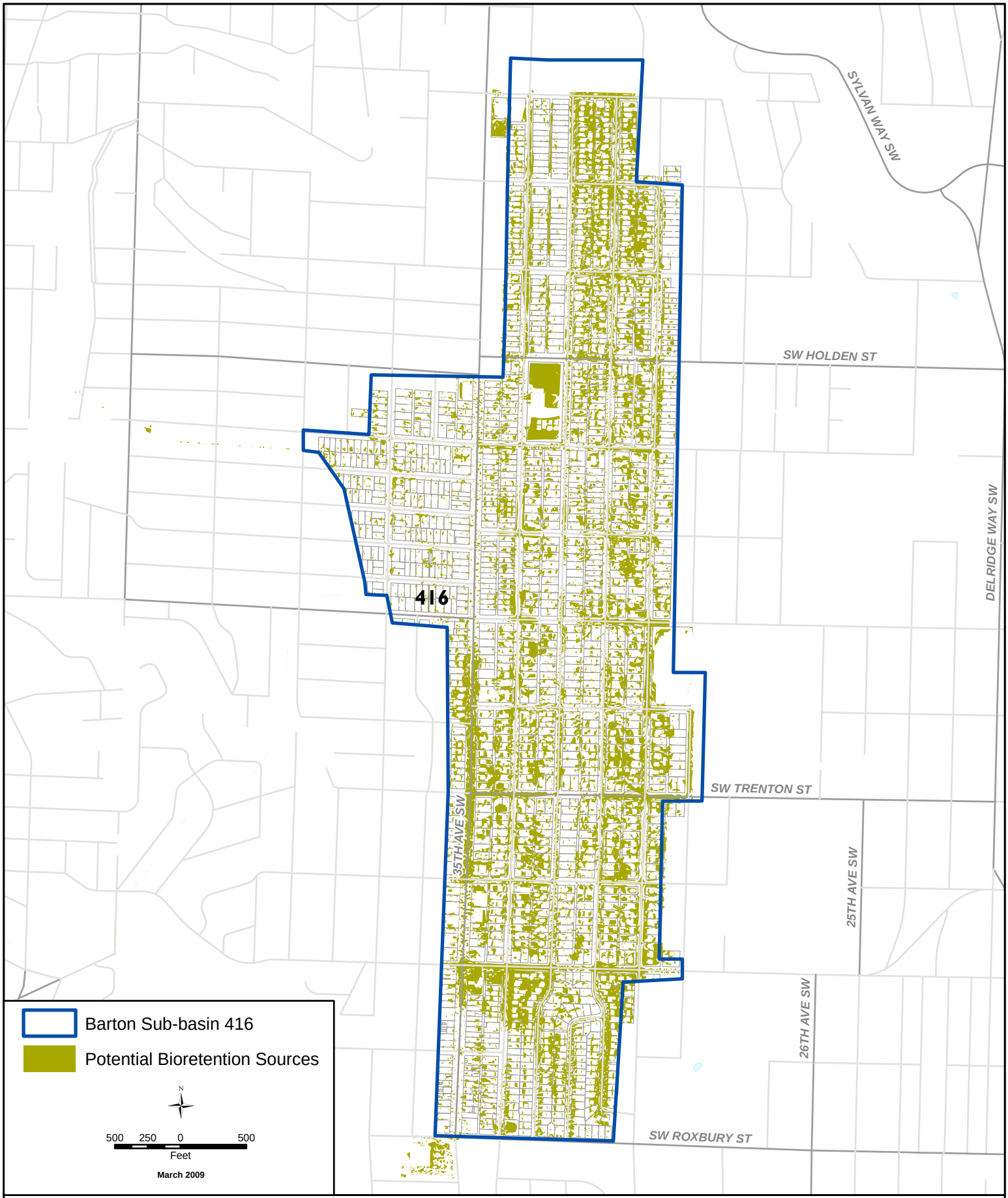
Barton CSO Basin
Sub-Basin 416
Areas with
Street Tree Potential



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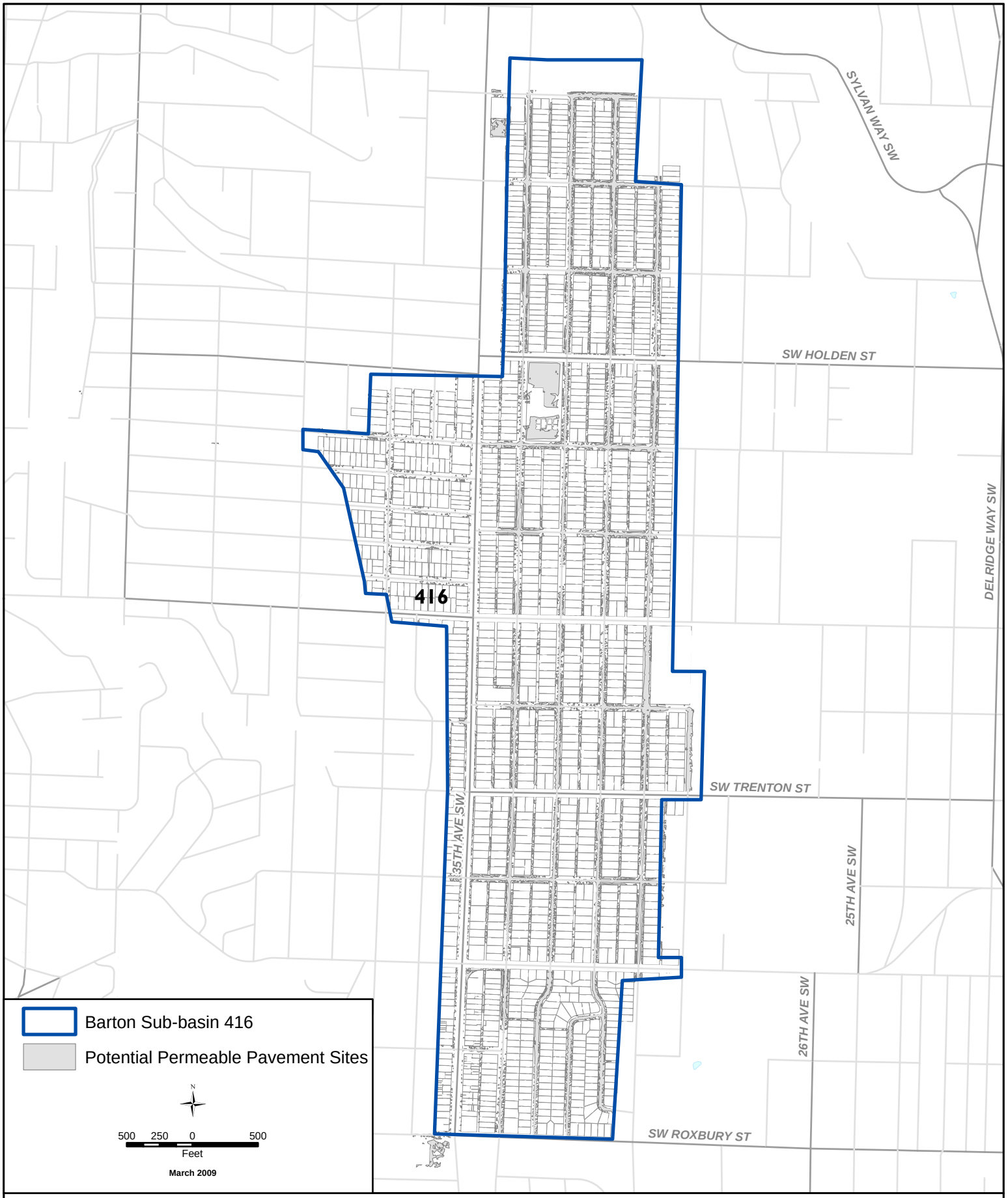
