Seattle Public Utilities | Protecting Seattle's Waterways

Volume 3

Integrated Plan

Final | May 29, 2015

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Integrated Plan

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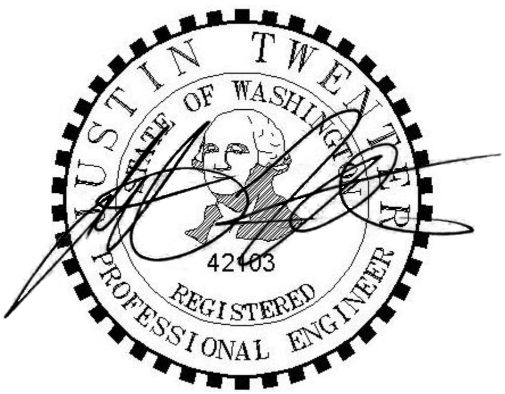

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List of Abbreviations

Term	Definition
µg/L	microgram(s) per liter
303(d)	list of impaired water bodies
As	arsenic
AVL	Automated Vehicle Location
AWQC	ambient water quality criteria
BMP	best management practice
BOD	biochemical oxygen demand
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CESF	chitosan-enhanced sand filtration
CFU	colony forming unit(s)
CI	confidence interval
City	City of Seattle
cPAH	carcinogenic polycyclic aromatic hydrocarbon
COC	Constituent of Concern
CSO	combined sewer overflow
Cu	copper
CWA	Clean Water Act
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
EIV	exposure index value
EMC	event mean concentration
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
kg	kilogram(s)
LCL	lower confidence limit
LTCP	Long-Term Control Plan
MCLG	maximum contaminant level goal
MG	million gallon(s)
mg/L	milligram(s) per liter
MG/yr	million gallons per year
mL	milliliter(s)
MODA	Multiple Objective Decision Analysis
MTCA	Model Toxics Control Act
N/A	not applicable
NDS	Natural Drainage Systems
NPDES	National Pollutant Discharge Elimination System

Term	Definition
O&M	operations and maintenance
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
PLM	pollutant load model
PM	particulate matter
PSP	Puget Sound Partnership
RCOC	Representative Constituent of Concern
RCW	Revised Code of Washington
RF	receptor factor
RfD	reference dose
ROS	regression on order statistics
SCADA	supervisory control and data acquisition
sdt	short dry ton(s)
SF	slope factor
SS4WQ	Street Sweeping for Water Quality program
SSI	Sewer System Improvements
State	Washington State
SWMM5	EPA Storm Water Management Model, Version 5
T&E	threatened and endangered
TSS	total suspended solids
UCL	upper confidence limit
UIC	underground injection control
USACE	U.S. Army Corps of Engineers
WAC	Washington Administrative Code
WQ	water quality
WTD	(King County) Wastewater Treatment Division
WWHM	Western Washington Hydrology Model
WWPCA	Washington Water Pollution Control Act
WWTP	wastewater treatment plant
yr	year(s)
Zn	zinc

Integrated Plan Summary

Background

The City of Seattle (City) is committed to protecting and enhancing water quality to sustain and improve the environment and Seattle's quality of life, while providing critical sewer and drainage services for Seattle residents, businesses, and visitors. The City operates a sewer system and a municipal separate storm sewer system, both of which are permitted under the National Pollutant Discharge Elimination System (NPDES) by the Washington Department of Ecology (Ecology).

The storm sewer system serves approximately two-thirds of the city, discharging approximately 13 billion gallons of stormwater to the receiving water bodies in and around the city during an average year. The combined sewer system serves approximately one-third of the city, conveying stormwater and sewage to regional wastewater treatment plants (WWTPs) owned and operated by King County. During heavy rainfall events, the combined sewer system is designed to allow discharge at designated relief points (outfalls) in order to avoid sewage overflows into streets, homes and businesses. These discharges are called combined sewer overflows (CSOs). CSOs are a mixture of untreated stormwater (about 90 percent) and wastewater that can adversely affect receiving water bodies.

The City is taking a number of actions to reduce water pollution reaching the receiving water bodies in and around Seattle. Those actions include implementing stormwater pollution reduction programs and constructing structural stormwater controls and CSO control projects. The City has completed numerous CSO control projects during the past 50 years, resulting in substantial reductions in CSO discharges. Despite these efforts, roughly 154 million gallons (MG) of stormwater and sewage were discharged during CSO events in 2012. Further reductions in CSOs are needed to protect our water bodies.

The City is developing a Long-Term Control Plan (LTCP) to achieve further reductions in CSO discharges. The LTCP focuses on the areas of the city that have not yet attained compliance with Washington state (State) and federal requirements for CSO discharges. The City is developing the LTCP under a Consent Decree agreement with the U.S. Environmental Protection Agency (EPA), U.S. Department of Justice, and Ecology, filed on April 16, 2013, and lodged on July 3, 2013, under Civil Action 2:13-cv-00678 (USA, 2013). The LTCP prescribes a number of CSO control projects (referred to herein as "LTCP projects") that must be constructed by December 31, 2025, in order to comply with the Consent Decree.

The City has devoted substantial resources to CSO controls over the past 50 years but only limited resources have been available to address the water quality impacts of discharges from the City's municipal separate storm sewer system. Ecology has found that stormwater runoff is the main pathway through which toxic pollutants enter Puget Sound (Ecology, 2011a), and the Puget Sound Partnership has identified stormwater pollution prevention as a top priority (PSP, 2013). Ecology estimates that stormwater contributes more than 50 times as much flow and 30 times as much solids loading as the CSO discharges to the Lower Duwamish Waterway (Ecology, 2013b).

To address this need, the City negotiated an "Integrated Plan" alternative in the Consent Decree. This alternative allows the City to implement stormwater control projects that will significantly benefit water quality in receiving water bodies, while deferring lower-benefit LTCP projects. For Ecology and EPA to accept the alternative proposal, the City must demonstrate that the stormwater projects provide water quality benefits beyond those that would be achieved by the LTCP projects alone. Deferred LTCP projects will still be implemented; however, the projects would be operational by 2030, as compared to 2025 under the LTCP alternative. Under the Integrated Plan alternative, LTCP projects with relatively high water quality benefits will not be deferred.

Controlling CSOs, complying with our state and federal requirements for CSO discharges is a top priority for the City and important for protecting the receiving water bodies in and around Seattle. The Integrated Plan allows the City to address pollution from stormwater as well as from CSOs. The Integrated Plan will cost more than the LTCP projects alone. However, the Integrated Plan will provide greater pollutant load reductions, water quality benefits, and protection of public health and safety and the environment than the LTCP projects alone.

Integrated Plan Development

The City prepared this Integrated Plan in accordance with the Consent Decree as well as with EPA guidance for integrated planning. The objective of the Integrated Plan is to propose stormwater projects that will provide significant benefits to water quality beyond those provided by the LTCP projects alone. The Integrated Plan identifies LTCP projects to be deferred until after 2025 so that the City can focus available resources on implementing the proposed stormwater projects.

To develop this Integrated Plan, the City completed the steps listed below:

1. Ranked local receiving water bodies and drainage basins based on the Consent Decree requirements (Chapter 2).
2. Engaged the public and regulatory agencies during development of the plan (Chapter 4).
3. Identified potential candidate stormwater projects for implementation and potential candidate LTCP projects for deferral based on the water body and drainage basin ranking and EPA guidance (Chapter 5).
4. Performed a screening evaluation to select candidate LTCP and stormwater projects for further evaluation (Chapter 5).
5. Compiled existing data relevant to the candidate projects and their potential impacts on pollutant loads and exposures for human and ecological receptors (Chapter 6).
6. Developed methods for evaluating and comparing the candidate projects based on the Consent Decree requirements (Chapter 6).
7. Obtained guidance from an independent Expert Panel on the methodology developed for evaluating and comparing the candidate projects (Chapter 6).
8. Estimated pollutant load reductions and exposure reductions for the candidate LTCP and stormwater projects (Chapter 7).
9. Identified the candidate stormwater projects that contribute significant water quality benefits compared to the candidate LTCP projects (Chapter 8).
10. Used Multiple Objective Decision Analysis (MODA) to score the candidate stormwater projects and compare the benefits of each project (Chapter 8).
11. Selected a combination of stormwater projects that would provide significantly more water quality benefits than the candidate LTCP projects proposed for deferral until after 2025. The Integrated Plan alternative to the LTCP consists of these selected LTCP and stormwater projects (Chapter 8).
12. Prepared the Integrated Plan document in accordance with relevant Consent Decree requirements and EPA guidance.
13. Included the Integrated Plan as Volume 3 in the City's Protecting Seattle's Waterways Plan, which consists of the following four volumes:
    - Volume 1: Executive Summary
    - Volume 2: Long-Term Control Plan
    - Volume 3: Integrated Plan
    - Volume 4: Programmatic Environmental Impact Statement

Selected Integrated Plan Projects

The City followed the steps listed above to develop this Integrated Plan, which is designed to provide significantly greater water quality benefits than the LTCP projects alone. The Integrated Plan consists of implementing three stormwater projects by 2025 and deferring construction completion of six candidate LTCP projects until 2030. The three stormwater projects are as follows:

- Natural Drainage Systems (NDS) Partnering
- South Park Water Quality (WQ) Facility
- Street Sweeping Expansion Arterials

NDS Partnering would entail reconstructing City rights-of-way to manage flow and provide water quality treatment for urban runoff using primarily the green infrastructure practice of bioretention (i.e., engineered rain gardens). The South Park WQ Facility would provide active basic treatment for roughly 74 million gallons per year (MG/yr) of stormwater runoff from a largely industrial area that discharges to the Lower Duwamish Waterway, thereby reducing the potential for recontamination of sediment remediation areas. The Street Sweeping Expansion Arterials would expand the area, frequency, and duration of the City's current arterial street sweeping efforts.

Under the Integrated Plan, LTCP Neighborhood Storage projects to control the following six CSO outfalls would be completed by 2030[1]:

- CSO Outfall 99
- CSO Outfall 107
- CSO Outfall 111
- CSO Outfall 138
- CSO Outfall 139
- CSO Outfall 140

All six LTCP projects involve detention of combined sewer flows. The detention facilities will be sized to reduce the frequency of CSO discharges to no more than once per year per outfall over a 20-year period. The six deferred LTCP projects are small relative to the largest non-deferred CSO projects included in the LTCP and the three stormwater projects in the Integrated Plan alternative.

Figure IPS-1 shows the locations of the stormwater projects to be implemented and the CSO outfalls whose control will be deferred under the Integrated Plan. Table IPS-1 summarizes these projects.

[1] Prior to 2025, SPU will implement Sewer System Improvements (SSI) designed to reduce oveflows from the CSO outfalls associated with the six deferred LTCP Neighborhood Storage projects. After the SSI have been completed, SPU will monitor the six affected outfalls to assess compliance with the state CSO control standard. SPU will then determine whether some or all of the deferred LTCP Neighborhood Storage projects can be downsized or eliminated.

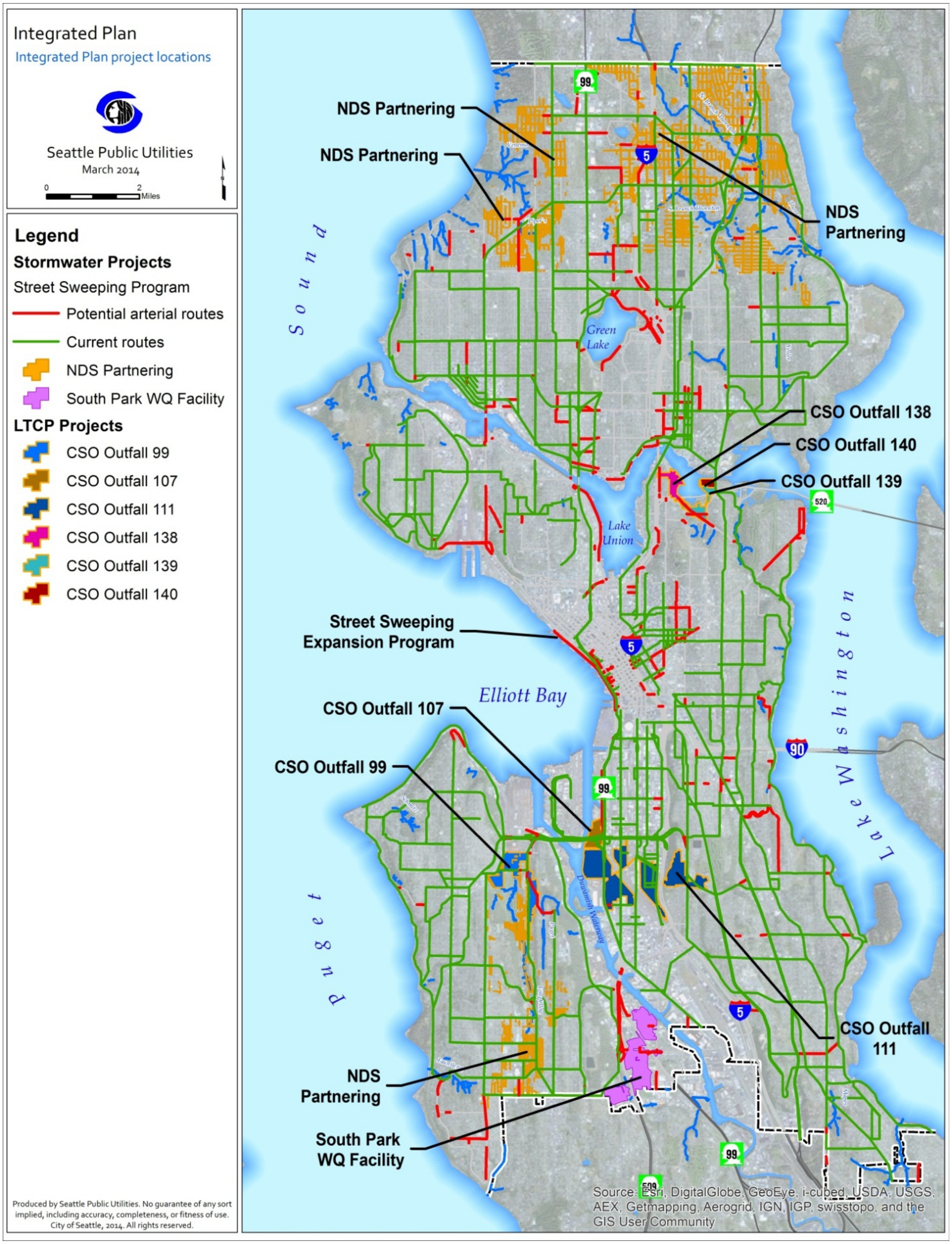

Figure IPS-1. Integrated Plan project locations

Table IPS-1. Summary of Integrated Plan Projects

Project name	Project type	Receiving water body	Average existing discharge frequency (average no. events/ yr)[a,b]	Average volume treated or removed (MG/yr)[c]	Life-cycle cost[d] (M$)	Construction completed (yr)
LTCP projects to be completed during 2028–30[e]						
CSO Outfall 99	Offline storage pipe	West Waterway of the Duwamish River	1.5	0.17	$8.2	2030
CSO Outfall 107	Offline storage tank	East Waterway of the Duwamish River	4.6	1.1	$24.2	2030
CSO Outfall 111	Offline storage pipes	Duwamish River	1.7	0.01	$7.3	2030
CSO Outfall 138	Offline storage tank	Portage Bay	1.4	0.09	$7.5	2030
CSO Outfall 139	Offline storage pipes	Portage Bay	1.2	0.01	$1.9	2030
CSO Outfall 140	Offline storage pipes	Portage Bay	3.7	0.05	$4.4	2030
Stormwater projects/programs to be implemented by 2025[f]						
NDS Partnering	Bioretention	Longfellow Creek, Piper's Creek, Thornton Creek	119	35	$27.2	2025
South Park WQ Facility	Basic, active treatment (e.g., CESF[g])	Duwamish Waterway	119	74	$34.8	2025
Street Sweeping Expansion Arterials	Street sweeping (weekly arterial sweeping)	Multiple	119	1,527[h]	$26.1	N/A[i]

a. For stormwater projects, the existing discharge frequency was estimated using data from 10 years' worth of recorded rainfall data from a City rain gauge. A discharge event was considered as an "event" if, on that particular day, the precipitation depth was at a minimum of 0.03 inch. Based on collected flow monitoring data, a rainfall depth of 0.03 inch generates flow in the storm sewer system.

b. The existing discharge frequencies for the candidate LTCP projects can be found in the 2012 Annual CSO Report.

c. The estimated annual average volume removed by the candidate LTCP projects was calculated using the moving 20-year average simulated volumes, without the consideration of climate change. This means that the precipitation data used for modeling were not modified to account for potential effects of climate change on rain; therefore, a scaling factor of 1 was assumed. See Volume 2 of the LTCP report on a more detailed discussion of the hydraulic modeling conducted.

d. Present value in 2014 dollars assuming 100-year project life and 3% discount rate based on Integrated Plan schedule.

e. Prior to 2025, SPU will implement Sewer System Improvements (SSI) designed to reduce oveflows from the CSO outfalls associated with the six deferred LTCP Neighborhood Storage projects. After the SSI have been completed, SPU will monitor the six affected outfalls to assess compliance with the state CSO control standard. SPU will then determine whether some or all of the deferred LTCP Neighborhood Storage projects can be downsized or eliminated.

f. SPU anticipates that the South Park and NDS Partnering projects will have a life span of 50 years. Street Sweeping Expansion for the Integrated Plan will be conducted up to 2030 or until all six of the deferred CSOs have been controlled. At that time, SPU will determine whether to continue the Street Sweeping Expansion program.

g. CESF is chitosan-enhanced sand filtration.

h. Volume is based on estimated runoff from swept streets.

i. The Street Sweeping Expansion Arterials program will begin in 2015. The purchase of sweepers and program implementation will be complete by 2016. Post-construction monitoring will occur between 2016 and 2019.

The Integrated Plan will result in significant benefits to water quality beyond those that would be achieved by the candidate LTCP projects alone. Figure IPS-2 shows that the three stormwater projects selected for the Integrated Plan would treat much larger volumes than the six deferred LTCP projects would control.

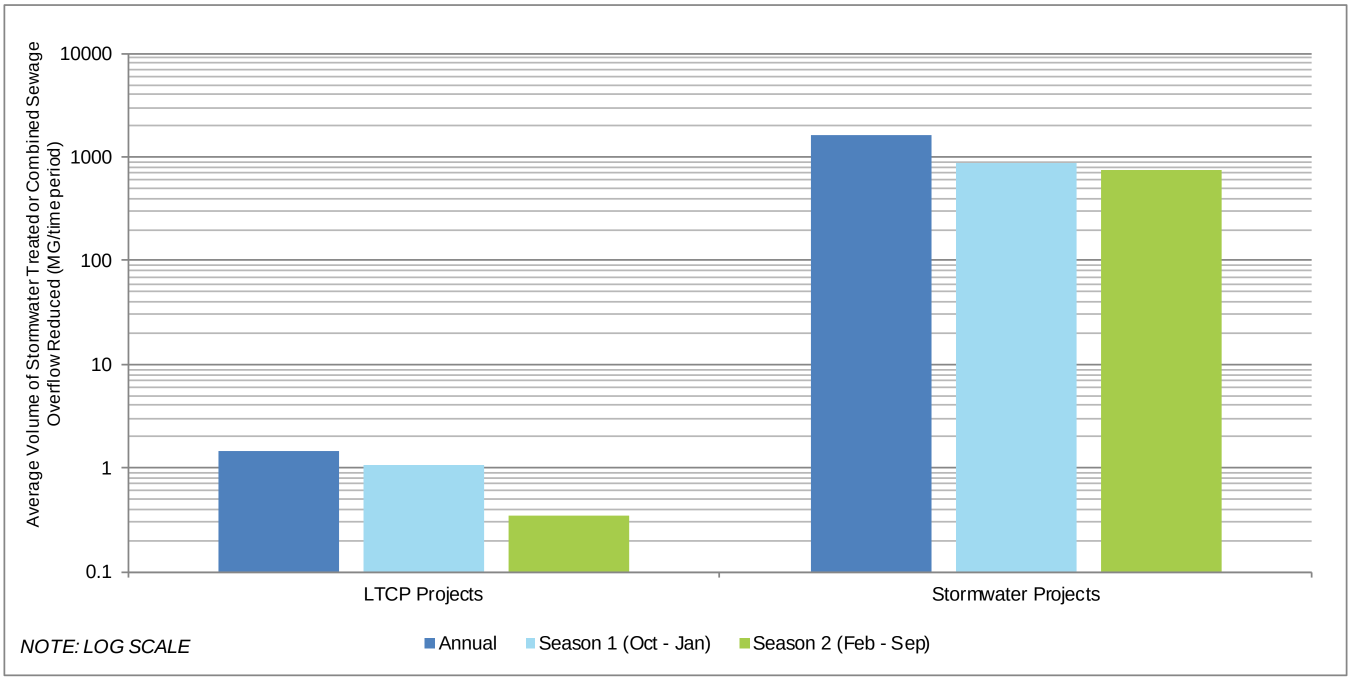

Figure IPS-2. Volume treated or reduced by Integrated Plan projects

Average volumes for Season 1 and Season 2 are shown to illustrate variations in seasonality. Season 1 is considered "wet," whereas Season 2 is considered "dry." Modeling of LTCP project discharges has shown that 65% of the CSOs occur during the "wet" season with their associated overflow volume at about 85% of the total simulated CSO volume.

Table IPS-2 lists the average projected pollutant load reduction benefits of each Integrated Plan project. Figure IPS-3 shows the cumulative load reduction of the selected Integrated Plan stormwater projects relative to the cumulative load reduction of the deferred LTCP projects. As shown in Figure IPS-3, the three stormwater projects would remove approximately 35 times as much dissolved copper, 100 times as much dissolved zinc, and 130 times as much total suspended solids (TSS) as the six deferred LTCP projects. As noted above, the six deferred LTCP projects are small relative to the largest non-deferred projects included in the LTCP.

Table IPS-2. Average Annual Pollutant Load Reduction Benefits from Each Project Included within the Integrated Plan

Project	Average volume treated or removed (MG/ yr)	Ammonia-N (kg)	Biochemical oxygen demand (kg)	Bis(2-ethylhexyl) phthalate (kg)	Dichlobenil (kg)	Dissolved copper (kg)	Dissolved zinc (kg)	Fecal coliform bacteria (billion CFU)	H+ (kg)	Oil and grease (kg)	PBDEs (kg)	PCBs (kg)	Phosphorus (kg)	Total copper (kg)	Total suspended solids (TSS) (kg)	Total zinc (kg)
Candidate LTCP projects																
CSO Outfall 99	0.17	0.78	12	0.0015	0.000070	0.0032	0.012	651	0.000073	2.2	0.000038	0.000032	0.37	0.0084	20	0.026
CSO Outfall 107	1.1	19	82	0.035	0.00029	0.027	0.14	4346	0.00049	15	0.00025	0.00046	6.6	0.22	494	0.57
CSO Outfall 111	0.0086	0.15	0.64	0.00027	0.000003	0.00021	0.0011	34	0.0000038	0.11	0.0000020	0.0000036	0.05	0.0017	4	0.0044
CSO Outfall 138	0.091	0.43	6.8	0.00081	0.000041	0.0018	0.0067	360	0.000040	1.2	0.000021	0.000018	0.21	0.0046	11	0.015
CSO Outfall 139	0.0057	0.027	0.42	0.000050	0.000003	0.00011	0.00042	22	0.0000025	0.075	0.0000013	0.0000011	0.013	0.00029	0.69	0.00090
CSO Outfall 140	0.051	0.24	3.8	0.00045	0.000023	0.0010	0.0038	201	0.000023	0.67	0.000012	0.000010	0.12	0.0026	6	0.0081
Total	**1.4**	**21**	**106**	**0.038**	**0.00043**	**0.034**	**0.16**	**5,614**	**0.00063**	**19**	**0.00032**	**0.00053**	**7.3**	**0.24**	**536**	**0.63**
Candidate stormwater projects																
NDS Partnering	35	9.2	684	0.22	0.0048	0.46	3.2	17,910	0.015	396	0.0029	0.0018	14	1.3	7,704	11
South Park WQ Facility	74	0.0	1,088	0.29	0.0	0.71	14	52,700	0.0	702	0.0047	0.0069	46	4.5	24,741	29
Street Sweeping Expansion Arterials	1,527[a]	N/A	337	0.14	N/A	N/A	N/A	2,100	N/A	69	0.0096	0.0033	24	5.2	36,200	10
Total	**1,636**	**9.2**	**2,109**	**0.64**	**0.0048**	**1.17**	**17**	**72,710**	**0.015**	**1,167**	**0.017**	**0.012**	**83**	**10.9**	**68,645**	**51**

N/A = not applicable.

a. *The average annual runoff volume treated for the street sweeping program was estimated based on street area swept, mean annual rainfall, the fraction of annual rainfall events that produces runoff, and a runoff coefficient. Refer to Appendix G, Section 2.2.3 for additional details.*

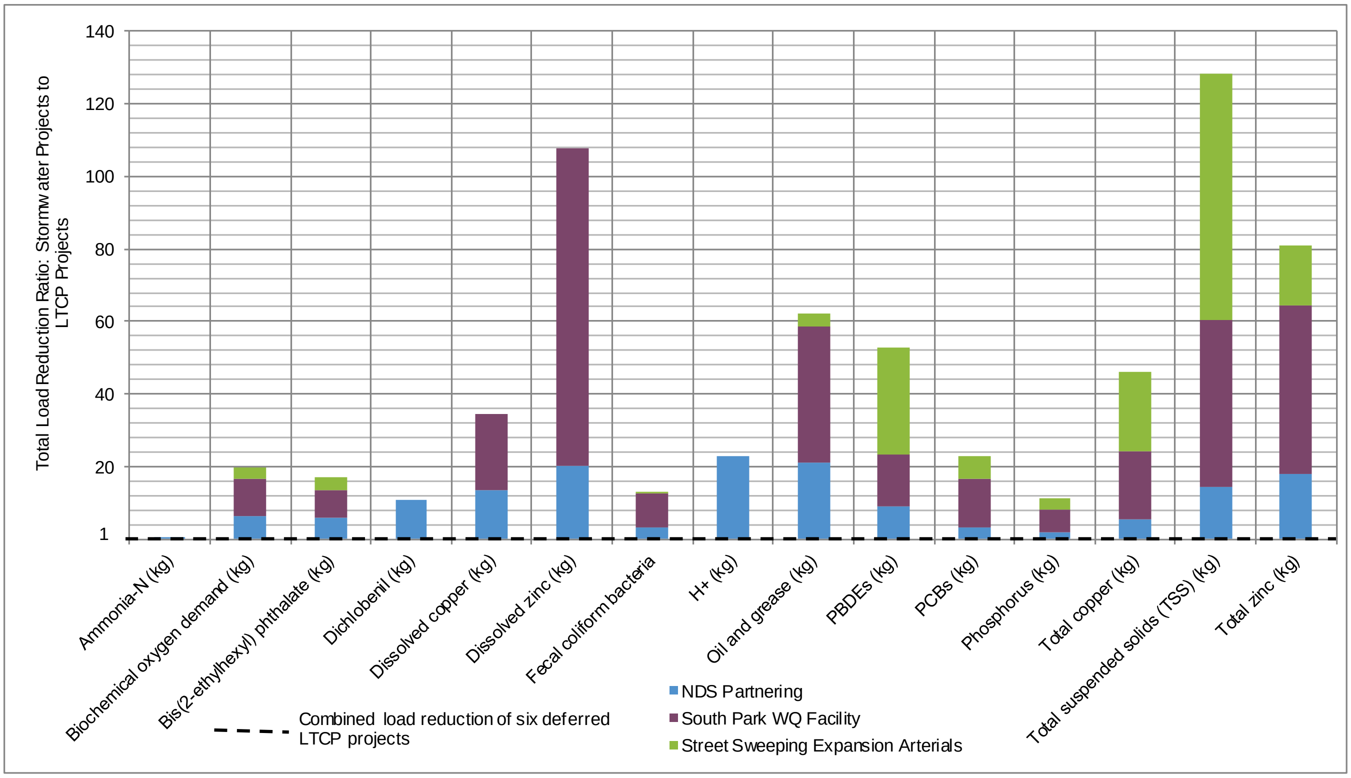

Figure IPS-3. Significant pollutant load reduction benefits of Integrated Plan

The Integrated Plan will provide pollutant load reductions to a number of receiving water bodies that the LTCP projects would not otherwise address, including impaired water bodies and water bodies that provide salmonid habitat. Moreover, the Integrated Plan will provide hydrologic benefits to several small creeks that have been adversely affected by hydromodification.

Integrated Plan Implementation Schedule

Table IPS-3 contains the schedule for implementing the LTCP projects and stormwater projects that compose the Integrated Plan. The City will implement all of the proposed stormwater projects by December 31, 2025. The City will begin designing the LTCP projects in 2024 and complete construction by 2030.

Table IPS-3. Implementation Schedule							
Project name	**Draft engineering report[a]**	**Final engineering report**	**Draft plans and specs**	**Final plans and specs**	**Construction start**	**Construction completion/ project completion[b]**	**Achieve controlled status/ post-construction monitoring completed[c]**
LTCP outfalls to be controlled during 2028-30							
CSO Outfall 99	6/30/2017	12/31/2026	6/30/2018	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 107	6/30/2017	12/31/2024	6/30/2019	12/31/2026	7/1/2027	9/30/2030	9/30/2031
CSO Outfall 111	6/30/2021	12/31/2026	6/30/2022	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 138	6/30/2016	12/31/2026	6/30/2017	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 139	6/30/2016	12/31/2026	6/30/2017	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 140	6/30/2016	12/31/2026	6/30/2017	12/31/2027	7/1/2028	9/30/2030	9/30/2031
Stormwater projects/programs to be implemented by 2025							
NDS Partnering	NA	NA	NA	NA	7/17/2019	12/28/2025	9/30/2029
South Park WQ Facility	NA	NA	NA	NA	12/31/2023	12/31/2025	9/30/2028
Street Sweeping Expansion Arterials	NA	NA	NA	NA	2015[d]	N/A	9/30/2019

a. SPU will submit the draft engineering report to Ecology for review.

b. "Construction Completion" dates apply to the LTCP projects and that "Project Completion" dates apply to the Stormwater projects/programs.

c. "Achieve Controlled Status" dates apply to the LTCP projects and that "Post-Construction Monitoring Completed" dates apply to the Stormwater projects/programs.

d. *The "Construction Start "for Street Sweeping Expansion Arterials is the notice to proceed date for SDOT to initiate the program.*

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CHAPTER 1

Introduction

On July 3, 2013, a Consent Decree addressing the control of sewage discharges from the City of Seattle (City)'s combined sewer system was entered in U.S. District Court under Civil Action 2:13-cv-00678 (USA, 2013). The Consent Decree agreement between the City, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) requires the City to develop a Long-Term Control Plan (LTCP) and implement measures for controlling combined sewer overflows (CSOs) by the end of 2025. Section V.B. paragraph 20 of the Consent Decree allows the City to propose an Integrated Plan alternative that would allow certain stormwater quality improvements to be implemented prior to implementing the CSO control measures that provide the least water quality benefit. The City prepared this Integrated Plan in accordance with the Consent Decree and applicable EPA guidance (EPA, 2012).

1.1 Project Background

The City owns and operates a sewer system that conveys sewage to regional wastewater treatment plants (WWTPs) owned and operated by King County. Approximately one-third of the city is served by combined sewers, which convey both stormwater and sewage. The combined sewer system is designed to overflow at permitted relief points during heavy rainfall events. CSOs help the City avoid serious operational, environmental, and public-safety concerns, such as sewage overflowing into streets or basements. CSO discharges contain untreated wastewater and stormwater that can adversely affect receiving water bodies. The City is required to reduce these discharges to no more than one overflow per outfall per year on a long-term basis. Figure 1-1 shows the areas of the city (also referred to as the locations of the CSO basins) that currently do not meet this requirement. The City is developing an LTCP (Volume 2: Long-Term Control Plan) to address these CSO basins. The LTCP identifies CSO control projects that will meet the performance requirement by December 31, 2025, as required by the Consent Decree.

In addition to the sewer system, the City owns and operates a municipal separate storm sewer system. The storm sewer system discharges approximately 13 billion gallons during an average year. Stormwater is the main pathway through which toxic pollutants enter Puget Sound (Ecology, 2011a), and the Puget Sound Partnership has identified stormwater pollution prevention as a top priority (PSP, 2013).

Seattle has devoted substantial resources toward CSO reduction over the past 50 years. As a result, current CSO discharges are a small fraction of historical flows. The City's CSO discharge volume of 154.2 million gallons (MG) in 2012 was many times lower than the average annual discharge volume from the City's storm sewer system. Ecology has estimated that stormwater contributes more than 50 times the flow and 30 times the solids loading of the CSO discharges to the Lower Duwamish Waterway (Ecology, 2013b).

The Consent Decree allows the City to propose an Integrated Plan as an alternative to the LTCP. EPA and Ecology approval of the Integrated Plan would allow the City to defer certain CSO control projects so that stormwater quality improvements providing greater water quality benefit could be implemented sooner. The City would still be required to meet the CSO performance standard, but would have longer to complete the last few CSO control projects.

If approved by EPA and Ecology, the Integrated Plan would allow the City to (1) defer implementation of selected CSO control projects (referred to herein as "candidate LTCP projects") until after 2025 and (2) implement stormwater projects by 2025 that would provide significant benefits to water quality beyond those that would be achieved by implementing the LTCP projects alone. All CSO basins would still achieve the CSO performance standard but the City would defer completion of the last few CSO control projects to 2030.

In order to meet the 2025 deadline for controlling all CSO outfalls, the City would need to focus its resources on CSO control measures. Approval of the Integrated Plan would allow the City to defer some of the smallest LTCP projects and devote resources to stormwater quality projects that provide substantially greater water quality benefits.

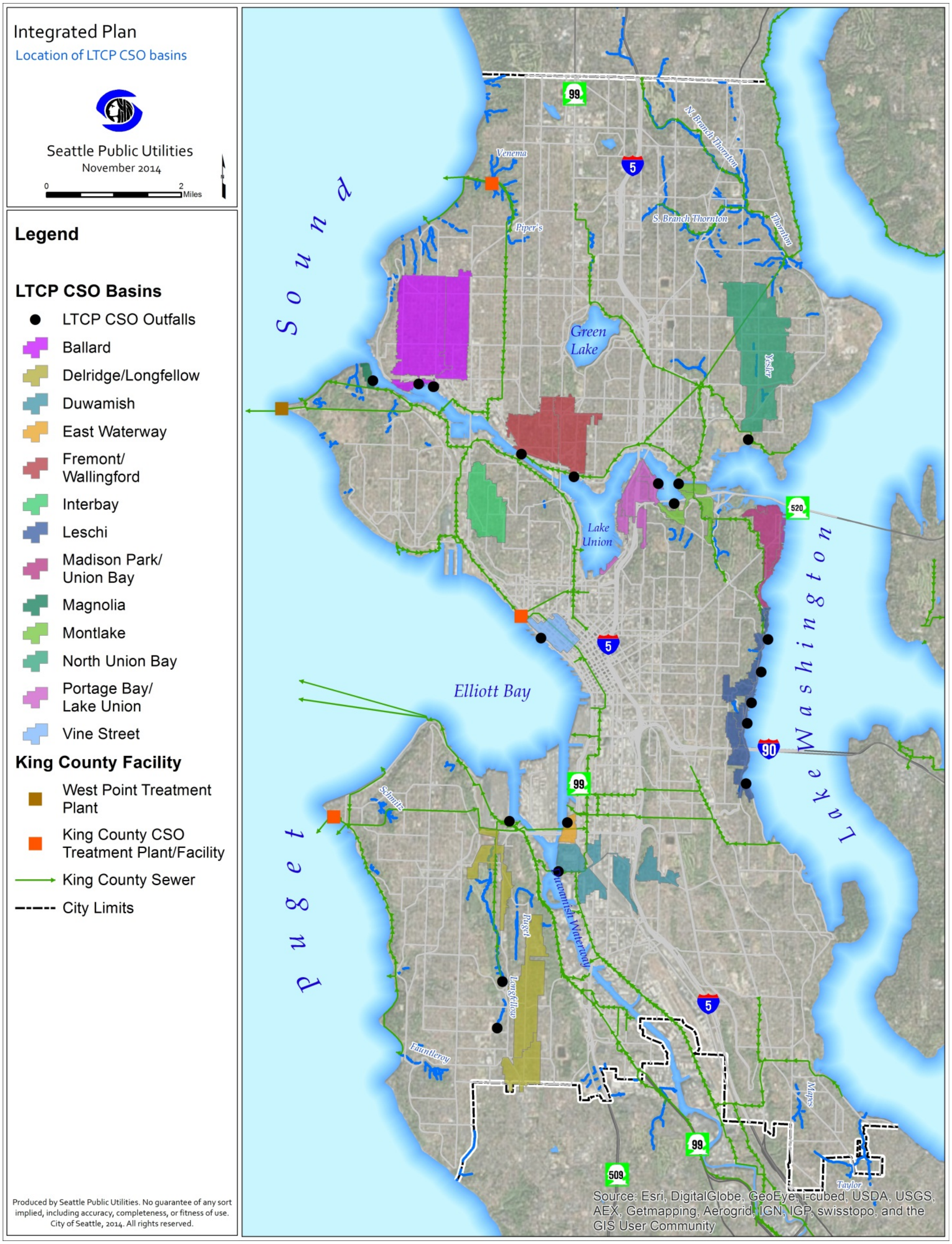

Figure 1-1. Location of LTCP CSO basins

1.2 Integrated Planning Objectives

The objective of the Integrated Plan is to propose a mix of stormwater improvements and LTCP projects that together will provide significantly more benefit to water quality than the LTCP projects alone. This Integrated Plan will allow the City the opportunity to prioritize its investments in water quality and provide more benefits to the city's receiving water bodies.

1.3 Seattle's Approach to Integrated Planning

The City developed its integrated planning approach based on the Consent Decree Section V.B. paragraph 20 (USA, 2013), recent EPA guidance (EPA, 2012), and input provided by an independent Expert Panel. Figure 1-2 shows the basic steps that were used to create this plan. Section 5.3.1 provides a more detailed discussion of this approach.

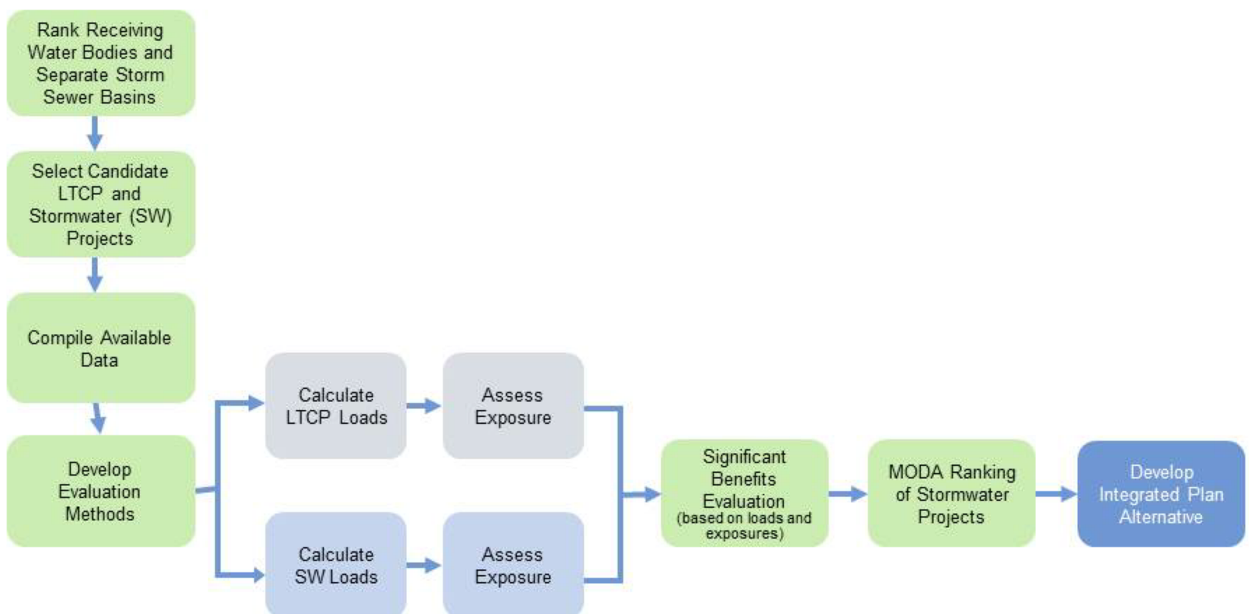

Figure 1-2. Integrated planning approach

The City ranked local receiving water bodies and drainage basins based on the Consent Decree requirements and estimated stormwater total suspended solids (TSS) loads, which were used as an initial indicator, from stormwater basins. While not required by the Consent Decree, the ranking was done to focus planning on water bodies that have the characteristics identified by the Consent Decree as important. The City then developed an initial list of stormwater projects for potential inclusion in the Integrated Plan and conducted a screening evaluation to select candidate stormwater projects for further evaluation.

To identify candidate LTCP projects for potential deferral, the City ranked the LTCP projects in the LTCP based on EPA criteria (EPA, 1995). The City selected six low-frequency, low-volume LTCP projects, also called LTCP Neighborhood Storage projects, as candidates for deferral under the Integrated Plan.

The City compiled existing data relevant to the candidate LTCP and stormwater projects and their potential impacts on pollutant loads and exposures for human and ecological receptors. Based on review of the existing data and input from an independent Expert Panel, the City developed methods for evaluating and comparing the candidate projects. The City then applied these methods to estimate pollutant load reductions and exposure reductions for the candidate LTCP and stormwater projects. These results were used to identify candidate stormwater projects that appeared to provide significant water quality benefits compared to the candidate LTCP projects. The next steps involved scoring the projects using a Multiple Objective Decision Analysis (MODA) and conducting a cost-benefit analysis.

The City used the results of the preceding steps to select a combination of stormwater projects that would provide significantly more water quality benefits than the six candidate LTCP projects alone. The Integrated Plan alternative to the LTCP consists of these three stormwater projects and six LTCP projects.

1.4 Supporting Documentation

The City developed this Integrated Plan using the reports and documents listed below:

- Long-Term Control Plan Hydraulic Modeling Reports (Brown and Caldwell, 2012). Volume 1 is the Executive Summary. CSO basins assessed in this Integrated Plan are described in Volume 3, Delridge/Longfellow; Volume 4, Duwamish; Volume 9, Montlake; and Volume 11, Portage Bay.
- Calibrated Storm Water Management Model (SWMM) hydrologic/hydraulic models for the six candidate LTCP CSO basins. (SPU, 2014a; in progress). (Hydraulic models of the uncontrolled LTCP CSO areas contain all of the public pipes and maintenance holes in the system. These models also contain special hydraulic structures, including pump stations, weirs, gates, orifices, storage tanks, and HydroBrakes. All modeling work was performed using Build 5.0.022 of EPA SWMM5.)
- Integrated Plan: CSOs for Potential Deferral Technical Memorandum. Prepared by Seattle Public Utilities. April 9, 2013 (SPU, 2013b).
- Integrated Plan: Stormwater Treatment Project Screening Technical Memorandum. Prepared by Seattle Public Utilities. April 10, 2013 (SPU, 2013c).
- Briefing Memorandum for April 29, 2013, Expert Panel Meeting. Briefing Memorandum on Stormwater and CSO Project Evaluation and Exposure Assessment Methods. Prepared by Seattle Public Utilities. April 22, 2013, revised May 23, 2013 (SPU, 2013e).
- Geographic information system (GIS)-based models for estimating TSS loads and flows for various land covers in Seattle. (The GIS-based model was developed by Seattle Public Utilities. It is described in Appendix C.)
- Western Washington Hydrology Models (WWHM) for the candidate stormwater project drainage areas. (WWHM was developed by Ecology. The most recent update was in 2012.)
- Pollutant load models (PLM). (These models were developed for the Integrated Plan. Refer to Appendices F and G.)

Most of these documents are included in the appendices to this Integrated Plan. The remainder are available from Seattle Public Utilities.

1.5 Conformance with Consent Decree Requirements and EPA Guidance

This Integrated Plan document was prepared to meet requirements of the Consent Decree, Section V.B. paragraph 20, which establishes requirements for the development and documentation of the evaluation of the candidate LTCP (CSO reduction) and stormwater projects for inclusion within the Integrated Plan. This plan summarizes the process used in developing the proposed Integrated Plan and serves as Volume 3 of the four reports to be submitted to Ecology and EPA. The following four volumes will be submitted in accordance with the Consent Decree requirements:

- Volume 1: Executive Summary
- Volume 2: Long-Term Control Plan
- Volume 3: Integrated Plan
- Volume 4: Programmatic Environmental Impact Statement

A summary of the Consent Decree items and EPA guidance references is provided below. Table A-1 in Appendix A provides a crosswalk that describes where the Consent Decree requirements and EPA guidance suggestions are addressed.

1.5.1 Consent Decree Item Summary

This Integrated Plan addresses a number of criteria or requirements described in Section V.B. paragraph 20 of the Consent Decree, including the following:

- stormwater quality project(s) that result in significant benefits to water quality beyond those that would be achieved by implementation of the LTCP (CSO reduction) projects alone
- a schedule for implementation of the Integrated Plan projects and the candidate LTCP projects that would be completed after 2025

All LTCP projects in the LTCP will be completed, but some would be deferred beyond 2025 under an approved Integrated Plan.

The Consent Decree cites specific elements that must be included within the Integrated Plan. Appendix A contains a brief description of each element required by the Consent Decree.