Barton CSO Basin
Sub-Basin 416
Areas with Bioretention Potential



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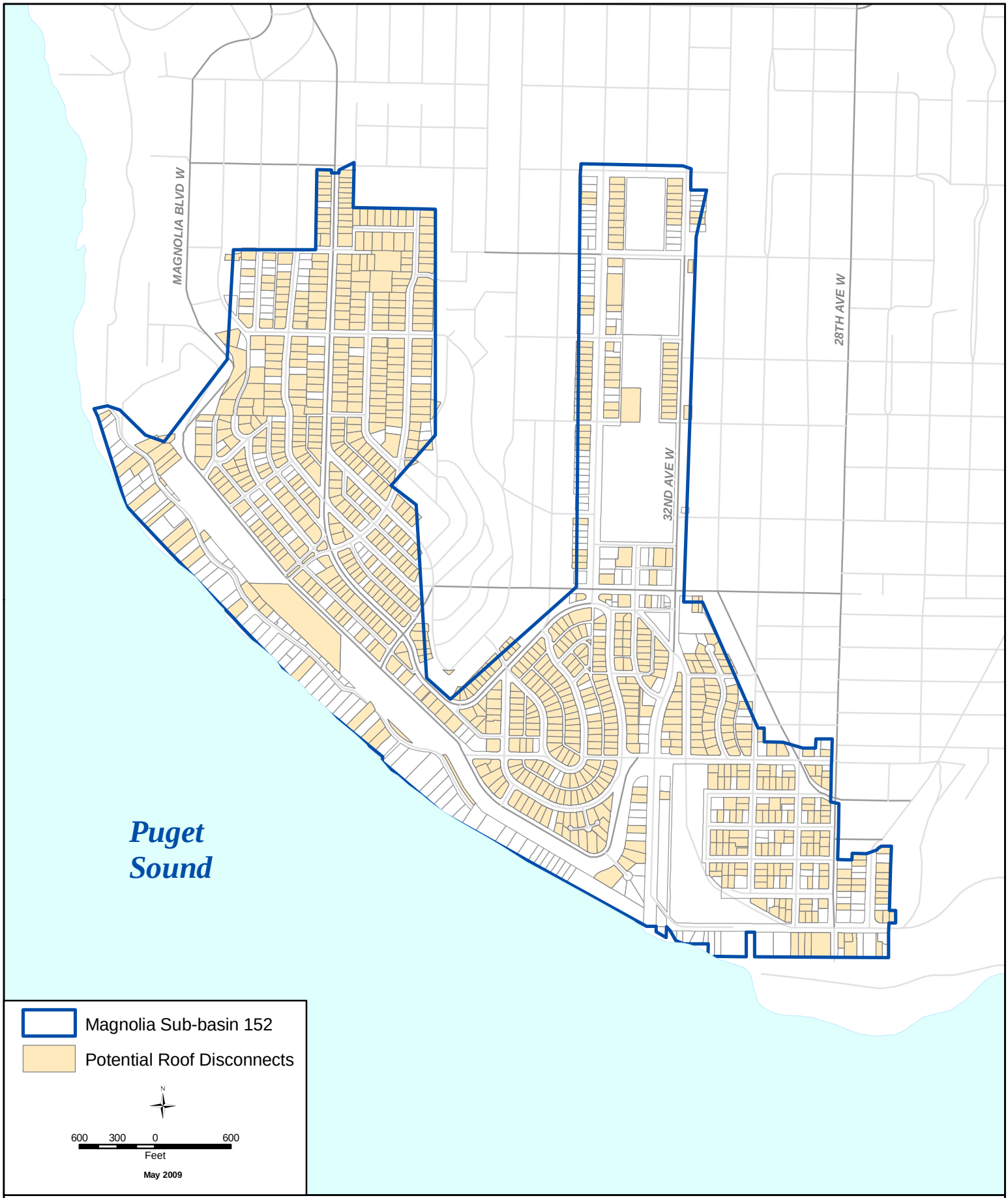
Barton CSO Basin
Sub-Basin 416
Areas with
Permeable Pavement Potential



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Shaun O'Neil 20090521

Magnolia CSO Basin
Sub-Basin 152
Structures with Roof Disconnection Potential