CHAPTER 2

Receiving Waters Characterization

This chapter describes the key receiving water bodies in the city. As shown in Figure 2-1, the key water bodies include the Lower Duwamish Waterway, Lake Washington, Puget Sound, Elliott Bay, Lake Washington Ship Canal/Lake Union, Thornton Creek, Longfellow Creek, and Piper's Creek. Appendix B contains additional information about each water body.

2.1 Lower Duwamish Waterway

The Duwamish Waterway originates at the confluence of the Green and Black rivers near Tukwila, Washington, and flows northwest for approximately 12 miles, splitting at the southern end of Harbor Island to form the East and West waterways before discharging into Elliott Bay. The downstream portion of the Duwamish Waterway is brackish and serves as a major shipping route for bulk and containerized cargo, and most of the shoreline along the lower Duwamish has been developed for industrial and commercial land uses. A portion of the lower Duwamish is maintained as a federal navigation channel by the U.S. Army Corps of Engineers (USACE).

According to State water quality standards, the Lower Duwamish Waterway is designated for secondary contact recreation uses. This designation is intended to protect people engaged in boating, wading, and others uses where contact with the water is likely to be limited. There are no monitored swimming beaches on the Duwamish and therefore no information on beach closures.

The Lower Duwamish Waterway is listed as a Superfund Site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA, 2013a) and as a Model Toxics Control Act (MTCA) site (Ecology, 2013b). The CERCLA and MTCA listings are for bottom sediments that contain elevated concentrations of polychlorinated biphenyls (PCBs), carcinogenic polycyclic aromatic hydrocarbons (cPAHs), arsenic (As), dioxins, and furans.

The Lower Duwamish Waterway is listed as having critical habitat for proposed, threatened, and endangered species (City of Seattle, 2012).

2.2 Lake Washington

Lake Washington is the second-largest natural lake in Washington, with a surface area of 21,500 acres and a watershed of 472 square miles. The Lake Washington drainage system has been highly altered and now drains through the Lake Washington Ship Canal system rather than the Green/Duwamish River (Chrzastowski, 1983). Most of the lake shoreline is highly developed and lake levels are regulated by the USACE through operation of the Hiram M. Chittenden Locks (Chrzastowski, 1983; USACE, 2012a, 2012b).

Union Bay is also considered part of Lake Washington, and is located near the eastern end of the Ship Canal.

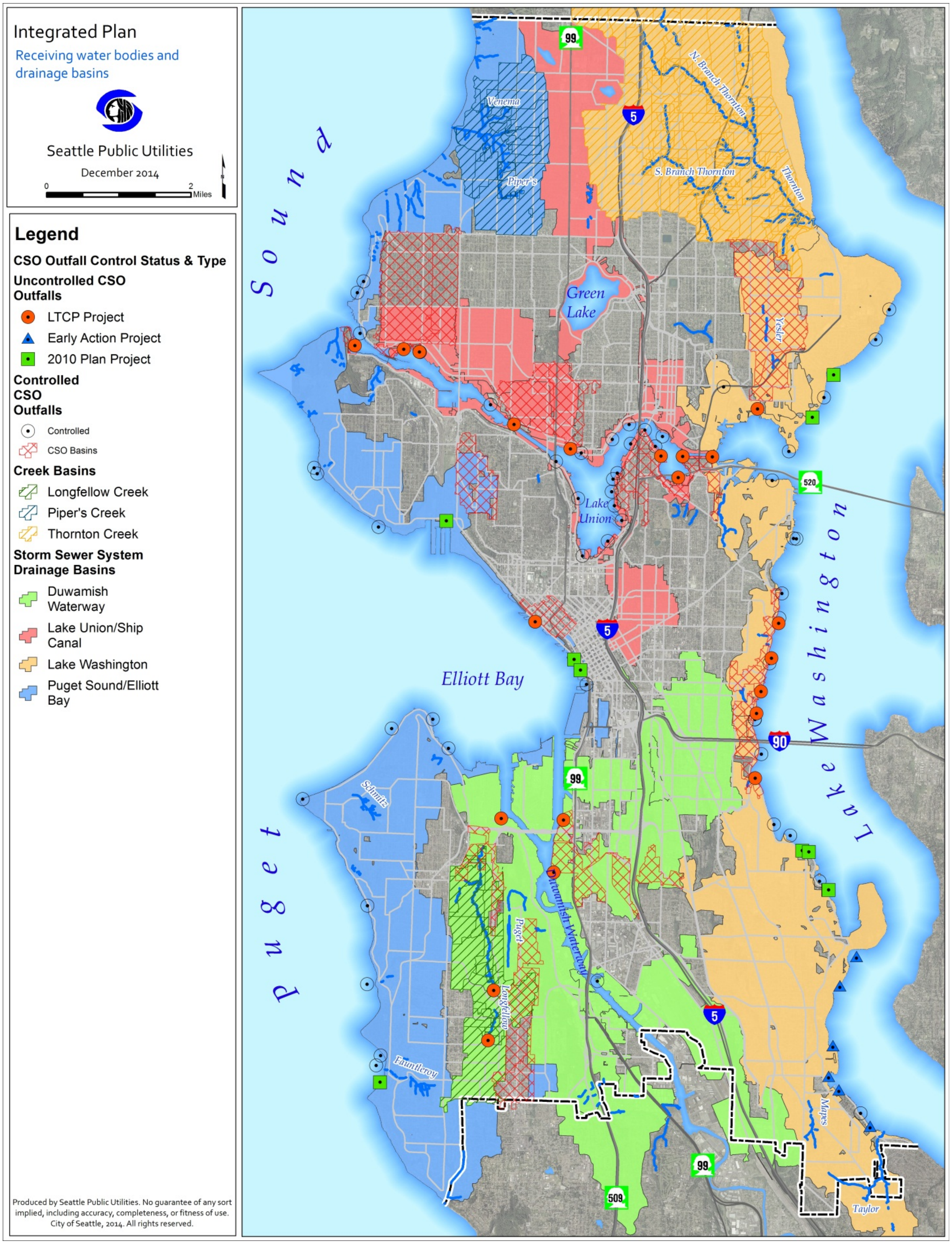

Figure 2-1. Receiving water bodies and drainage basins

King County (2013b) monitors swimming beaches on Lake Washington once per week from May through September to determine the fecal coliform levels and informs the public of potential risks to swimmers. There are seven monitored beaches in the city. During 1996–2012, there were 39 beach closures.

At present, there are no CERCLA or MTCA listings for Lake Washington adjacent to Seattle (EPA, 2013a and Ecology, 2013b).

Lake Washington is listed as having critical habitat for proposed, threatened, and endangered species (City of Seattle, 2012).

2.3 Puget Sound

Puget Sound is a fjord-like estuary that consists of four major interconnected basins that stretch from Hood Canal to north of Admiralty Inlet. The four basins include the Main (Admiralty Inlet and the Central Basin), Whidbey, Southern, and Hood Canal basins. All of Seattle's marine CSOs discharge to the Central Basin. Puget Sound borders the Ship Canal neighborhoods and Elliott Bay within the Integrated Plan area. CSOs in the Ballard, Fremont, and Wallingford area discharge to the Ship Canal and eventually drain to Puget Sound via the Hiram M. Chittenden Locks. Freshwater flows influence water circulation in this portion of Puget Sound with seasonal variation in the amount of freshwater input and an accompanying effect on water temperature, salinity, and density. The two main freshwater inputs to Puget Sound in the Integrated Plan area are the Green/Duwamish River, which enters Elliott Bay, and the Cedar River (Lake Washington drainage basin), which flows into Puget Sound through the Lake Washington Ship Canal.

The city encompasses 21 official beach/water access locations on Puget Sound. The State monitors four of these locations between Memorial Day and Labor Day each year. There were 13 beach closures for the period of 2004–10 (Ecology, 2013a).

At present, there are no CERCLA or MTCA listings for Puget Sound in the waters adjacent to Seattle (EPA, 2013a and Ecology, 2013b).

Puget Sound is listed as having critical habitat for proposed, threatened, and endangered species occurring within Puget Sound adjacent to Seattle (City of Seattle, 2012).

2.4 Elliott Bay

Elliott Bay is a partially enclosed embayment that is bordered on the north, east, and south sides by urbanized areas and by Puget Sound on the west. The eastern shoreline borders the Downtown neighborhoods and has been heavily modified from historical development. As a result, the shoreline along Elliott Bay is much steeper than a natural shoreline. The southern portion of Elliott Bay is heavily altered through man-made port facilities including Harbor Island, which was completed in 1909. Elliott Bay is influenced by Green River freshwater flows through the heart of Seattle's industrial area and port facilities, where the Green River becomes the Duwamish Waterway.

Information on beach closures for Elliott Bay is included in Section 2.3 above. At this time there are no CERCLA or MTCA listings for Elliott Bay in the waters adjacent to Seattle (EPA, 2013a and Ecology, 2013b).

Like Puget Sound, Elliott Bay is listed as having critical habitat for proposed, threatened, and endangered species occurring within Puget Sound adjacent to Seattle (City of Seattle, 2012).

2.5 Lake Washington Ship Canal/Lake Union

The Lake Washington Ship Canal system is an 8.6-mile-long, man-made navigable waterway connecting Shilshole Bay in Puget Sound to Union Bay in Lake Washington in Seattle. This system includes several interconnected waterways: the Hiram M. Chittenden Locks, Salmon Bay, Salmon Bay Waterway, Fremont Cut, Lake Union, Portage Bay, and Montlake Cut. Lake Union is a freshwater lake and receives most of its inflow from Lake Washington via the Montlake Cut and Portage Bay.

There are no monitored swimming beaches on the Lake Washington Ship Canal/Lake Union water body. Consequently, there is no information on beach closures.

Gas Works Park, a City of Seattle park, is located on the north shore of Lake Union and is listed by Ecology as a MTCA site (Ecology, 2013b). It is the former location of a plant that converted coal and oil into manufactured gas. The sediments off the shore of Gas Works Park contain polycyclic aromatic hydrocarbons (PAHs). The sediments are currently being studied to determine the best cleanup remedy.

The Lake Washington Ship Canal/Lake Union is listed as having critical habitat for proposed, threatened, and endangered species (City of Seattle, 2012).

2.6 Thornton Creek

Thornton Creek and its many tributaries flow through the northeast part of Seattle, forming the city's largest watershed. The watercourse is the longest in Seattle with nearly 20 miles of main stream channel and 20 tributaries. The headwaters of Thornton Creek start in the city of Shoreline, Washington, and the creek discharges to Lake Washington at Matthews Beach Park in Seattle.

There are no monitored swimming beaches on Thornton Creek and therefore no information on beach closures. At this time there are no CERCLA or MTCA listings for Thornton Creek in Seattle (EPA, 2013a and Ecology, 2013b). Thornton Creek is listed as having critical habitat for select proposed, threatened, and endangered species (City of Seattle, 2012).

2.7 Longfellow Creek

The Longfellow Creek basin encompasses approximately 1,504 acres within the Delridge area of West Seattle. The creek is 4.6 miles long and flows into the Duwamish River near Harbor Island through a 3,250-foot-long culvert (City of Seattle, 2007). Approximately one-third of the main channel length is piped. The watercourse is relatively flat compared to other major watercourses in Seattle, dropping 250 feet in elevation from its headwaters near the southern city limits to its mouth at the Duwamish River near Harbor Island.

There are no monitored swimming beaches on Longfellow Creek and therefore no information on beach closures. Currently, there are no CERCLA or MTCA listings for Longfellow Creek in Seattle (EPA, 2013a and Ecology, 2013b). Longfellow Creek does not contain any critical habitat for threatened or endangered species.

2.8 Piper's Creek

Piper's Creek basin encompasses approximately 1,578 acres in the northwest portion of Seattle. The mainstem of the creek is approximately 2 miles long, including the major tributary, Venema Creek. The headwaters of the creek watershed are located in developed neighborhoods, including Broadview and Greenwood. The mainstem flows through a steep ravine in Carkeek Park before discharging into Puget Sound.

There are no monitored swimming beaches on Piper's Creek and therefore no information on beach closures. At present there are no CERCLA or MTCA listings for Piper's Creek in Seattle (EPA, 2013a and Ecology, 2013b). Piper's Creek does not contain any critical habitat for threatened or endangered species.

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CHAPTER 3

Existing Combined and Separated Systems Characterization

The City's sewer and drainage infrastructure includes combined, fully separated, and partially separated systems, each serving approximately one-third of the city (Figure 3-1). These systems are described below.

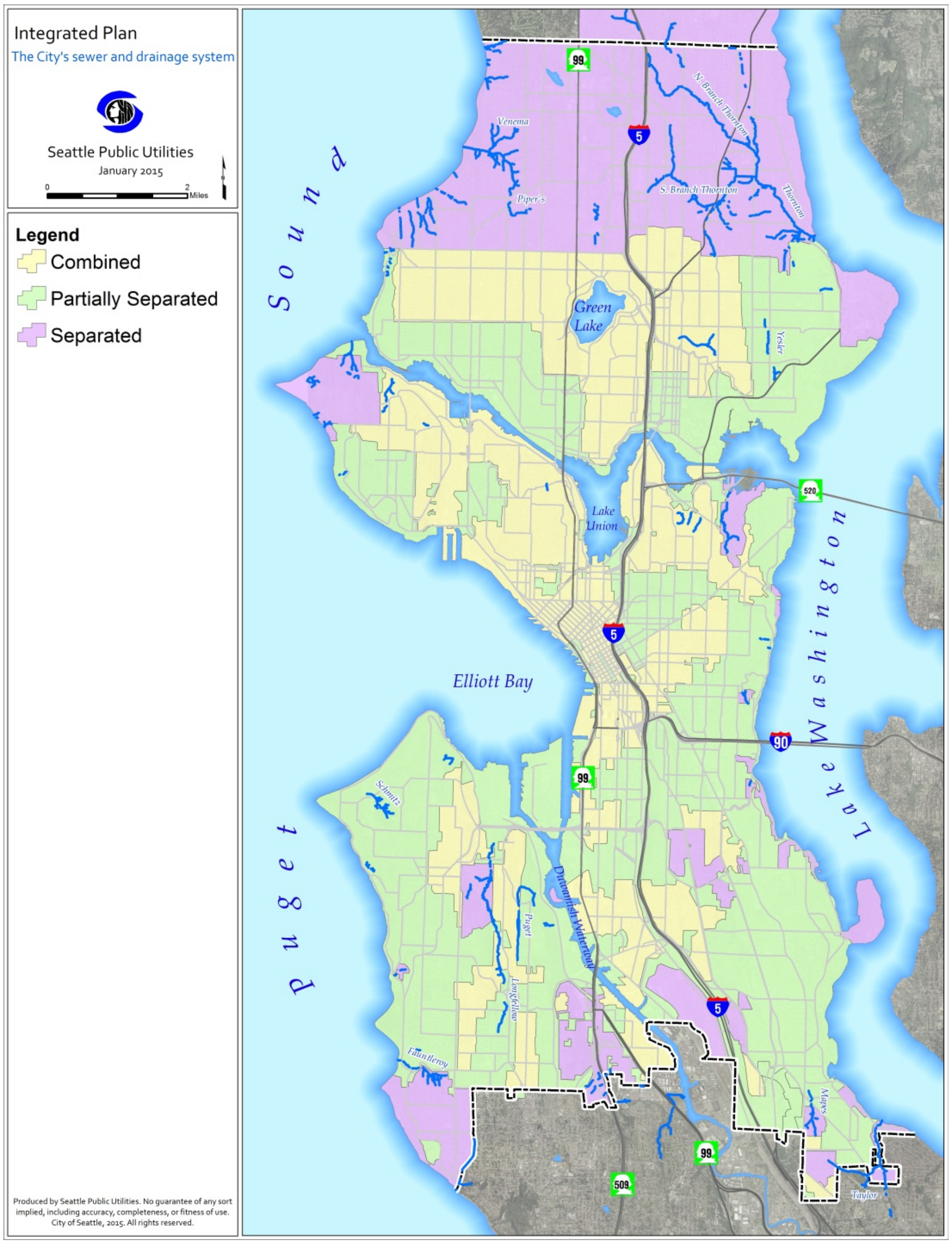

Figure 3-1. The City's sewer and drainage system

3.1 Description of the Combined System

King County and the City own and operate combined sewer systems that serve about one-third of the city. Each combined sewer system is a piped system that carries both sewage and stormwater to a wastewater treatment plant (WWTP). Figure 3-2 shows the key components of a typical combined sewer system.

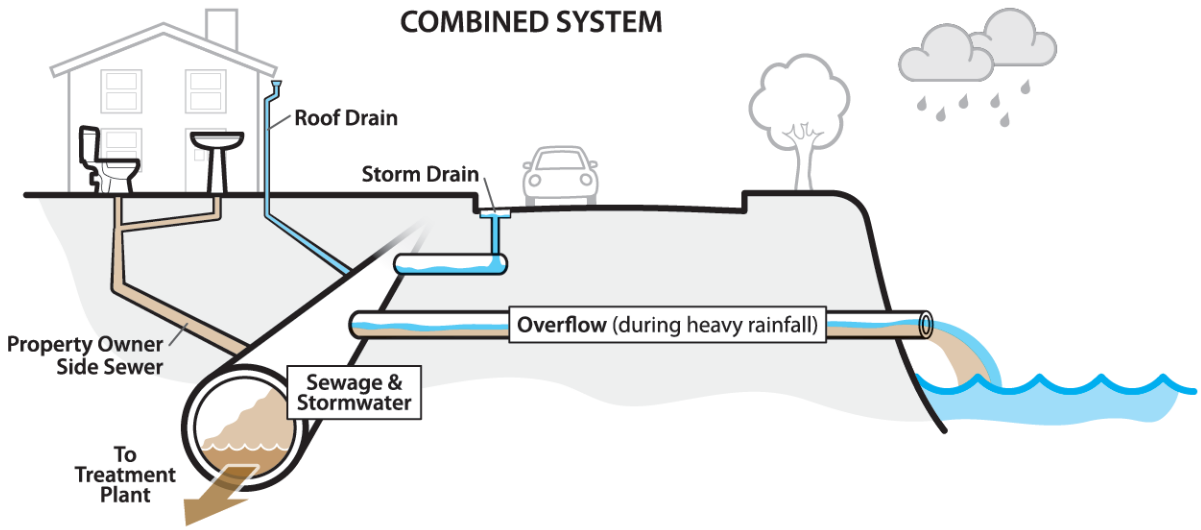

Figure 3-2. Combined sewer system

King County currently operates three secondary WWTPs (West Point WWTP, South WWTP, and Brightwater WWTP) and four combined sewage wet weather treatment facilities (Alki, Carkeek, Elliott West, and Henderson/MLK). These facilities discharge treated wastewater to Puget Sound, Elliott Bay, and the Lower Duwamish Waterway.

The combined sewer systems overflow at designed relief points during heavy rain events. CSO discharges consist of stormwater, wastewater, and groundwater in varying proportions. King County and the City manage CSOs based on the size of the sewer system basin served by each CSO outfall, with the City managing basins smaller than 1,000 acres and the County managing basins larger than 1,000 acres. The City manages 86 CSO outfalls and the County manages 38 CSO outfalls. However, parts of King County's system are interconnected with the City's and the operations of one may impact the operations of the other. Some of the City-owned CSO outfalls are located upstream and in close proximity to King County-owned CSO outfalls.

During the 1980s, increasing the storage capacity of the system became the City's preferred solution to controlling CSOs, resulting in construction of 38 facilities for overflow control. Currently, 34 CSO basins are still uncontrolled, and 12 of the uncontrolled basins are being addressed under the City's current state and federal requirements for CSO discharges. The LTCP is focused on the 22 remaining uncontrolled CSO basins, which are located in the Ballard, Delridge/Longfellow, Duwamish, Fremont/Wallingford, Interbay, Leschi, Montlake, North Union Bay, Portage Bay, Magnolia, and Central Waterfront (Vine Street) areas.

3.2 Description of the Separated System

Beginning in the 1950s, additions to the sewer system were designed as separated systems, with separate networks of pipes for sewage and stormwater. In the areas served by the City's municipal separate storm sewer system, runoff is collected and conveyed in a storm drain system. Wastewater is collected in a separate sanitary sewer and conveyed to a WWTP (Figure 3-3). Some portions of the City's municipal separate storm sewer system are piped while others have an informal system of ditches and culverts, most of which drain to creeks or larger receiving waters. For example, the area north of NE 85th Street, which the City annexed in 1954, is served primarily by ditch-and-culvert drainage systems (City of Seattle, 2009).

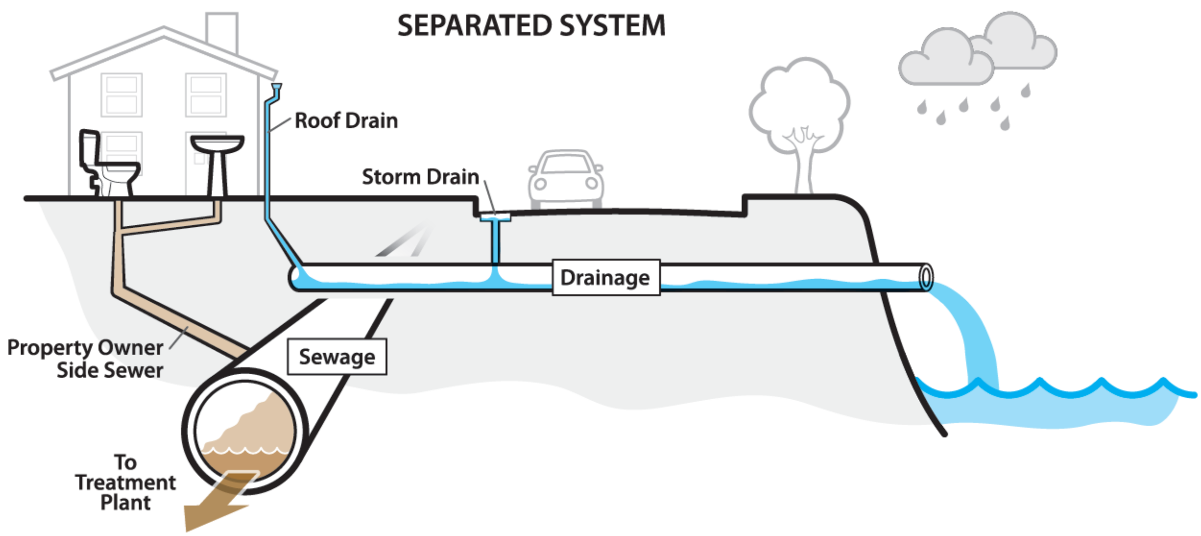

Figure 3-3. Separated storm sewer system

3.3 Description of the Partially Separated System

During the 1960s, some combined sewer system areas were retrofitted with storm drain separation projects that diverted street runoff in pipes to the municipal separate storm sewer system and receiving waters but did not collect runoff from rooftops or private properties outside the road rights-of-way (Figure 3-4). The primary objective of separation projects was to reduce CSOs. In these partially separated areas, runoff from rooftops and other private-property areas is still collected and conveyed to wastewater treatment plants (City of Seattle, 2009). Some of the candidate LTCP projects are in areas with partially separated storm drainage systems.

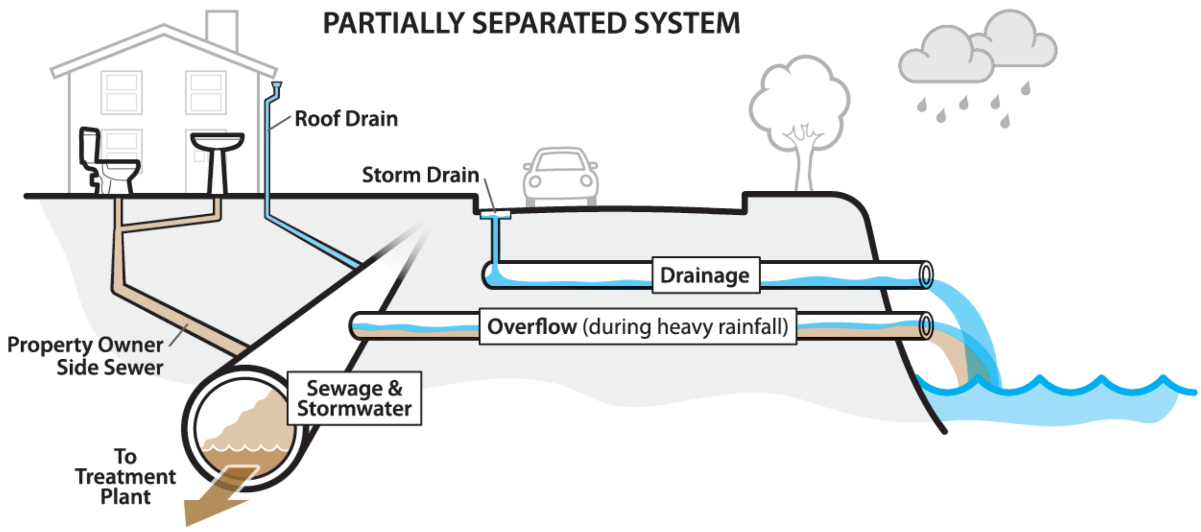

Figure 3-4. Partially separated system

CHAPTER 4

Public and Regulatory Agency Participation Plan

The Consent Decree specifies that the Integrated Plan shall include a public and regulatory agency participation program. The purpose of this program is to ensure that there is ample public participation throughout all stages of development of the City's Integrated Plan. Table 4-1 lists the public and regulatory agency participation requirements of the Consent Decree and the corresponding activities performed by the City during development of the Integrated Plan. The City is using the same public participation process for the LTCP.

Table 4-1. Description of Public and Regulatory Agency Participation Program

Requirement	Activities
The means by which the City will make information pertaining to the development of the Integrated Plan available for public review	The City will provide updates on the LTCP/Integrated Plan and Programmatic EIS through: • Community Guide updates • Animations • Visualizations • Video for Web site • Briefings • Web site updates • Updates to the project listserv
The means by which the City will solicit comments from the public on the development of the Integrated Plan	• Scoping meetings (October 2011) • Online questionnaires • Re-scoping meetings (May 2013) • Briefings • Public meeting/hearing on the Draft Plan/DEIS Spring 2014 • Comments and questions can be submitted anytime to the City via e-mail at CSO_LTCP@seattle.gov
Summary of public hearings at meaningful times during the Integrated Plan development process to provide the public with information and to solicit comments from the public regarding components of the Integrated Plan	• Draft EIS public hearing summary report
Program for consideration of comments provided by the public as the City develops the Integrated Plan	• Summary reports to be prepared for all public meetings. The following summary reports will include a comment response section: • Scoping Summary Report (2011) • Re-scoping summary report (spring 2013) • Final EIS comment response • LTCP/Integrated Plan Public and Regulatory Agency Participation Final Summary Report

Table 4-1. Description of Public and Regulatory Agency Participation Program

Requirement	Activities
Measures that the City will employ to ensure that EPA and Ecology are kept informed of the City's progress in developing its Integrated Plan development process and regular submittal of reports to EPA and Ecology summarizing the public comments received throughout implementation of the Program	• Quarterly meetings with EPA/Ecology (addresses both LTCP and Integrated Plan) • Webinars for EPA and Ecology at meaningful times: emphasis of webinar will be to report on public involvement activities and comments received at major milestones • June/July 2013: Re-scoping recap • May 2014 Draft LTCP/Integrated Plan/DEIS rollout • October/November 2014: LTCP/Integrated Plan/DEIS public hearing recap

CHAPTER 5

Selection of Candidate LTCP and Stormwater Projects

This chapter provides an overview of the methods the City used to identify candidate LTCP and stormwater projects.

5.1 Identification of Candidate LTCP Projects

The City developed its approach for identifying and ranking candidate LTCP projects for deferral based on the document, *Integrated Municipal Stormwater and Wastewater Planning Approach Framework* (EPA, 2012) and consultations with the LTCP project team. The City's approach and results are summarized below (see Volume 2 for additional details).

The candidate LTCP projects were selected for deferral by ranking the CSO basins using site-specific information together with criteria recommended in EPA document 832-B-95-004, *Combined Sewer Overflows Guidance for Screening and Ranking* (EPA, 1995). This approach, as well as a list of the selected LTCP projects, is described in Volume 2 and summarized below.

The City used two guiding principles from EPA's integrated planning guidance (EPA, 2012) to identify candidate LTCP projects:

- The Integrated Plan should allow the City to balance Clean Water Act (CWA) requirements in a manner that addresses the most pressing public-health and environmental protection issues first.
- The Integrated Plan should describe the relative priorities of the selected projects and how those priorities reflect the relative importance of adverse impacts on public health and water quality along with the permittee's financial capability.

5.1.1 Consultation with LTCP Team: Ranking and Scoring Process

The City's Integrated Plan team consulted with the LTCP team in order to identify, score, and rank the candidate LTCP projects. The CSO basins were scored based on seven criteria using site-specific information. The CSO basins were ranked from highest to lowest score and divided into two categories: higher-priority CSO basins and lower-priority CSO basins. In keeping with EPA guidelines, the City selected a group of potential candidates for deferral from the lower-priority CSO basins.

Next, the City screened out some of the LTCP projects that likely would be controlled by constructing sewer system retrofits rather than Neighborhood Storage Projects. The City further refined its deferral candidate list based on opportunities for partnering with King County to build projects that jointly address the agencies' CSO outfalls.

Through this process, the City identified six LTCP CSO control projects, each of which would control basins that experience a low frequency and volume of CSOs, for potential deferral until after 2025. The City will implement the other LTCP CSO control projects by 2025, in accordance with the LTCP. The LTCP document (Volume 2) provides additional details regarding selection of candidate LTCP projects for deferral.

5.2 Candidate LTCP Projects

The candidate LTCP projects will reduce CSO discharges to the Lower Duwamish Waterway and Lake Washington Ship Canal/Lake Union. All six LTCP projects will store excess flows and release the stored flows back to the combined sewer when conveyance and treatment capacity becomes available. Water released from LTCP storage facilities in CSO Outfalls 99, 111, 138, 139, and 140 will be treated at King County's West Point Treatment Plant and discharged via a deep-water outfall in Puget Sound. For the candidate project controlling flows from CSO Outfall 107, the stored water may be either conveyed to the West Point Treatment Plant or pumped from the storage facility back to the interceptor and conveyed to a King County CSO wet weather treatment facility.

Table 5-1 lists the estimated average annual overflow frequency and overflow volume for each of the six candidate LTCP projects. Figure 5-1 shows the drainage areas and outfalls associated with each project. For a detailed discussion on each of these CSO basins, including the basin characteristics and predictive tools used for estimating overflow frequency and volumes, refer to the respective LTCP Hydraulic Modeling Report for that particular basin (Brown and Caldwell, 2012 [Volumes 2–10]).

Table 5-1. Candidate LTCP Projects

CSO area	CSO outfall and basin number	Receiving water body	Average existing discharge frequency (average events/yr)[a]	Average volume treated or removed (MG/yr)[b]
Delridge/Longfellow	99	West Waterway of the Duwamish River	1.5	0.17
East Waterway	107	East Waterway of the Duwamish River	4.6	1.11
Duwamish	111 (B, C, and H)	Duwamish River	1.7	0.01
Portage Bay	138	Portage Bay	1.4	0.09
Montlake	139	Portage Bay	1.15	0.01
Montlake	140	Portage Bay	3.7	0.05

a. Average annual overflow frequency for 1993–2012 from Table 5-8 of the 2012 Annual Report, CSO Reduction Program.

b. The volume treated for each approved candidate LTCP project is the moving 20-year average simulated volume without climate change (scaling factor = 1).

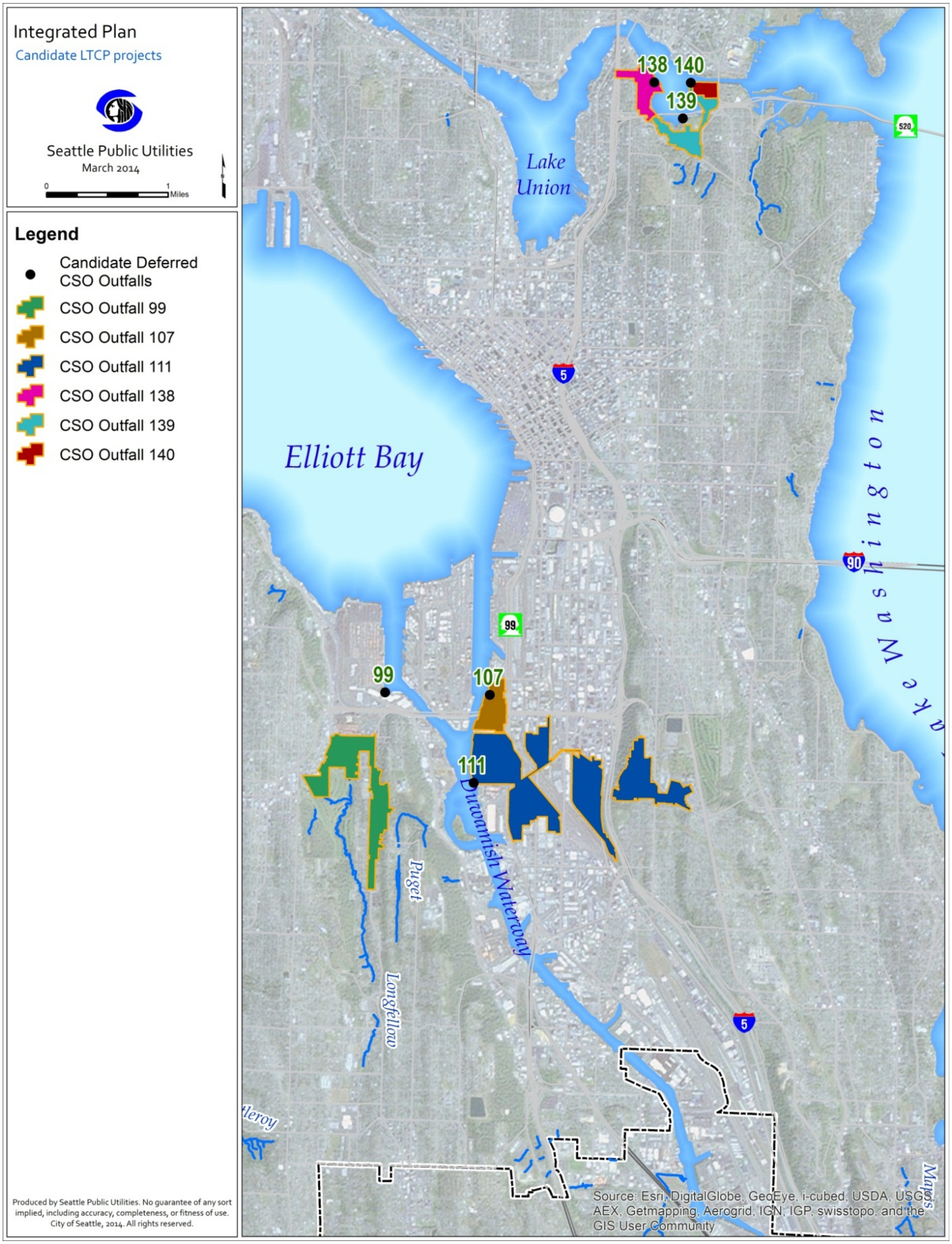

Figure 5-1. Candidate LTCP projects

5.3 Identification of Candidate Stormwater Projects

The City followed a systematic approach to select candidate stormwater projects for potential inclusion in this Integrated Plan, as summarized below.

5.3.1 Approach

Identification of candidate stormwater projects entailed the general steps listed below:

1. Rank receiving water bodies and identify their pollutants of concern
2. Develop TSS loads for each stormwater basin based on estimates of average annual volumes and pollutant concentrations
3. Rank each stormwater basin and characterize priority basins
4. Identify potential project locations and stormwater projects
5. Screen project list
6. Develop a planning-level cost estimate for potential projects
7. Conduct initial ranking of potential stormwater projects based on estimated cost per kilogram (kg) of TSS removed per year

The City's approach is documented in Appendix C to this Integrated Plan and the following technical memoranda:

- Integrated Plan: Stormwater Priority Basins Technical Memorandum (Draft), March 22, 2013; (Final), April 9, 2013 (SPU, 2013a)
- Integrated Plan: Stormwater Treatment Project Screening Technical Memorandum (Final), April 10, 2013 (SPU, 2013c)
- Integrated Plan: Stormwater Project Selection Process for Further Consideration (Final), May 15, 2013 (SPU, 2013d)
- Integrated Plan-Briefing Memorandum on Stormwater and CSO Project Evaluation and Exposure Assessment Methods. Revised May 23, 2013 (SPU, 2013e)

These memoranda describe the tools used and the results obtained from these analyses, including the identification of the City's high-priority drainage basins for stormwater treatment.

5.3.2 Candidate Stormwater Projects

The City initially identified 15 stormwater projects as candidates for potential inclusion in the Integrated Plan. Thirteen of the candidate projects were structural measures such as media filters, swirl concentrators, bioretention, biofiltration, and "active" treatment. The two candidate programmatic stormwater measures both involved street sweeping.

The City subsequently removed five of the candidate structural projects from further consideration. Two projects were removed because the City is already installing a large stormwater quality project in the same basin. Two pretreatment projects were removed because the City decided that the Integrated Plan should focus on treatment projects rather than pretreatment projects, which are intended primarily to reduce maintenance needs and ensure performance of downstream treatment facilities. The Joint Hanford-Lander-Kingdome-King (HLKK) Wet Weather Treatment project was screened out based on timing with King County and costs.

The candidate structural stormwater projects would affect the Lower Duwamish Waterway, Lake Washington, Lake Washington Ship Canal/Lake Union, Longfellow Creek, Piper's Creek, and Thornton Creek. The street sweeping programs would reduce pollutant loads to all of these water bodies as well as Elliott Bay and Puget Sound.

Table 5-2 contains a brief summary of the candidate stormwater projects and programs. Figure 5-2 shows the drainage basins where the eight structural candidate stormwater projects would be located. Figures 5-3 and 5-4 show the areas encompassed by the two street sweeping programs.

Table 5-2. Candidate Stormwater Treatment Projects and Programs, Tributary Areas, and Project Types

Project name	Receiving water body	Total drainage tributary area[a]	Project type
Longfellow Cascades	Longfellow Creek	68 acres	Bioretention receiving runoff from multiple upstream blocks
NDS Partnering	Longfellow Creek Piper's Creek Thornton Creek	Longfellow Creek: 557 Piper's Creek: 684 Thornton Creek: 2,703[b]	Bioretention receiving runoff from adjacent block
Piper's Cascades	Piper's Creek	160 acres	Bioretention receiving runoff from multiple upstream blocks
South Myrtle St. Shoulder Stabilization	Duwamish Waterway	3.2 acres	Biofiltration swale
South Myrtle St. StormFilter Vault	Duwamish Waterway	8.5 acres	Cartridge media filter
South Park Water Quality (WQ) Facility	Duwamish Waterway	254 acres	Active treatment (CESF)[c]
Street Sweeping Expansion Arterials	Multiple	10,600 annual curb miles (approx. 1,736 acres)	Street sweeping (weekly arterial sweeping)
Street Sweeping Expansion Residential	Multiple	11,500 annual curb miles (approx. 1,120 acres)	Street sweeping (residential biweekly)
SW Hinds SD StormFilter Vault	Duwamish Waterway	29.45 acres	Cartridge media filter
U Village Filterras	Lake Washington	5.4 acres	Media filter

a. A complete discussion of the areas included in each pollutant load model (PLM) is provided in Appendix F.

b. See Appendix J, Project Sheet for NDS Partnering, for a thorough discussion on the impervious and pervious areas included within the tributary areas for each watershed.

c. CESF = chitosan-enhanced sand filtration.

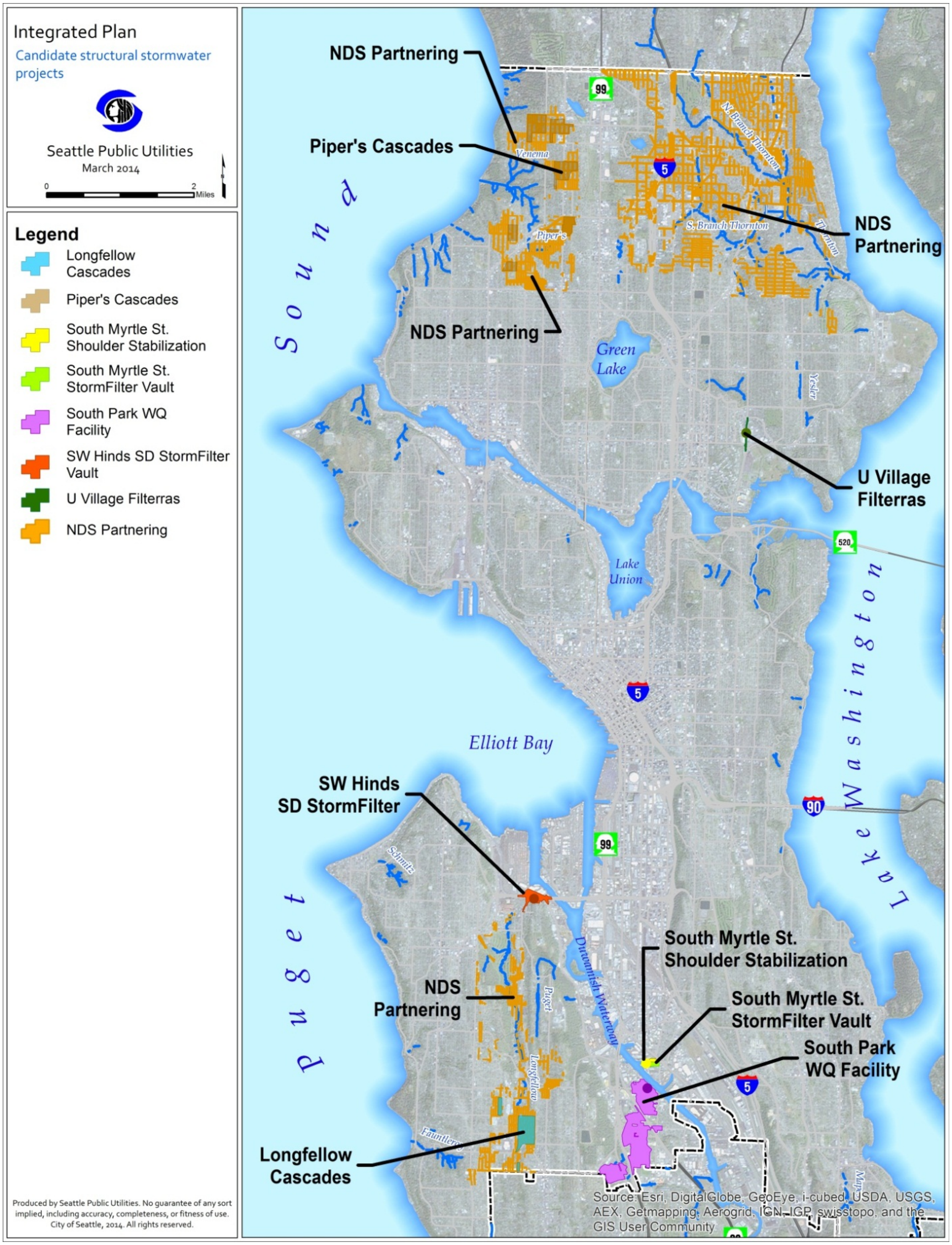

Figure 5-2. Candidate structural stormwater projects, not including the street sweeping program expansions

Figure 5-3. Candidate stormwater program: Street Sweeping Expansion Arterials

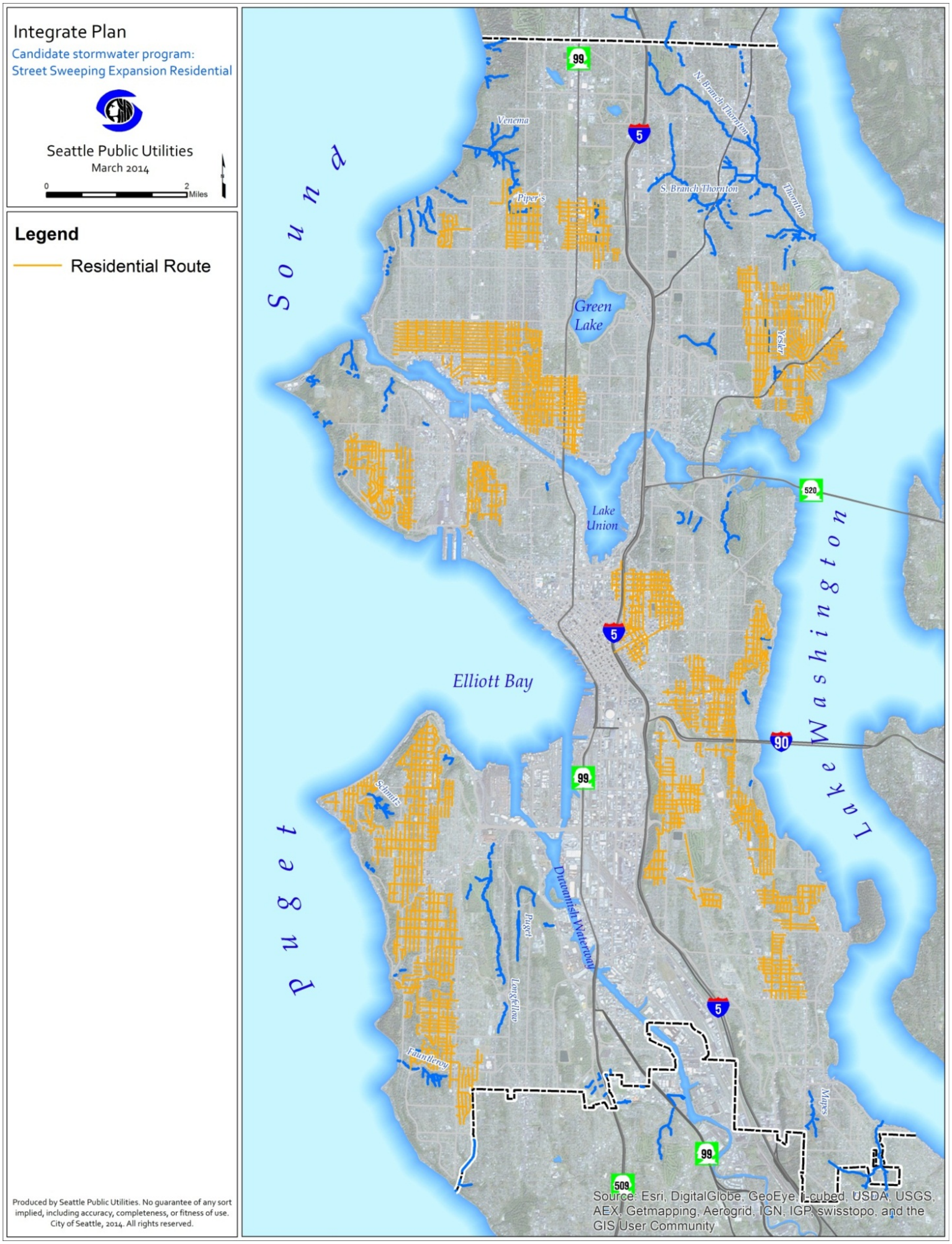

Figure 5-4. Candidate stormwater program: Street Sweeping Expansion Residential

A brief description of each candidate project is provided below. Appendix C contains additional details about each candidate project.

5.3.2.1 Longfellow Cascades

The Longfellow Cascades project is a green infrastructure project that would provide treatment and flow control/volume reduction for a portion of the stormwater runoff from approximately 68 acres. The project entails constructing bioretention elements along four to seven blocks along 22nd and 24th Avenues SW and constructing pipe or ditch improvements to collect and convey runoff from several blocks upstream of the project to treat a portion of the Longfellow Creek storm sewer system basin. Stormwater treatment would be provided by bioretention and volume reduction through infiltration.

5.3.2.2 NDS Partnering

The Natural Drainage Systems (NDS) Partnering project is a regional green infrastructure project that would construct bioretention facilities (i.e., engineered rain gardens) in the storm sewer system basins that drain to Longfellow, Piper's, and Thornton creeks. In addition to providing stormwater treatment and flow control/volume reduction, the NDS Partnering project would provide community benefits such as mobility, traffic calming, and beautification, and would increase community awareness around the stormwater quality impacts generated by impervious surfaces.

The NDS Partnering project would entail reconstructing the City rights-of-way to manage flow and provide water quality treatment for urban runoff primarily using bioretention. It would focus on managing runoff generated on a given block with green infrastructure approaches on that block. As noted above, the right-of-way improvements may include curbs, sidewalks, and other community amenities.

The City would work in partnership with local residents or community groups to identify candidate blocks within each basin. Candidate blocks must be among the potential blocks identified by the City as potentially feasible for bioretention. The City anticipates that most of the candidate blocks will be in areas that currently lack curbs and gutters. The project locations would be prioritized based primarily on stormwater management goals, but factors such as community support and overlapping City priorities will be included in the project prioritization.

5.3.2.3 Piper's Cascades

The Piper's Cascades project is a localized green infrastructure project that would provide stormwater treatment and flow control/volume reduction. The project would install bioretention elements as well as pipe or ditch improvements to collect and convey runoff from several blocks upstream of the project site. The project would provide treatment and flow control within high-priority subbasins of Piper's Creek as well as subbasins that overlap with the Broadview Sewer and Drainage Improvement Project.

5.3.2.4 South Myrtle St. Shoulder Stabilization

The South Myrtle St. Shoulder Stabilization project is a localized project that would provide stormwater source control and flow control/volume reduction. The project site is an unpaved gravel/dirt road shoulder on a heavily traveled industrial roadway that drains to the Duwamish Waterway. Currently, stormwater runoff is collected in a series of catch basins located along the south edge of the street. The site is the subject of an adaptive management response under Special Condition S4F of the City's municipal stormwater discharge permit due to contaminants (PCBs and metals) discharged to the roadway from an adjacent industrial property. Ecology is concerned that the unpaved shoulder could contribute contaminated sediment to the Duwamish Waterway.

This project would involve paving a wide strip along the north side of S Myrtle Street in order to widen the traveled surface; installing a gravel-surface, angled parking area on the north side of the street; and installing a biofiltration swale in the remainder of the shoulder to treat runoff from the parking area and the adjacent properties to the north, which currently drain to the City right-of-way.

5.3.2.5 South Myrtle St. StormFilter Vault

The South Myrtle St. StormFilter Vault project is a localized project that would provide stormwater treatment. The project entails installation of a cartridge media filter and stabilization of the unpaved shoulder with biofiltration. The 40-foot-wide shoulder on the north side of S Myrtle Street would be paved to reduce erosion and a StormFilter unit would be installed to treat runoff from the entire 8.5-acre drainage basin.

5.3.2.6 South Park Water Quality Facility

The South Park Water Quality (WQ) Facility would treat stormwater runoff from approximately 254 acres in the 7th Avenue S drainage system. The City would install a basic, active treatment system, such as a chitosan-enhanced sand filtration (CESF) system, prior to discharge into the Duwamish Waterway. The treatment facility would be co-located with a new stormwater pump station that the City plans to build in order to reduce flooding in the 7th Avenue S drainage system. The proposed project would take advantage of the opportunity to integrate water quality treatment with flood control.

5.3.2.7 Street Sweeping Expansion Arterials

The Street Sweeping Expansion Arterials program would entail increased sweeping of arterials to remove potential stormwater pollutants from storm sewer system basins. This program includes the following three expansions:

- increase the route coverage from 83 percent to approximately 85 percent of curbed arterials (for a total 10,600 curb-miles), by adding 1 route, for a total of 25 routes
- increase the sweeping season from 40 to 48 weeks per year
- increase the sweeping frequency from biweekly to weekly for some routes: 21 routes will be swept on a weekly basis and 4 routes will be swept on a biweekly basis

5.3.2.8 Street Sweeping Expansion Residential

The Street Sweeping Expansion Residential program would focus on the storm sewer system basins and would cover 11,500 curb-miles (approximately 65 percent of the curbed local streets within the city). This street sweeping program would be an expansion of the City's current street sweeping efforts. Streets would be swept biweekly during the day over a 46-week period. The street sweeping would take place within various basins that affect all of the receiving water bodies in the city.

5.3.2.9 SW Hinds SD StormFilter Vault

The SW Hinds SD StormFilter Vault project is a localized project that would provide stormwater treatment. The project entails installing a cartridge media filter within the Duwamish River Basin, along W Marginal Way SW, for stormwater treatment. Runoff from the eastern 29.45 acres of the SW Hinds Street drainage basin is conveyed along W Marginal Way SW in a 36-inch-diameter pipe, before connecting with the 96-inch-diameter outfall pipe. A diversion structure would be installed to route stormwater underneath the existing 48-inch-diameter sanitary sewer owned by King County to the Port of Seattle property on the south side of W Marginal Way SW. If the City can obtain an easement from the Port, the StormFilter vault would be installed underneath the Port's parking lot.

5.3.2.10 U Village Filterras

The U Village Filterras project is a localized project that would treat stormwater runoff from approximately 5.4 acres that drains to Lake Washington. The project consists of installing Filterra media filters in the right-of-way for water quality treatment of runoff from 25th Avenue NE between NE Blakely Street and NE 44th Street.

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CHAPTER 6

Methods for Evaluation of Candidate Projects

This chapter discusses the methods the City used to evaluate the candidate LTCP and stormwater projects.

6.1 Introduction

The Consent Decree requires a pollutant load reduction analysis for each stormwater project proposed for implementation and each candidate LTCP project. In addition, the Consent Decree requires an assessment of the potential reductions in pollutant exposure for human and ecological receptors. The Consent Decree lists a range of water quality constituents that the Integrated Plan must address.

The City developed methods for evaluating pollutant load and exposure reductions from the candidate LTCP and stormwater projects based on the following: Consent Decree requirements, review of the available relevant data, and input from an independent Expert Panel. Section 6.2 summarizes the Expert Panel's involvement. Section 6.3 describes climate change considerations. Section 6.4 describes how the City identified the "Representative Constituents of Concern" (RCOCs) to be evaluated for each candidate project. Sections 6.5 and 6.6, respectively, summarize the pollutant load evaluation methods for the candidate LTCP (CSO) and stormwater projects and Section 6.7 outlines exposure assessment methods applied.

6.2 Expert Panel

The City worked with a five-member Expert Panel during the development of the Integrated Plan. The primary role of the Expert Panel was to provide input on the data, methods, and assumptions used to develop the Integrated Plan. The Expert Panel acted as a technical sounding board for the City, reviewing and commenting on technical questions and issues relevant to the methodology. The Expert Panel was not involved in the selection of the stormwater projects included in the Integrated Plan. Appendix D contains information on the Expert Panel members and summaries of the Expert Panel meetings.

6.3 Climate Change

The LTCP Volume 2 modeling reports discuss the modeling conducted on each of the LTCP (CSO) projects. As discussed in each of these modeling reports, climate change factors were taken into consideration for determining long-term overflow estimates. The LTCP models were run both with and without "scaling factors," which were intended to allow the City to factor climate change and other uncertainties into the design of the LTCP control projects. (Scaling factors are multipliers for the rainfall time series.) A scaling factor of 1.0, which represents no climate change, was used for estimating the pollutant loads for the candidate LTCP projects. A scaling factor of 1.0 was used for two reasons:

- Climate change was not factored into the pollutant load reduction estimates for the candidate stormwater projects. For the Integrated Plan candidate project evaluations, the load reduction estimates for the candidate LTCP projects need to be directly comparable to the candidate stormwater project pollutant load reduction estimates.

- The candidate stormwater projects and LTCP projects would all be built within the next 16 years. The climate change portion of the scaling factors is based on the physics associated with a 1-degree Celsius rise in the surface temperature of the north Pacific, which is expected to occur over a longer time frame.

See Volume 2: LTCP, of the City's Protecting Seattle's Waterways Plan, for additional details on the incorporation of climate change and scaling factors used for the hydraulic models.

6.4 Representative Constituents of Concern

Section V.B. paragraph 20 of the Consent Decree lists a number of specific constituents that the Integrated Plan must address. These include fecal coliform bacteria, TSS, biochemical oxygen demand (BOD), ammonia, phosphorus, oil and grease, and pH. The Consent Decree also lists several general categories of constituents (e.g., metals, pesticides, semi-volatile organic compounds).

Due to the very tight schedule for developing the Integrated Plan, it was not possible to collect new water quality data. Therefore, the City compiled and reviewed existing stormwater, CSO, and receiving water data in light of the Consent Decree requirements to develop a list of RCOCs. In some cases, the City identified surrogates to represent a category of constituents (e.g., dissolved and total copper [Cu] and dissolved and total zinc [Zn] for metals; PCBs and polybrominated diphenyl ethers [PBDEs] for toxic organic compounds).

To help develop this list of RCOCs, the City reviewed its existing stormwater sampling data and receiving water data to identify representative data sets to link pollutant concentrations (and their inherent variability) with different land uses. To supplement the local stormwater data, additional data were used such as from the City of Tacoma, King County, Oregon Association of Clean Water Agencies, and other suitable regional and/or national databases.

The Consent Decree listed numerous specific constituents as well as categories of constituents. For some of these constituents, little or no data were available for an adequate evaluation. Also, it was not feasible to model each Constituent of Concern (COC) given the available data and schedule. Therefore, the Integrated Plan team selected RCOCs with input from the Expert Panel. RCOCs were selected based on Consent Decree requirements, data availability, and professional judgment. Table 6-1 lists the COCs listed in the Consent Decree and the recommended RCOCs to be used in the pollutant load and exposure reduction evaluations.

Table 6-1. COCs Identified in the Consent Decree and Recommended RCOCs Used for Project Evaluations

Constituents of Concern (COCs) identified in the Consent Decree	Recommended Representative Constituents of Concern (RCOCs)
Biochemical oxygen demand (BOD)	BOD
Semi-volatile organic compounds	Bis(2-ethylhexyl)phthalate
Pesticides	Dichlobenil
Pathogens (fecal coliform bacteria)	Fecal coliform bacteria
pH	H+
Nitrogen ammonia	Ammonia-N
Oil and grease	Oil and grease
Polybrominated diphenyl ethers (PBDEs)	PBDEs[a]
Projected dissolved oxygen (DO)	Projected DO

Table 6-1. COCs Identified in the Consent Decree and Recommended RCOCs Used for Project Evaluations

Constituents of Concern (COCs) identified in the Consent Decree	Recommended Representative Constituents of Concern (RCOCs)
Polychlorinated biphenyls (PCBs)	PCBs[a]
Phosphorus	Phosphorus[a]
Total suspended solids (TSS)	TSS
Metals	Dissolved copper
	Dissolved zinc
	Total copper
	Total zinc

a. Total phosphorus, total PCBs, and total PBDEs were used as RCOCs.

6.5 Pollutant Load Evaluation Methods for Candidate LTCP Projects

The City estimated pollutant load reductions from the candidate LTCP projects based on the expected reductions in overflow volumes and available information on RCOC concentrations in City and King County CSO discharges.

6.5.1 Overflow Volume Reduction

The reduction in CSO discharge volumes from the candidate LTCP projects was estimated using results from calibrated hydrologic and hydraulic models. The City developed hydrologic and hydraulic models (EPA-SWMM 5 Build 5.0.022) for the currently uncontrolled CSO basins to support development of the LTCP. The models were developed to assess the performance of the existing system, predict wet weather flows, and estimate the frequency and volume of CSO events. The models were calibrated to flow monitoring data collected within each CSO basin. In addition, the model for CSO Outfall 107 used supervisory control and data acquisition (SCADA) data to supplement the available flow monitoring data. A full discussion of the modeling conducted for each of these CSO basins is provided within the LTCP reports Volumes 2–10 (Brown and Caldwell, 2012).

These calibrated models provide simulated, long-term time series of CSO events (including discharge volumes and duration). They also allow estimation of the groundwater, stormwater, and sanitary contributions to overflows. In addition, the models were used to develop estimates of control volumes (i.e., required storage) to limit CSOs to one or fewer overflow per outfall per year.

The control volume estimates and simulated CSO event volumes were used to generate pre- and post-project CSO frequencies and volumes. The difference between pre- and post-project CSO event volumes was the expected reduction in overflow volume, which was used in estimating pollutant load reductions for the candidate LTCP projects.

6.5.2 RCOC Concentrations

The City sampled CSO water quality at 16 locations between 2007 and 2010. Sites were sampled from one to four times. In addition, King County sampled CSO water quality at two locations in the Duwamish area between 2007 and 2009. These sites were sampled from three to five times. The samples were analyzed for most of the RCOCs. Only one of the six candidate LTCP projects (CSO Outfall 99) was sampled.

The City evaluated the land use data for the sampled and unsampled CSO locations. The tributary areas for the 16 CSOs sampled by the City were primarily residential. The tributary areas for four of the six candidate LTCP projects (CSO Outfalls 99, 138, 139, and 140) are mostly residential. Therefore, the data from the 16 sampled CSOs were pooled together to estimate RCOC concentrations for CSO Outfalls 99, 138, 139, and 140.

CSO Outfalls 107 and 111 serve largely industrial areas. As noted above, the City's CSO data were collected from residential areas. Therefore, the City used water quality data collected from two King County CSOs that are located near CSO Outfalls 107 and 111 and have tributary areas with industrial land uses. The data from the two King County CSOs were pooled to estimate RCOC concentrations for CSO Outfalls 107 and 111.

Data for PCBs, PBDEs, and pesticides were not available from the City sampling data. Data from a King County report describing PCBs and PBDEs (King County, 2011) were used to fill these data gaps.

The herbicide dichlobenil was used as a surrogate for pesticides. Local stormwater sampling provided data on dichlobenil concentrations for runoff from residential, commercial, and industrial land uses. However, no data on dichlobenil or other pesticides were available for City CSO discharges. Therefore, median dichlobenil concentrations for stormwater from each land use type were used to estimate a weighted concentration based on the land use of each CSO basin. This weighted concentration was factored by the percentage of flow attributable to groundwater and stormwater within each CSO basin, as indicated by the CSO models.

The King County sampling data did not include BOD, fecal coliform bacteria, oil and grease, or H+. The City sampling data were used to fill this data gap. The City and King County water quality data are discussed in more detail in Appendix E.

The RCOC concentrations used in the CSO analysis were the mean of the data set, and included both the upper confidence limit (UCL) and lower confidence limit (LCL) as calculated by the bootstrap method (Singh et al., 1997). The bootstrap method samples from the data set with replacement several thousand times and calculates the desired descriptive statistics from the sampled data; it is fundamentally a procedure based on the Central Limit Theorem, which suggests that even when the underlying population distribution is non-normal, averaging produces a distribution more closely approximated with normal distribution than the sampled distribution (Devore, 1995). A comprehensive description of the bootstrap method is provided in Appendix F, which discusses the pollutant reduction estimation method applied to the stormwater projects.

Table 6-2 lists the RCOC concentrations used for the CSO load evaluations. This bootstrap method that was used for deriving the mean, LCL, and UCL of the CSO water quality data set was also applied to the data set used for the stormwater project evaluation, as discussed in Section 6.6.

Table 6-2. Mean, LCL, and UCL of RCOCs Applied to the CSO Volumes for Estimating Pollutant Reductions

Constituents of concern	Units	Residential/commercial			Industrial		
		Bootstrap mean	Bootstrap 95% lower confidence limit (LCL)	Bootstrap 95% upper confidence limit (UCL)	Bootstrap mean	Bootstrap 95% lower confidence limit (LCL)	Bootstrap 95% upper confidence limit (UCL)
Ammonia-N	mg/L	1.2	1.0	1.6	4.6	2.8	7.0
BOD	mg/L	19	15	24	19	15	24
Bis(2-ethylhexyl) phthalate	mg/L	0.0023	0.0018	0.0030	0.0083	0.0025	0.019
Dichlobenil	mg/L	Residential: 0.00012 Commercial: 0.000098	N/A	N/A	0.000070	N/A	N/A
Dissolved copper	mg/L	0.0051	0.0046	0.0057	0.0065	0.0041	0.011
Dissolved zinc	mg/L	0.019	0.018	0.021	0.032	0.022	0.046
Fecal coliform bacteria	CFU/100 mL	103,885	72,200	140,048	103,885	72,200	140,048
H+	mg/L	0.00012	0.000088	0.00017	0.00012	0.000088	0.00017
Oil and grease	mg/L	3.5	2.8	4.4	3.4	2.8	4.4
PBDEs	mg/L	0.000060	N/A	N/A	0.000060	N/A	N/A
PCBs	mg/L	0.000052	0.000040	0.000067	0.00011	0.000063	0.00020
Phosphorus	mg/L	0.60	0.44	0.75	1.6	1.2	2.1
Total copper	mg/L	0.013	0.011	0.016	0.053	0.034	0.068
TSS	mg/L	32	26	39	118	78	179
Total zinc	mg/L	0.042	0.038	0.048	0.14	0.10	0.19

6.5.3 Pollutant Load Reduction Estimation

Pollutant load reductions were estimated as the product of the RCOC concentrations and simulated CSO volume reductions for each candidate LTCP project. Appendix E contains a more detailed discussion of the predicted volumes and RCOC concentration used for estimating the pollutant load reductions from the LTCP projects.

6.5.4 Projected DO Estimation

A simplified approach was used to calculate the potential impact of each candidate LTCP project on dissolved oxygen (DO). The Streeter-Phelps equation was used to calculate the maximum DO deficit based on the change in nitrogen and carbonaceous BOD concentrations. The deficit value was used to estimate the percent change from DO at saturation. The same method was used to estimate potential DO impacts from the candidate stormwater projects. Appendix F contains a detailed description of the method.

6.6 Pollutant Load Evaluation Methods for Candidate Stormwater Projects

The City estimated the potential pollutant load reductions for each candidate stormwater project. The City used the loads modeling results to help determine which stormwater projects should be included in the Integrated Plan. This section summarizes the pollutant loads modeling methods for the candidate stormwater projects. Appendix F provides a detailed description of the stormwater project loads evaluations and results.

6.6.1 Model Overview

The City used existing information and a relatively simple spreadsheet pollutant load model (PLM) to estimate pollutant load reductions for the candidate stormwater projects. Although the PLM was not calibrated to site-specific conditions, local information provided by the City (e.g., local stormwater runoff study data and local precipitation data) were used where possible. Information from literature and the International Stormwater Best Management Practice (BMP) Database (Geosyntec Consultants and Wright Water Engineers, Inc., 2011) was also used for parameterizing the PLM.

The pre-project component of the model was based on observed and literature-developed rainfall/runoff relationships and estimated pollutant concentrations in stormwater runoff. The volume of stormwater runoff was estimated using a simple volumetric runoff coefficient, an empirical expression that relates runoff volume to the rainfall depth and the basin characteristics, such as imperviousness and soil infiltration characteristics. The pollutant concentration in stormwater runoff was represented by an expected average pollutant concentration, developed based on analysis of event mean concentrations (EMCs). The EMCs used in this analysis were obtained from available monitoring data from other studies and are dependent on the land-use type. See Appendix F for additional details on the data used and the methodology applied for this analysis.

The post-project component of the model utilizes the pre-project concentrations and runoff volumes and applies stormwater project performance estimates to each of the candidate stormwater projects. The modeled performance of each project depends on the following three factors:

- the fraction of average long-term stormwater runoff volume receiving treatment (referred to hereafter as "capture efficiency")
- the pollutant removal achieved in the stormwater project by virtue of surface runoff reduction via infiltration and/or evapotranspiration (generically referred to as "volume reduction")
- the pollutant removal achieved in the stormwater project by virtue of improved water quality of treated runoff

The flow chart in Figure 6-1 provides an overview of the post-project modeling component. See Appendix F for additional details on the data used and the methodology applied for this analysis.

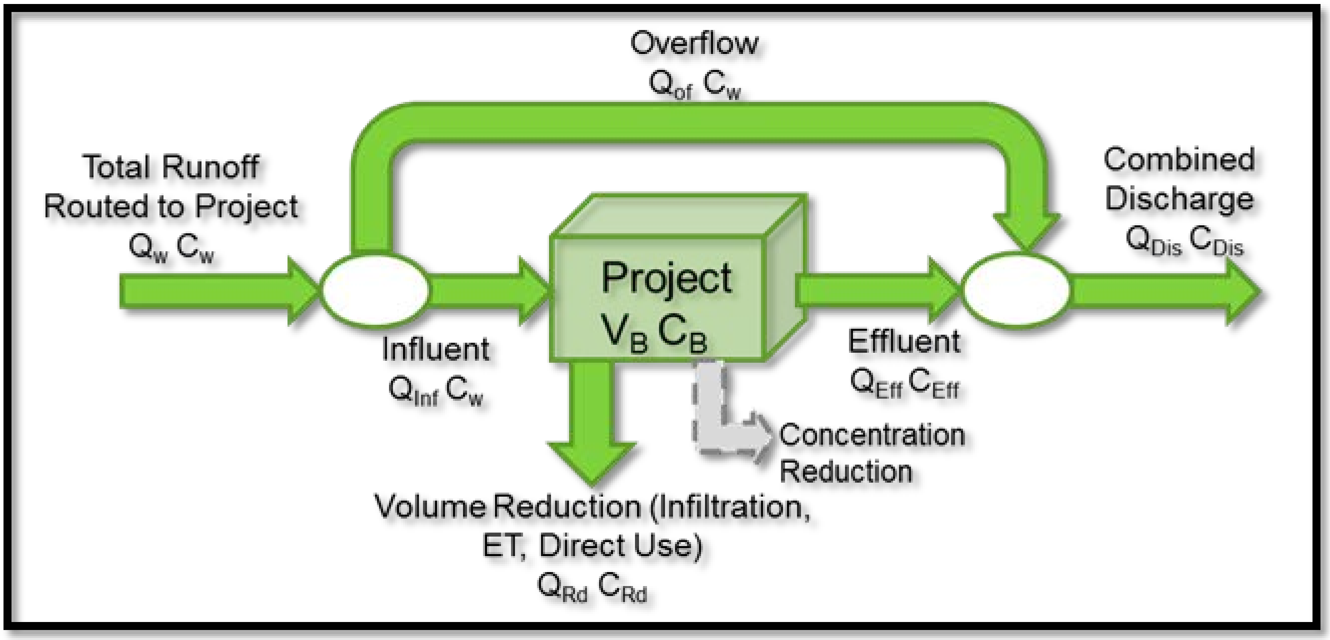

Figure 6-1. Flow chart used for stormwater project evaluation

6.6.2 Uncertainty in Input Parameters

There is an inherent level of uncertainty in the stormwater sampling data, watershed characteristics, GIS data, stormwater project performance data, and other data sets that were used to help understand the water quality benefits of stormwater projects. Therefore, understanding and quantifying these sources of uncertainty and incorporating them into the PLM created a more robust analysis. A statistical modeling approach (Monte Carlo Analysis) was employed to allow the uncertainty in input parameters to be reflected in model inputs and provide an indication of the average characteristics and variability of the stormwater concentrations and loadings in model results. For each Monte Carlo iteration, the PLM randomly selected a value between the lower and upper bounds for each key parameter to develop a unique estimate of average long-term conditions. The calculation was repeated for a large number of iterations, resulting in a large distribution of different estimates of potential long-term runoff volume, pollutant concentrations, and pollutant loadings results from each of the project tributary areas (see Appendix F for a complete discussion of the uncertainty in the input parameters as well as a description of the Monte Carlo Analysis).

The first step was to develop a lower and upper bound for each of the parameters that is sensitive in the analysis and can be meaningfully quantified. When possible, the model expressed these input parameters in terms of a 95 percent confidence interval (CI) on the long-term average (i.e., bounded by the LCL and the UCL). CIs were developed for the land use runoff concentrations, project effluent concentrations, and street sediment concentrations using the bootstrap method approach, as defined in Section 6.5.2 above, in combination with regression on order statistics (ROS). Additionally, when the underlying data sets did not allow for the explicit estimation of CIs, the LCL and UCL for each key model input parameter were estimated using other methods, such as modeling calculations, data analysis, literature, or best professional judgment (see Appendix F for a comprehensive discussion of this methodology).

The PLM was intended to estimate long-term average annual conditions for a given location and project. It did not seek to describe the temporal variability that is inherent in stormwater pollutant loading. Additionally, the PLM was not intended to predict conditions for a given storm event or monitoring period.

6.6.3 Street Sweeping Model Overview

The City developed a separate model to characterize long-term average pollutant loading reductions and concentration reductions for the candidate street sweeping stormwater projects. This model uses a rate of pollutant removed by sweeping per curb-mile (pick-up rate) calculated from data measured during the City's current street sweeping program. The pick-up rate is then applied to the area that will receive additional sweeping to generate the total pollutant mass removed. Adjustments were applied to the total pollutant mass removed to convert this mass into a portion that would have been expected to be washed off the street during rain events and discharged at stormwater outfalls. A detailed discussion of the street sweeping analysis is included in Appendix G. The methodology and data provided by the City were then used to characterize the uncertainty inherent in the street sweeping data, as described below, and run with the Monte Carlo iterations.

6.6.4 Model Input Parameters

The PLM input parameters for the pre-project pollutant loadings included precipitation, stormwater project drainage area, runoff coefficients, and land use runoff concentrations. PLM input parameters for the post-project pollutant loadings included candidate stormwater project performance parameters, including capture efficiency, volume reduction, and effluent quality and/or other expressions of treatment efficiency. Appendix F provides a detailed discussion on all of the model input parameters and includes a discussion on the precipitation characteristics, stormwater project drainage areas, including the effective drainage area adjustments and their degree of project implementation, runoff coefficients, land use runoff concentrations, and project performance metrics. As noted in Appendix F (section 3.2.3), the "degree of project implementation" is the ratio of the constraints that will limit the treatment area size to the overall area that may be available. Additional model input parameters for street sweeping include ranges of uncertainty and seasonal variations in street sweeping load reductions. Appendix G contains a detailed description of the street sweeping analysis.

6.6.5 Model Methodology

The application of the PLM involved several calculation steps, as summarized below:

1. Calculate the implemented effective drainage area for each land use type within the stormwater project drainage area, based on degree of project implementation, GIS land use (e.g., residential, commercial, industrial), surface type (e.g., street, building, sidewalk, landscaped area), and drainage system connection factors (parameters selected from within CIs).
2. Estimate the runoff coefficient for each land use type within the stormwater project drainage, based on GIS land use and pervious surface type data, and source type runoff coefficients (parameters selected from within CIs).
3. Select the rainfall depth for the time period (from CIs) to calculate the stormwater runoff volume from each land use type within the stormwater project drainage area and then sum volumes for the pre-project runoff volume.
4. Select a pollutant concentration in stormwater runoff for each land use type and each RCOC (from respective CIs), and multiply by runoff volume to calculate the pre-project load from each discrete contributing area.
5. Sum load and volume contributions from each contributing area and use these sums to calculate the pre-project concentration for each RCOC.

6. Route the pre-project load through the candidate stormwater project to estimate the post-project pollutant load and volume associated with candidate stormwater project bypass, volume reduction, and change in concentration via treatment (each selected from within CIs). Sum each element to compute the composite load, volume, and resultant average concentration discharged downstream of the candidate stormwater project.
7. Calculate the post-project average volume reduction, concentration reduction, and load reduction for each RCOC based on the difference between pre-project and post-project results.
8. To calculate the distribution of results, repeat steps 1–7 a total of 1,000 times for each RCOC and time period, recording the pre-project and post-project, and reduction model results for each iteration.

Appendix F of this plan provides a complete discussion on the methodology used by the City for evaluation of the pollutant load reductions for each of the stormwater projects, excluding the street sweeping stormwater programs. Appendix G of this plan describes the City's recent street sweeping monitoring and how the results were used to estimate pollutant load reductions for the two candidate street sweeping programs.

6.7 Exposure Assessment Methods

The City developed a conceptual model to estimate the relative exposure reduction associated with each candidate LTCP project and structural stormwater project. The model used metrics for potential hazard and exposure to calculate an exposure index value (EIV) for each structural project. Section 6.7.1 summarizes the EIV calculation methods. Appendix H contains a more detailed description of the EIV methods.

It was impractical to calculate EIVs for the candidate street sweeping programs. Therefore, the City performed a more qualitative exposure assessment for street sweeping. After tentatively selecting the projects for the Integrated Plan, the City performed a qualitative assessment to compare the selected stormwater projects to the selected LTCP projects. Section 6.7.2 summarizes the qualitative exposure assessment methods.

6.7.1 Exposure Index Value Method

The City developed a conceptual model that used metrics for potential hazard and exposure to calculate an EIV for each structural project. The EIV was designed to compare and rank candidate projects based on their relative reductions in human and ecological exposures. The EIVs were used to help compare the candidate projects and select projects to be included in the Integrated Plan.

The EIV model included three basic components:

- characterization of the RCOCs
- identification of potential human and ecological receptors in the receiving water body affected by each candidate project
- identification of potential exposure pathways and exposure rates for the receptors near each discharge location

Based on input from the Expert Panel, the City calculated the following three separate EIV metrics for each candidate structural project:

- human receptors exposed to toxic constituents, based on chronic water quality criteria
- human receptors exposed to fecal coliform, based on acute water quality criteria
- ecological receptors exposed to toxics and nutrients, based on chronic water quality criteria

The EIV calculation was based on the following parameters:

- pre-project RCOC concentration
- water quality criterion for each RCOC
- change in RCOC load resulting from project implementation
- exposure potential for each receptor type and at each project location

EIVs were calculated as follows:

$$EIV_{Human\ or\ Eco-RCOC} = \frac{C_{Pre}}{WQC_{Human\ or\ Eco}} \times relative\ change\ in\ load \times\ RF_{Human\ or\ Eco}$$

Where:

C_{pre} = concentration in effluent discharged pre-project (mg/L, or CFU/100 mL for fecal coliform)

WQC = human or ecological water quality criterion (mg/L, or CFU/100 mL for fecal coliform)

Relative change in load = (pre-project load – post-project load for a specific RCOC) / total change in load across all projects (candidate LTCP and stormwater projects) for this RCOC

RF = receptor factor (unitless)

The EIV calculations require information about receptors at each affected outfall location. As noted above, EIVs were not calculated for the candidate street sweeping programs because they would affect more than 100 outfalls and numerous water bodies throughout the city.

6.7.1.1 Hazard Potential

The hazard potential is calculated based on the ratio of the pre-project RCOC concentration from the candidate LTCP or stormwater project outfall to the applicable water quality criterion for the RCOC, which can vary depending on the receptor.

$$Hazard\ potential = \frac{C_{Pre}}{WQC_{Human\ or\ Eco}}$$

Tables 6-3 and 6-4 show the water quality criteria for human receptors and ecological receptors, respectively.

Table 6-3. Water Quality Criteria for Human Receptors

RCOC	Criterion (mg/L)	Basis	Health impact basis	Source
Bis(2-ethylhexyl) phthalate	0.0012	Assuming ingestion of water and fish consumption	Chronic, cancer (liver cancer in rodents, EPA SF)	EPA AWQC (EPA, 2002b)
Copper	1.3	EPA drinking water MCLG	Chronic, non-cancer (gastrointestinal effects in humans, EPA RfD)	EPA AWQC (EPA, 2013b)
Dichlobenil	0.44	Assuming ingestion of water and fish consumption	Chronic, non-cancer (decreased body weight in dogs, EPA RfD)	Derived using EPA AWQC equation (EPA, 2000)
Fecal coliform	50 CFU/100 mL 100 CFU/100 mL 200 CFU/100 mL	Extraordinary primary contact (Ship Canal, Portage Bay, Piper's Creek, Thornton Creek) Primary contact (Longfellow Creek) Secondary contact (Duwamish Waterway)	Acute infection	Ecology, 2011b
PBDEs	0.000088	Assuming ingestion of water and fish consumption	Chronic, non-cancer (neurobehavioral effects in rats, EPA RfD)	Derived using EPA AWQC equation (EPA, 2000)
PCBs	0.000000064	Assuming ingestion of water and fish consumption	Chronic, cancer (liver cancer in rats, EPA SF)	EPA AWQC (EPA, 2013b)
Zinc	7.4	Assuming ingestion of water and fish consumption	Chronic, non-cancer (enzyme activity in humans, EPA RfD)	EPA AWQC (EPA, 2013b)

AWQC = ambient water quality criteria.
CFU = colony forming unit(s).
MCLG = maximum contaminant level goal.
RfD = reference dose.
SF = slope factor.

Table 6-4. Water Quality Criteria for Ecological Receptors

RCOC	Chronic criterion: freshwater (mg/L)	Chronic criterion: marine (mg/L)	Basis	Source
Ammonia-N	Location-specific; see Appendix H	8.21 (Oct–Jan) 5.52 (Feb–Sep)	Calculated as un-ionized ammonia and converted to total ammonia, as N, assuming salmonids present; see Appendix H	Ecology, 2011b
Bis(2-ethylhexyl) phthalate	0.003	0.003	No criteria, based on data suggesting chronic toxicity to aquatic life as low as 3 µg/L	EPA, 1980
Dichlobenil	0.33	0.33	Chronic criteria for fisheries	Ecology, 2013c
Dissolved copper	0.0041 (mesotrophic) 0.011 (streams)	0.0031	For freshwater, based on water-body-specific hardness assumptions using EPA equation. For marine, equal to EPA value; see discussion below.	EPA, 2007
Dissolved zinc	0.054 (lakes) 0.14 (streams)	0.081	Based on water-body-specific hardness assumptions; see Appendix H of this plan.	EPA, 2007
PCBs	0.000014	0.00003	Total PCBs	Ecology, 2011c
Phosphorus	0.00875 (lakes) 0.010 (streams)	No value	Total phosphorus, Ecoregion II	EPA, 2002a

6.7.1.2 Change in Load

Pre-project and post-project pollutant loads were estimated as described in Sections 6.5 and 6.6. The change in load for each project was normalized (taken as a ratio) to the total estimated load reductions of all of the candidate LTCP and stormwater projects combined. Data were normalized to allow for a comparison of load reduction for RCOCs with different units and the EIVs for the candidate projects.

6.7.1.3 Receptor Factor

The receptor factor (also known as exposure potential) is a function of the receptor type (human or ecological) and project location (or receiving water body). The City identified potential receptor exposure pathways for the following receiving water bodies:

- Duwamish River
- Lake Washington
- Puget Sound/Elliott Bay
- Lake Washington Ship Canal/Lake Union
- Thornton Creek
- Longfellow Creek
- Piper's Creek

Human Receptor Factor

The exposure potential for humans was estimated based on the following three factors:

- relative dose of the RCOC
- relative distance from outfall to the activity location (or length of the exposure pathway)
- likelihood of the activity

The City evaluated the following five potential activities in the receiving water bodies affected by each candidate project:

- swimming
- wading
- recreational boating
- fishing
- shellfishing

The analysis considered the following three potential pathways for exposure during the activities listed above:

- incidental ingestion of surface water
- dermal contact with surface water
- ingestion of fish or shellfish

The likelihood of an activity was estimated as a range from 1 to 5 (5 = most likely), based on the frequency and duration of the activity by season.

Ecological Receptor Factor

The ecological receptor factor considers the presence and sensitivity of three specific life stages (egg/breeding, juvenile, and adult) for eight fish species (bull trout, Chinook salmon, chum salmon, coho salmon, cutthroat trout, pink salmon, sockeye salmon, and steelhead).

For the ecological receptor, pathways include:

- ingestion of water
- contact with water

The likelihood of the life-stage presence was estimated as a range from 1 to 5, where 5 indicates the most presence. The following values were assigned based on estimated duration of presence:

- 1: if present during 1 month
- 3: if present during 2–3 months
- 5: if present for greater than 3 months

The relative distance from the outfall to the receptor was estimated by direct measurements at the site or with GIS. Appendix H of this plan provides a detailed discussion of the methodology used to calculate EIVs.

6.7.2 Qualitative Exposure Assessment

EIVs were not calculated for the two candidate street sweeping programs because the EIV calculations require information on potential receptors near each affected outfall. Runoff from the swept streets would affect more than 100 outfalls and numerous receiving water bodies throughout the city. It was not feasible to assess the potential receptors at each location. Therefore, potential exposure reductions from sweeping were evaluated using a more qualitative approach based on load reductions and the frequency and timing of runoff from the swept streets. Section 8.2.3 describes the potential reductions in exposure that would result from the candidate street sweeping programs.

After the City had tentatively selected projects and programs for the Integrated Plan, a qualitative evaluation was performed to compare the selected stormwater projects to the LTCP projects in terms of overall exposure reduction benefits. This comparative assessment considered pollutant loads, discharge frequency, discharge timing, potential human and ecological receptors, and hydromodification benefits of the Integrated Plan. Section 8.4.3.2 describes the exposure reduction benefits assessment.

CHAPTER 7

Project Evaluation Results

This chapter discusses the pollutant load reduction results and exposure assessment results for each of the evaluated candidate LTCP and stormwater projects.

7.1 Introduction

The City used the methods described in Chapter 6 to estimate pollutant load reductions for the candidate LTCP and stormwater projects considered for potential inclusion in this Integrated Plan. The pollutant loads results were then used with other existing data to calculate EIVs for the candidate projects.

Section 7.2 summarizes the results from the pollutant load reduction evaluations of the LTCP projects identified as candidates for deferral under the Integrated Plan. Section 7.3 presents the pollutant load reduction results for the candidate stormwater projects and programs. Section 7.4 summarizes the EIV results for the candidate LTCP and stormwater projects. Appendices E, F, and G contain additional information on the pollutant loads modeling results for the candidate LTCP projects, stormwater projects, and street sweeping programs, respectively. Appendix H provides additional details regarding the EIV results.

7.2 Pollutant Load Reductions for Candidate LTCP Projects

The City used the methods described in Chapter 6 to estimate the pollutant load reductions associated from implementing each of the candidate LTCP projects. Table 7-1 lists maximum and minimum annual RCOC reductions that would be provided by the candidate LTCP projects. For example, the largest of the six candidate LTCP projects (CSO 107) would reduce the average annual flow volume by 1.1 MG/yr, while the smallest project (CSO 138) would reduce the annual flow volume by only 0.0057 MG/yr. (Note that this is not directly comparable to Table IPS-1, which lists the average annual load reductions for each LTCP project.) See Appendix E for a more comprehensive discussion of these results.

Table 7-1. Range of Volume and RCOC Load Reduction Results for the Six Candidate LTCP Projects

Evaluated metric	Units	Maximum annual reduction[a]	Minimum annual reduction[b]
Volume[c]	MG/yr	1.1	0.0057
Ammonia-N	kg/yr	19	0.027
BOD	kg/yr	82	0.42
Bis(2-ethylhexyl)phthalate	kg/yr	0.035	0.000050
Dichlobenil	kg/yr	0.00029	0.0000025
Dissolved copper	kg/yr	0.027	0.00011
Dissolved zinc	kg/yr	0.14	0.00042
Fecal coliform bacteria	billion CFU/yr	4,346	22

Table 7-1. Range of Volume and RCOC Load Reduction Results for the Six Candidate LTCP Projects

Evaluated metric	Units	Maximum annual reduction[a]	Minimum annual reduction[b]
H+	kg/yr	0.00049	0.0000025
Oil and grease	kg/yr	15	0.075
PBDEs	kg/yr	0.00025	0.0000013
PCBs	kg/yr	0.00046	0.0000011
Phosphorus	kg/yr	6.6	0.013
Total copper	kg/yr	0.22	0.00029
TSS	kg/yr	494	0.69
Total zinc	kg/yr	0.57	0.00090

a. The largest average annual reduction that would be provided by one of the six candidate LTCP projects.
b. The smallest average annual reduction that would be provided by one of the six candidate LTCP projects.
c. The maximum and minimum annual volume reductions for the candidate LTCP projects were estimated from the moving 20-year (through 2012) average simulated CSO volumes without climate change (scaling factor = 1).

CSO Outfall 107 is predicted to have the greatest reduction in all of the evaluated RCOC concentration loads. The CSO Outfall 139 project would result in the least pollutant load reductions.

Figure 7-1 shows the estimated reductions in volume for each of the six candidate LTCP projects. Figures 7-2 through 7-6 show the estimated load reductions for key RCOCs (i.e., TSS, fecal coliform, dissolved copper, PCBs, and ammonia-N). Appendix E of this plan contains the data for all of the RCOCs evaluated.

Figures 7-1 through 7-6 show results for three time periods: annual, Season 1, and Season 2. These three types of results are shown to illustrate the variation in seasonality. A review of CSO discharges and modeling results show that most CSO discharges occur during Season 1 (October through January). More specifically, modeling of the candidate LTCP locations indicates that about 65 percent of the CSOs occur during Season 1, with the associated overflow volume at about 85 percent of the total simulated CSO volume from the candidate LTCP locations. During Season 2 (February through September), CSO discharge frequencies and volumes are relatively low.

7.2.1 Dissolved Oxygen

As discussed in Section 6.5.4, in order to characterize the impact of pollutant load reductions on receiving water dissolved oxygen (DO) concentrations, a simplified approach based on the Streeter-Phelps equation was used to estimate the change in projected DO concentration associated with each candidate LTCP project. The Streeter-Phelps equation calculates the average daily DO deficit (i.e., difference between DO at saturation and actual DO).

The Streeter-Phelps equation does not implicitly account for flow. As LTCP project improvements are quantified by reductions in flow and not by decreases in pollutant concentrations, improvements in BOD concentrations are first normalized to account for changes in loading. Using a common normalizing volume, equal to the maximum flow from all the stormwater and LTCP projects (e.g., 140.457 MG/yr), allowed for a comparison between stormwater and LTCP projects.

Reductions in the normalized DO deficit between pre- and post-project implementation were calculated for each of the LTCP projects. Table 7-2 provides a summary of the annual DO load reduction results from each LTCP project (see Appendix F for a more comprehensive discussion of these results).

Table 7-2. Normalized DO Deficit Results from the Six Candidate LTCP Projects (mg/L)

LTCP project	Maximum annual reduction	Minimum annual reduction	Median annual reduction
CSO Outfall 99	0.0035	0.0022	0.0028
CSO Outfall 107	0.034	0.018	0.025
CSO Outfall 111	0.0003	0.0001	0.0002
CSO Outfall 138	0.0019	0.0012	0.0015
CSO Outfall 139	0.0001	0.0001	0.0001
CSO Outfall 140	0.0011	0.0007	0.0009

7.2.2 Variability and Uncertainty in the LTCP Project Evaluation

The pollutant load reduction estimates derived from the candidate LTCP projects were based on predicted volumes from calibrated hydraulic models. These models are discussed in Volume 2: Long-Term Control Plan. The pollutant loads estimates for this Integrated Plan used the central tendency flow volumes from the LTCP hydraulic models. Although these models were calibrated, there is uncertainty associated with any model. The LTCP Hydraulic Modeling Reports contain a detailed discussion of the uncertainties associated with the predicted volumes generated from the LTCP hydraulic models.

Uncertainties are also associated with the RCOC concentrations that were used to estimate the pollutant load reductions for the candidate LTCP projects. These uncertainties were characterized by establishing a UCL and an LCL using the statistical analysis bootstrap method. Appendix F of this plan contains a detailed discussion of the statistical analysis conducted on all of the RCOC data used for assessing the candidate LTCP and stormwater projects. The UCL and LCL values are shown in the RCOC-related figures below via error bars.

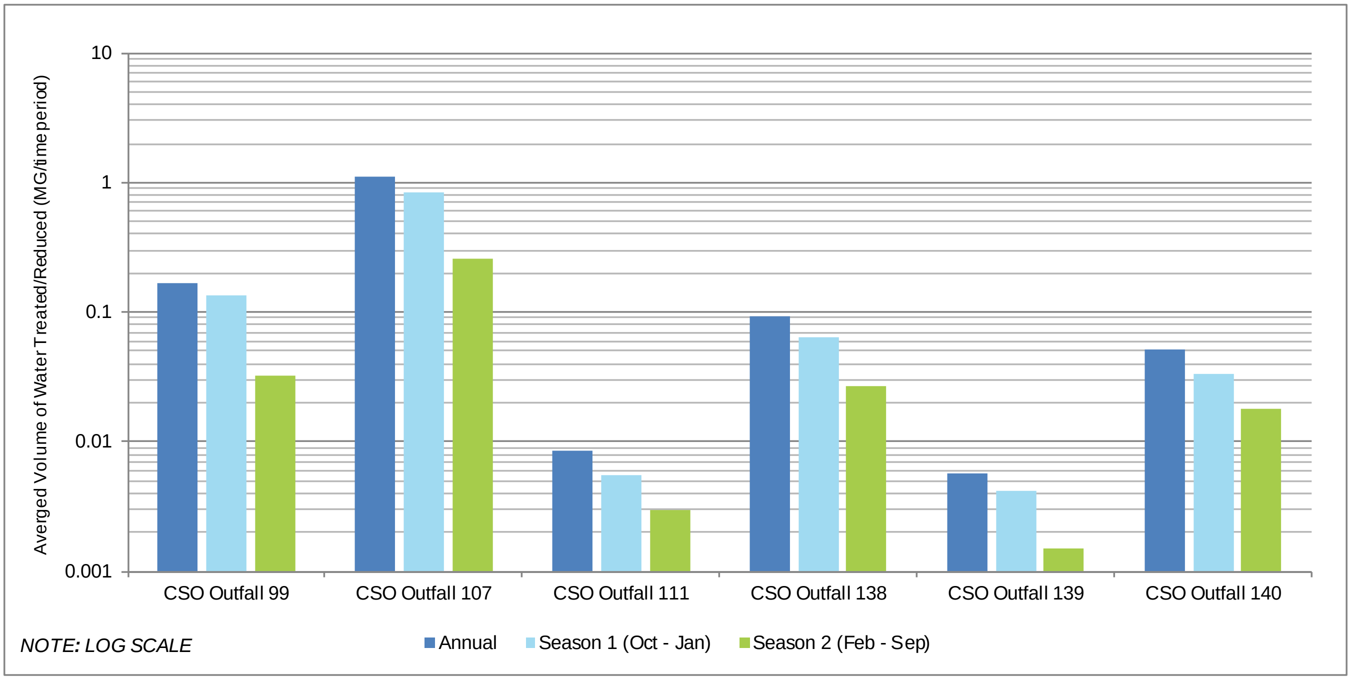

Figure 7-1. Average volume of water treated or reduced by the candidate LTCP projects

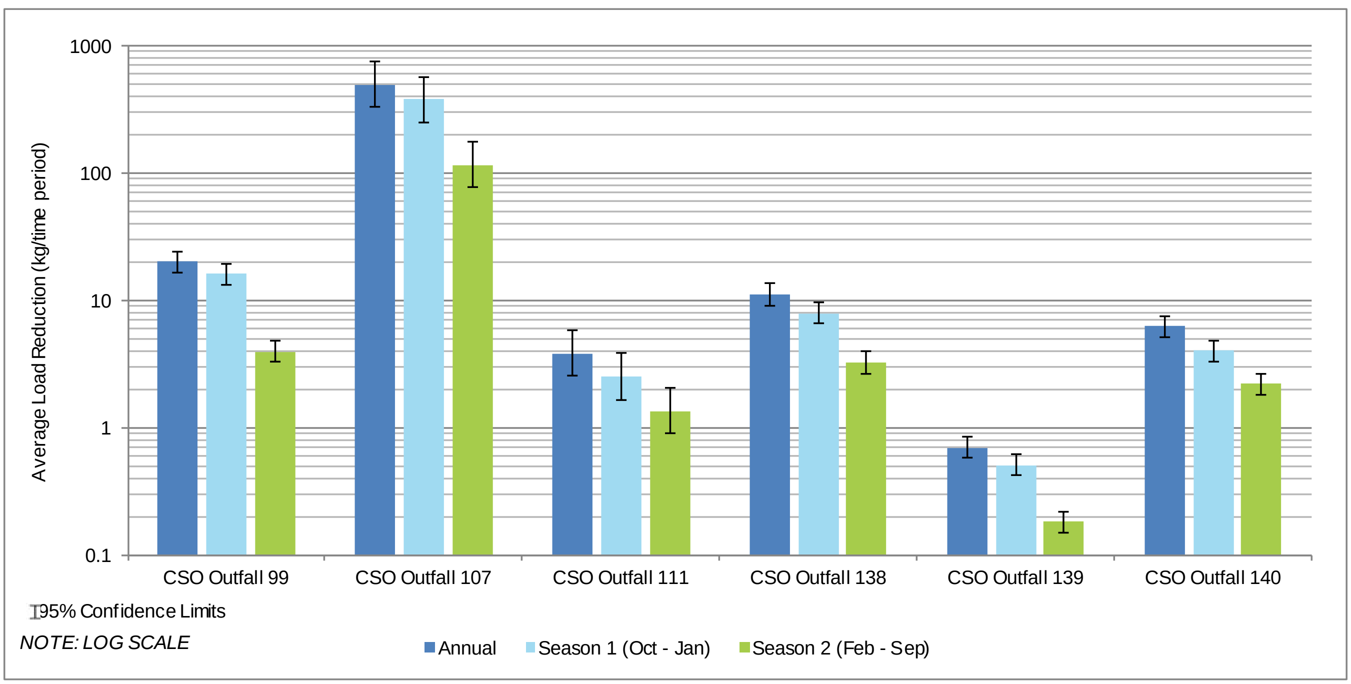

Figure 7-2. Average TSS load reduction from the candidate LTCP projects

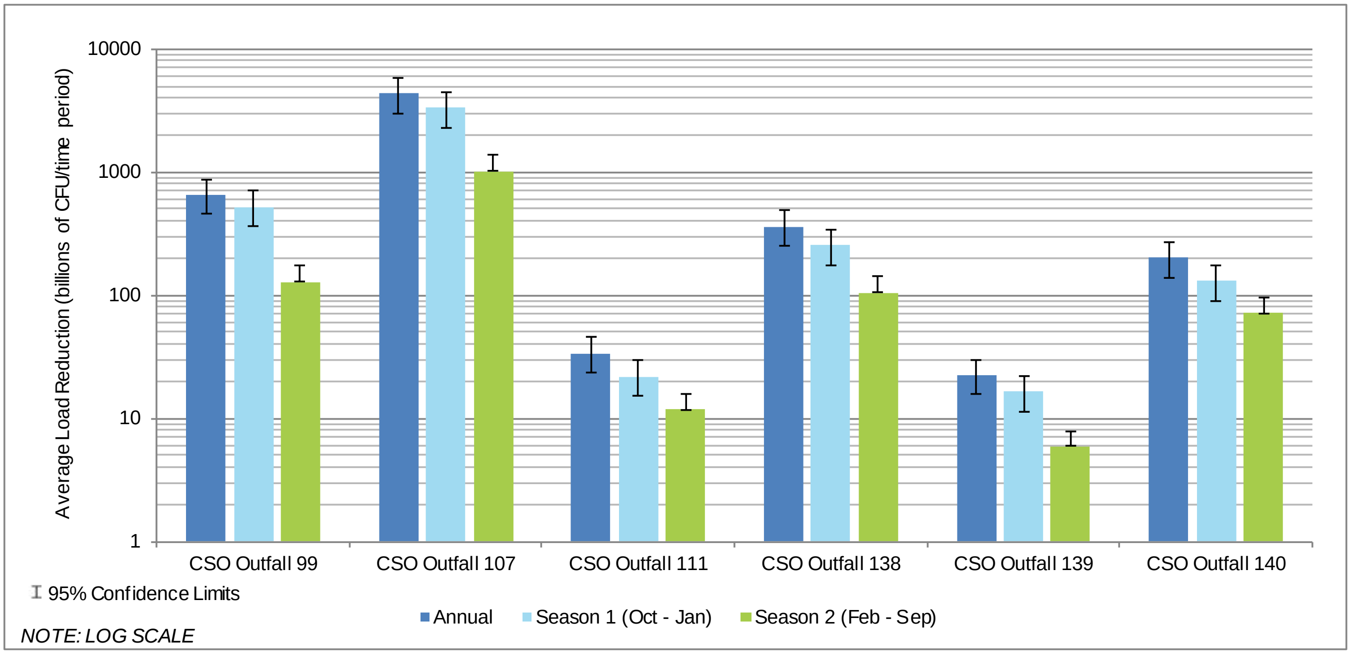

Figure 7-3. Average fecal coliform load reductions from the candidate LTCP projects

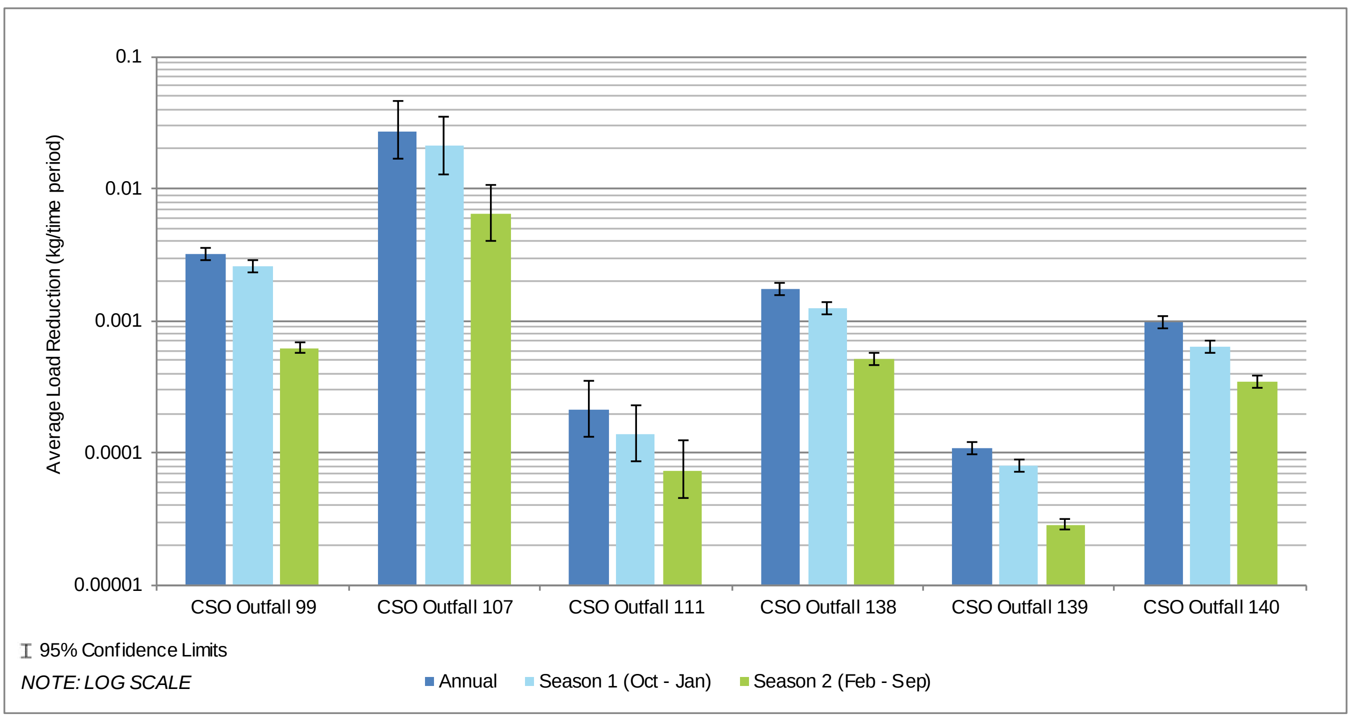

Figure 7-4. Average dissolved copper load reductions from the candidate LTCP projects

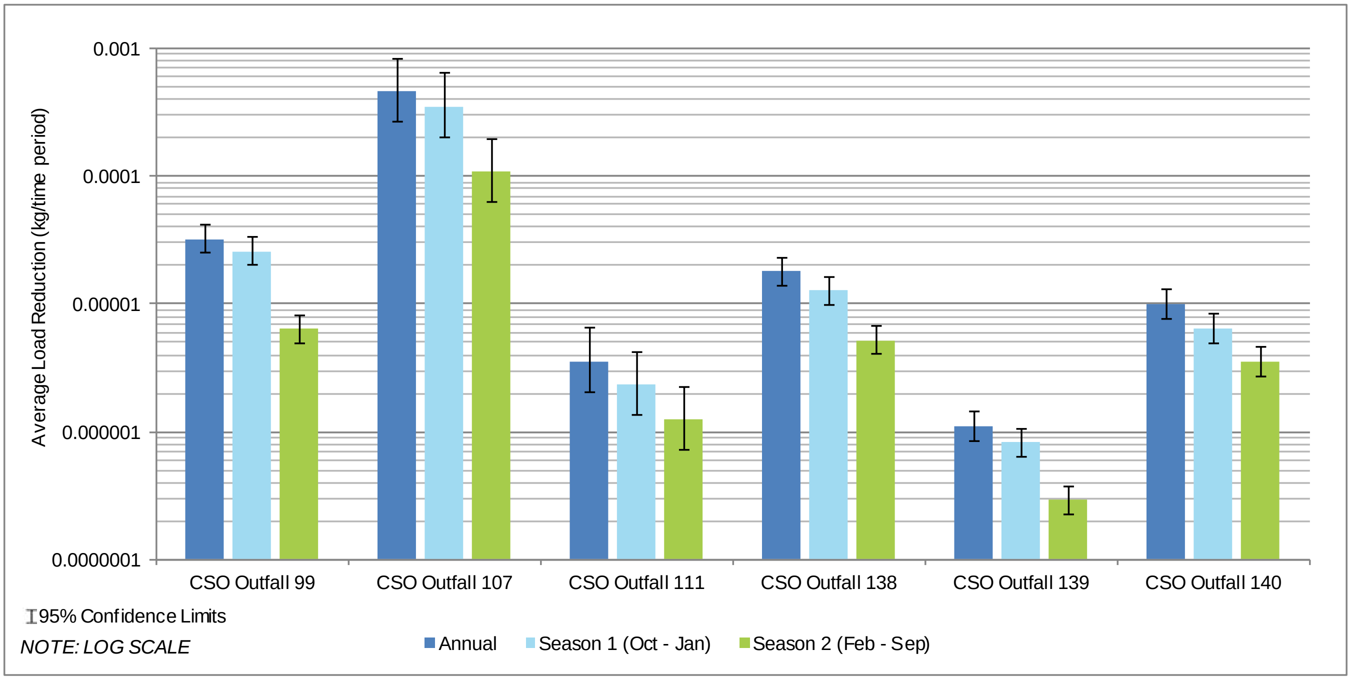

Figure 7-5. Average PCB load reductions from the evaluated candidate LTCP projects

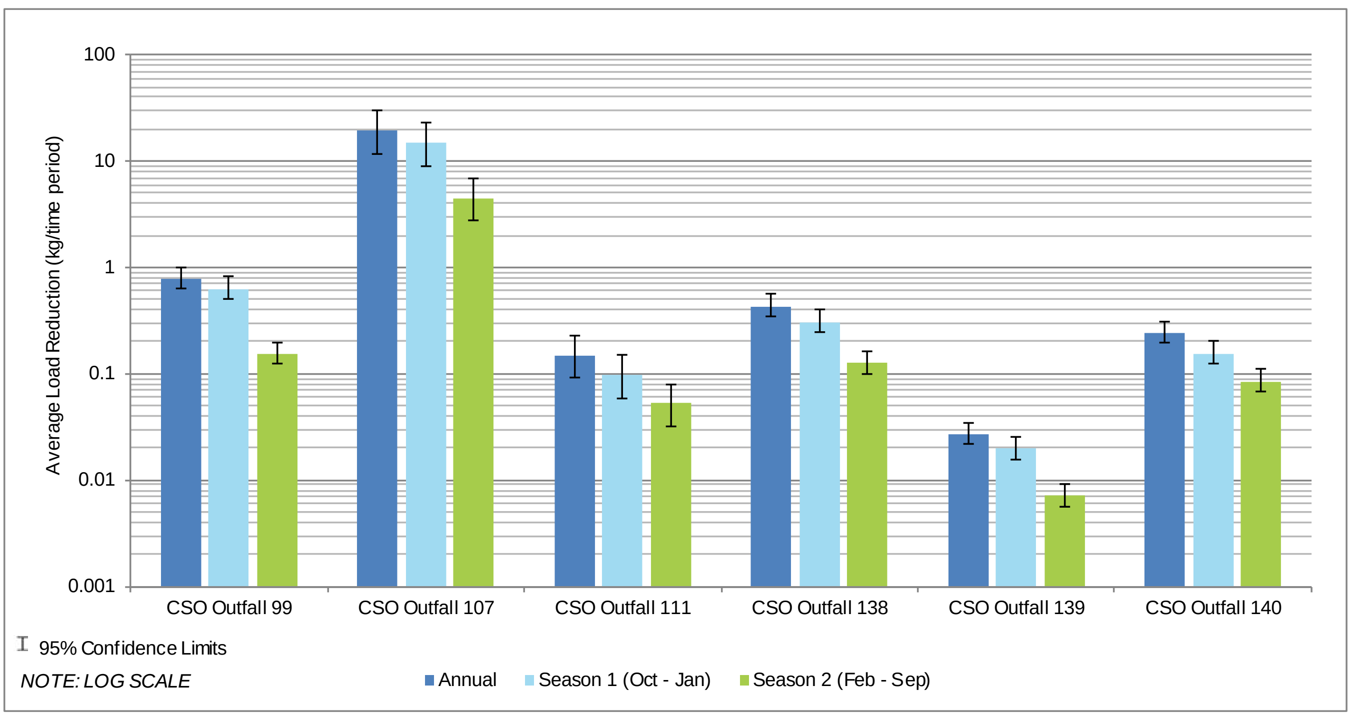

Figure 7-6. Average ammonia-N load reduction from the candidate LTCP projects

7.3 Pollutant Load Reductions for Candidate Stormwater Projects

The pollutant load reduction estimates for the candidate stormwater projects were based on City conceptual designs of the stormwater projects, performance data (i.e., effluent concentrations and volume reductions) from the International Stormwater BMP Database (Geosyntec Consultants and Wright Water Engineers, Inc., 2011), data from stormwater projects or treatment facilities recently piloted (SPU, 2012a; SPU, 2012b; City of Tacoma and Taylor Associates, 2008; North Boeing Field, 2013; CDM, 2010), and best professional judgment in the cases of the RCOCs where data were unavailable (Bis(2-ethylhexyl)phthalate, total PCBs, and total PBDEs) or where data were limited (BOD, fecal coliform, oil and grease, and dissolved copper). Changes in conceptual designs and associated changes in load reduction estimates will be reflected in Version 3 of this plan. Table 7-3 lists the overall capture efficiency for the candidate stormwater projects. Table 7-4 shows the range of volume and RCOC load reductions estimated for the 10 candidate stormwater projects. See Appendix F for a more comprehensive discussion of these results.

Table 7-3. Project Capture Efficiency for Candidate Stormwater Projects

Stormwater project	Capture efficiency[a]
Longfellow Cascades	80%
NDS Partnering	80%
Piper's Cascades	80%
South Myrtle St. Shoulder Stabilization	91%[b]
South Myrtle St. StormFilter Vault	91%[b]
South Park WQ Facility	83%
Street Sweeping Expansion Arterials	N/A
Street Sweeping Expansion Residential	N/A
SW Hinds SD StormFilter Vault	91%[b]
U Village Filterras	91%[b]

a. Capture efficiency is defined as the percentage of the annual runoff volume a stormwater project will be capable of treating/managing.

b. The design criteria level was provided by the City: structural projects are designed to treat up to 91% of the average annual runoff volume.

Table 7-4. Range of Volume and RCOC Load Reduction Results for the 10 Candidate Stormwater Projects[a]

Evaluated metric	Units	Maximum annual reduction[a]	Minimum annual reduction[b]
Volume treated	MG/yr	1,527[c]	0.108[c]
Ammonia-N	kg/yr	9.2	0.0
BOD	kg/yr	1,088	8.72
Bis(2-ethylhexyl)phthalate	kg/yr	0.29	0.002
Dichlobenil	kg/yr	0.0048	0.0
Dissolved copper	kg/yr	0.71	0.0
Dissolved zinc	kg/yr	14	0.0
Fecal coliform bacteria	billion CFU/yr	52,700	125
H+	kg/yr	0.021	0.0
Oil and grease	kg/yr	702	0.0
PBDEs	kg/yr	0.011	0.000033
PCBs	kg/yr	0.0069	0.000069
Phosphorus	kg/yr	46	0.093
Total copper	kg/yr	6.3	0.027
TSS	kg/yr	41,900	142
Total zinc	kg/yr	29	0.24

a. The largest average annual reduction that would be provided by 1 of the 10 candidate stormwater projects.
b. The smallest average annual reduction that would be provided by 1 of the 10 candidate stormwater projects.
c. The maximum and minimum results refer to the stormwater project treatment volumes (i.e., not stormwater project reductions in runoff volumes).

Figure 7-7 shows the estimated treatment volumes for each of the candidate stormwater projects. Figures 7-8 through 7-12 show the estimated load reductions for key RCOCs. Appendix F of this plan contains the data for all of the RCOCs evaluated for the structural stormwater projects. As shown in Figure 7-8, Street Sweeping Expansion Residential, Street Sweeping Expansion Arterials, South Park WQ Facility, and NDS Partnering would provide the largest reductions in annual TSS loads. Figures 7-9 and 7-10, respectively, show that the South Park WQ Facility would provide the greatest load reductions in fecal coliform and dissolved copper, while NDS Partnering would provide the second-greatest reductions. Figure 7-11 shows that the South Park WQ Facility and sweeping projects would provide the greatest reductions in PCB loads. Figure 7-12 shows that the NDS Partnering project would provide the greatest reduction in ammonia-N. Several of the projects would have little or no load reduction for some of the RCOCs.

7.3.1 Dissolved Oxygen

Reductions in the normalized DO deficit between pre- and post-project implementation were calculated for each of the candidate stormwater projects, using the same method described in Section 7.2.1. Table 7-5 provides a summary of the annual DO load reduction results from each candidate stormwater project (see Appendix F for a more comprehensive discussion of these results).

Table 7-5. Normalized DO Deficit Results from the Candidate Stormwater Projects (mg/L)

Stormwater project	Maximum annual reduction	Minimum annual reduction	Median annual reduction
Longfellow Cascades	0.08	0.02	0.05
NDS Partnering	0.15	0.01	0.02
Piper's Cascades	0.13	0.03	0.08
South Myrtle St. Shoulder Stabilization	0.0036	0.0003	0.0018
South Myrtle St. StormFilter Vault	0.02	0.00	0.01
South Park WQ Facility	0.39	0.05	0.21
SW Hinds SD StormFilter Vault	0.08	0.01	0.04
U Village Filterras	0.03	0.00	0.01

7.3.2 Variability and Uncertainty in the Stormwater Project Evaluation

An inherent level of uncertainty comes with using sampling data, GIS data, and stormwater project performance data to estimate the water quality benefits of stormwater projects. The variability of stormwater quality and volume are widely recognized. For the Integrated Plan, the analysis method was intended to estimate long-term averages, and any inherent uncertainty in the data and input parameters. When possible, the model expressed these input parameters in terms of a 95 percent CI on the long-term average (i.e., bounded by the LCL and the UCL).

Sources of uncertainty also arise from spatial variability of processes, the stochastic nature of stormwater, limited data, monitoring techniques, and more. As a result, uncertainty is associated with PLM inputs such as runoff characteristics, pollutant load estimates per land use or source area, and spatial variability. As discussed in Section 6.6.2, Monte Carlo Analysis was used to quantify the uncertainty in long-term estimates of land use runoffs and stormwater project performance. A detailed discussion of the uncertainties associated with the stormwater project evaluations is provided in Appendix F.

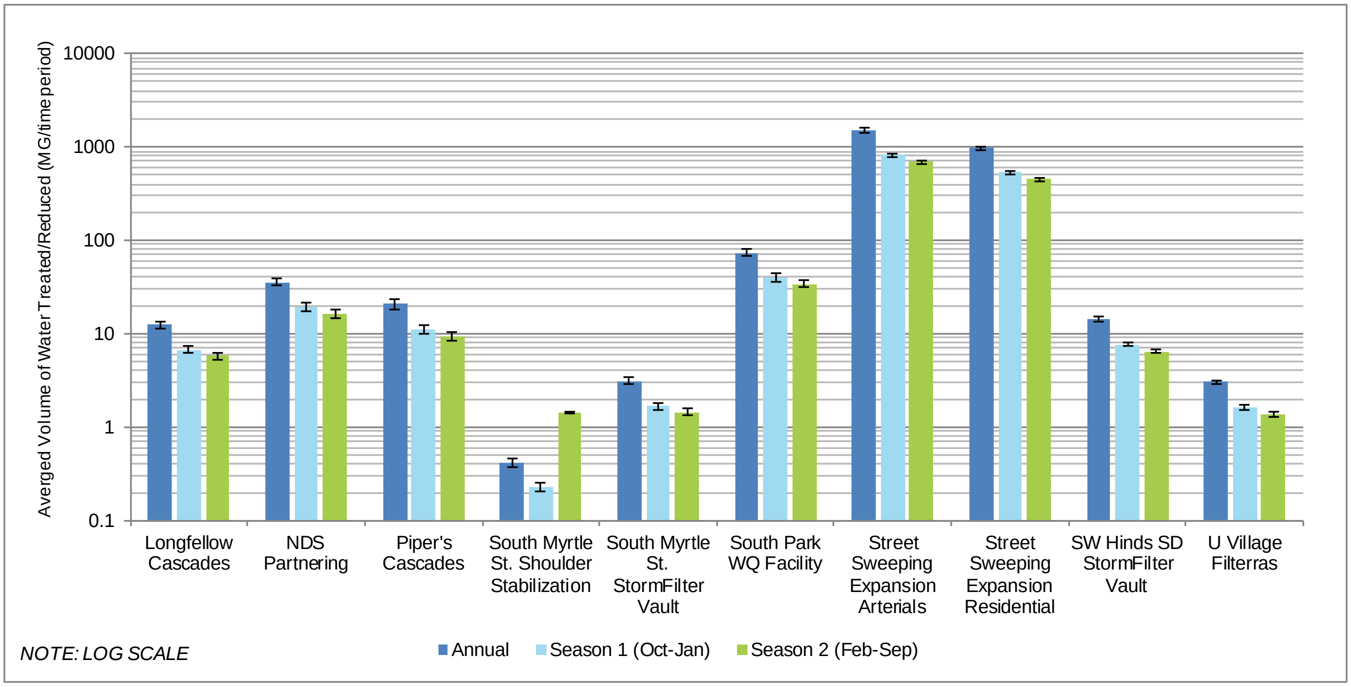

Figure 7-7. Long-term average volume of water treated or reduced by the candidate stormwater projects

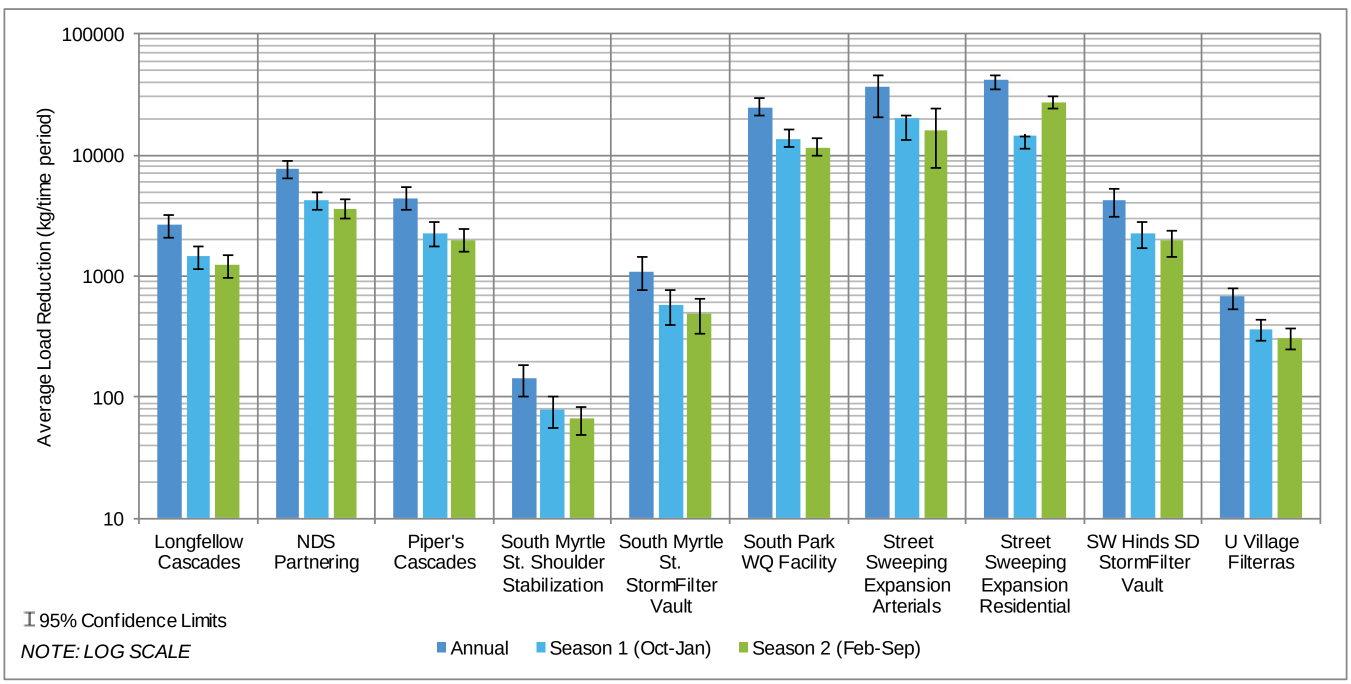

Figure 7-8. Long-term average TSS load reduction from the candidate stormwater projects

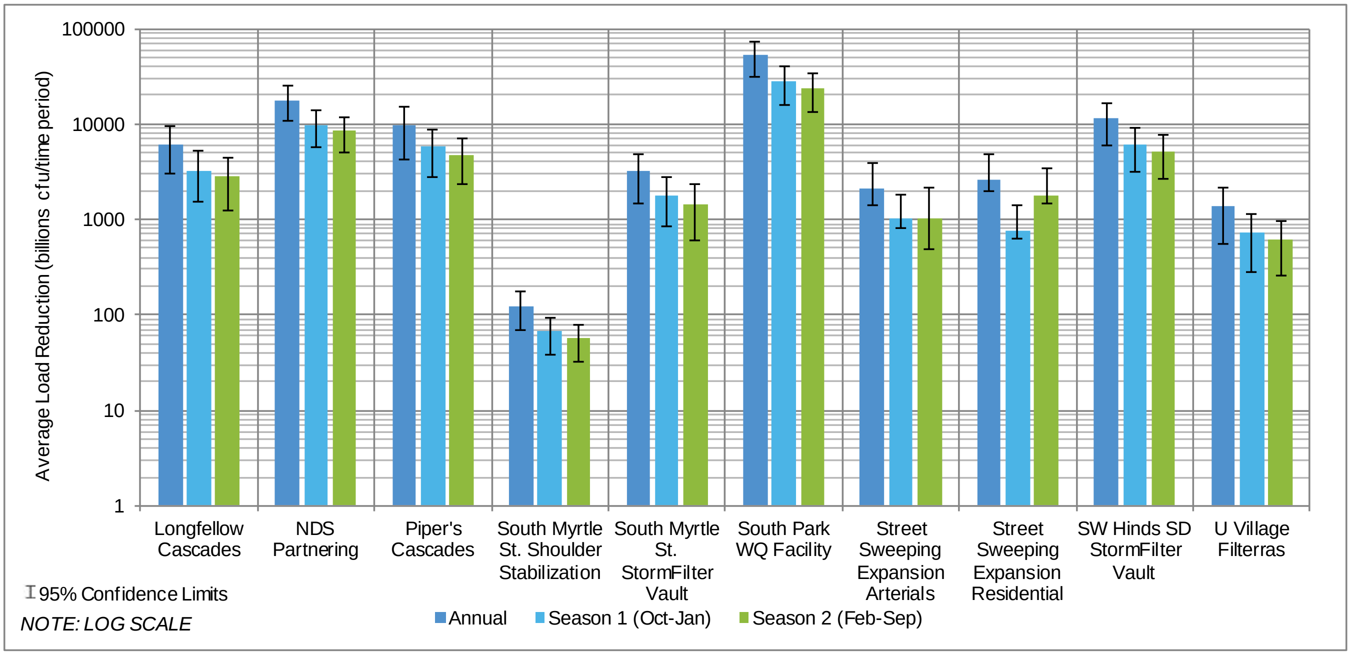

Figure 7-9. Long-term average fecal coliform load reduction from the candidate stormwater projects

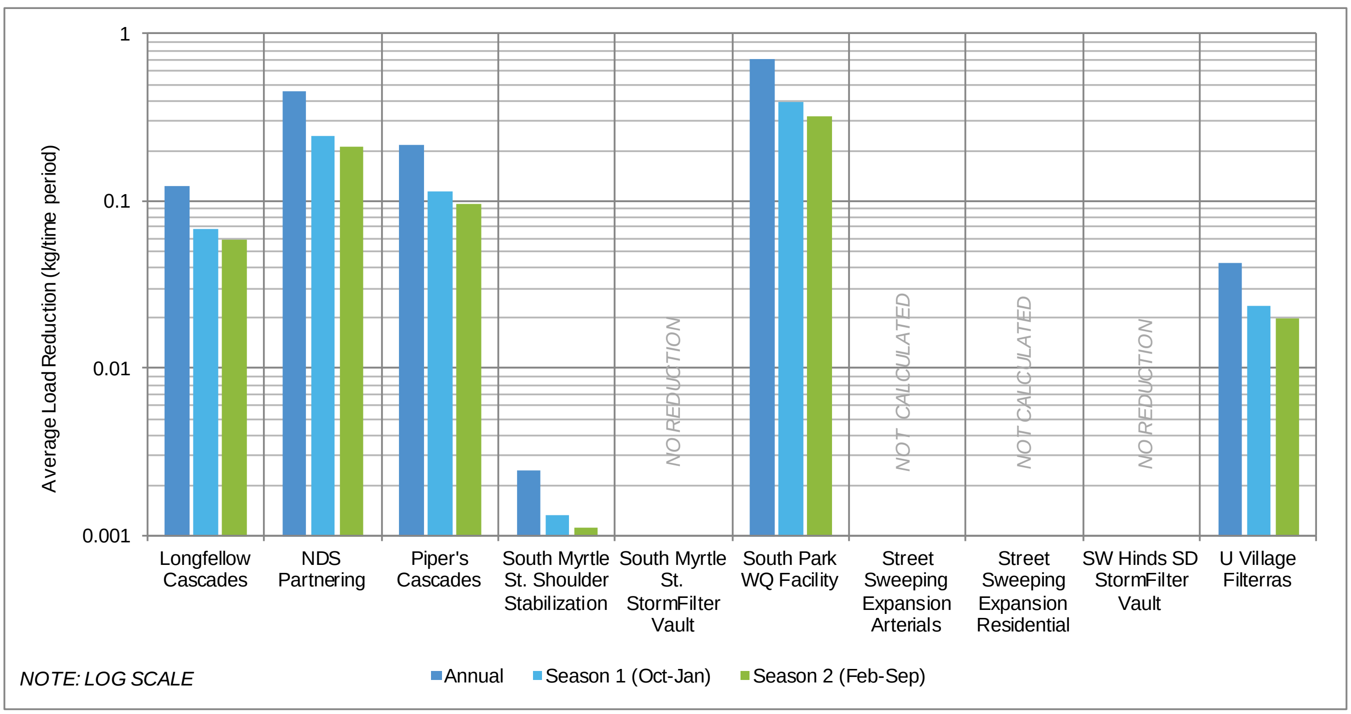

Figure 7-10. Long-term average dissolved copper load reduction from the candidate stormwater projects

Note that UCL and LCL values are not shown because they could not be calculated for selected projects due to limited data availability.

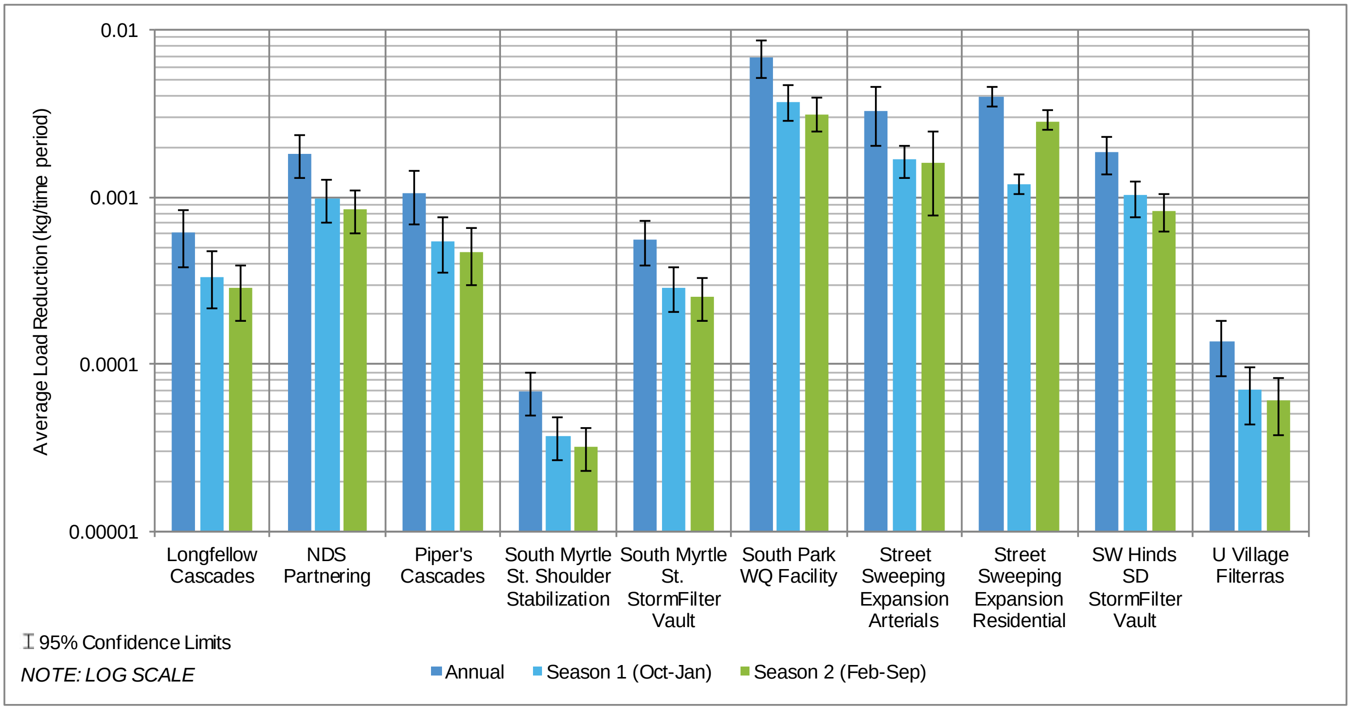

Figure 7-11. Long-term average PCB load reduction from the candidate stormwater projects

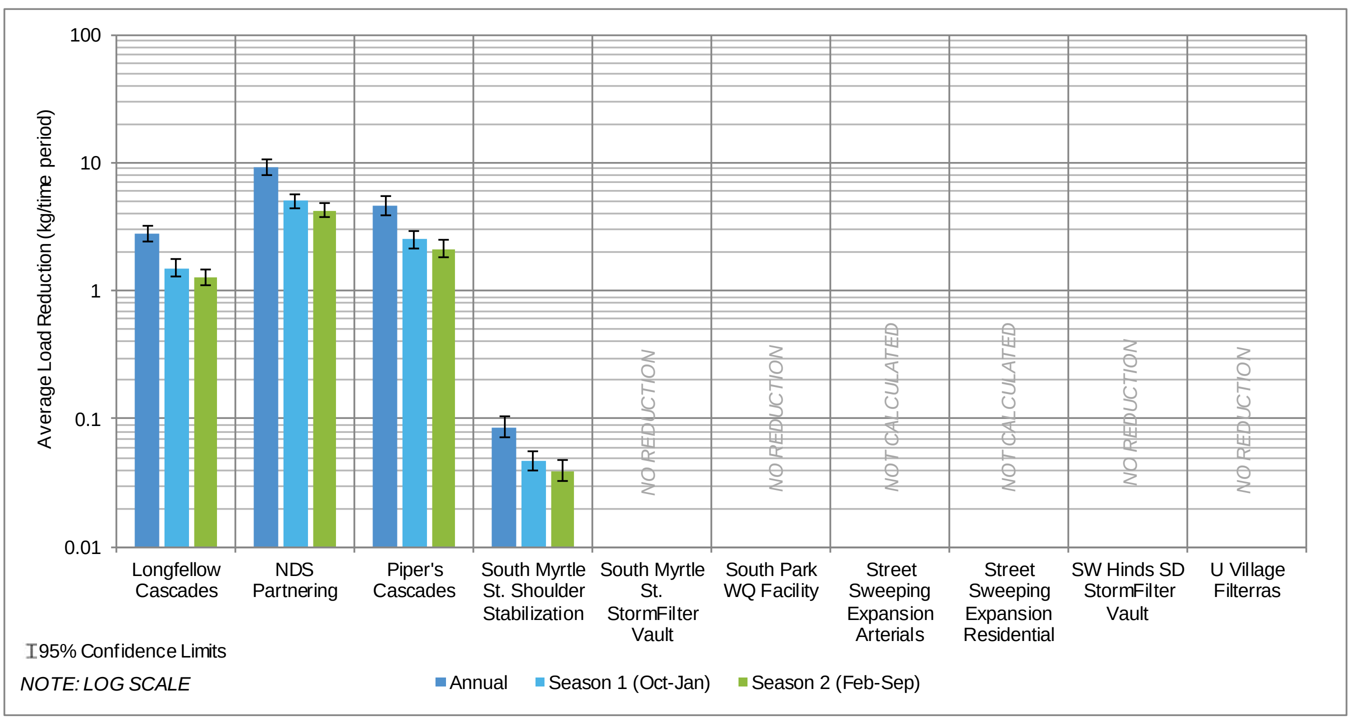

Figure 7-12. Long-term average ammonia-N load reduction from the candidate stormwater projects

7.4 Exposure Assessment Results

The City calculated exposure index values (EIVs) for each candidate LTCP and structural stormwater project. As described in Section 6.7, the following three EIVs were calculated for each project:

- human receptors exposed to toxics
- human receptors exposed to fecal coliform
- ecological receptors exposed to toxics and nutrients

Tables 7-6 through 7-8 list the EIVs for each candidate LTCP and structural stormwater project. The EIVs indicate the relative exposure reduction benefit provided by each project. Projects with higher EIVs provide more exposure reduction benefits than projects with lower EIVs.

Table 7-6. Human EIVs for Toxics (Annual)

Candidate project	Receiving water body	Human EIV: toxics (chronic)
CSO Outfall 99	West Waterway of the Duwamish River	0.39
CSO Outfall 107	East Waterway of the Duwamish River	13
CSO Outfall 111	Duwamish River	0.16
CSO Outfall 138	Portage Bay	0.13
CSO Outfall 139	Portage Bay	0.0061
CSO Outfall 140	Portage Bay	0.080
Longfellow Cascades	Longfellow Creek	0.27
NDS Partnering: Thornton Creek	Thornton Creek	3.8
NDS Partnering: Piper's Creek	Piper's Creek	0.89
NDS Partnering: Longfellow Creek	Longfellow Creek	0.12
Piper's Cascades	Piper's Creek	3.8
South Myrtle St. Shoulder Stabilization	Lower Duwamish Waterway	1.6
South Myrtle St. StormFilter Vault	Lower Duwamish Waterway	14
South Park WQ Facility	Duwamish Waterway	117
Street Sweeping Expansion Arterials	Multiple	Not calculated[a]
Street Sweeping Expansion Residential	Multiple	Not calculated[a]
SW Hinds SD StormFilter Vault	Lower Duwamish Waterway	36.2
U Village Filterras	Lake Washington Ship Canal/ Lake Union	2.0

a. EIVs were not calculated for street sweeping because the receptor factors are based on the outfall location, and runoff from the swept streets would enter many outfalls throughout the city.

Table 7-7. Human EIVs for Fecal Coliform (Annual)

Candidate project	Receiving water body	Human EIV: fecal coliform (acute)
CSO Outfall 99	West Waterway of the Duwamish River	0.18
CSO Outfall 107	East Waterway of the Duwamish River	1.3
CSO Outfall 111	Duwamish River	0.019
CSO Outfall 138	Portage Bay	2.0
CSO Outfall 139	Portage Bay	0.093
CSO Outfall 140	Portage Bay	1.4
Longfellow Cascades	Longfellow Creek	1.1
NDS Partnering: Thornton Creek	Thornton Creek	7.0
NDS Partnering: Piper's Creek	Piper's Creek	1.2
NDS Partnering: Longfellow Creek	Longfellow Creek	0.52
Piper's Cascades	Piper's Creek	5.3
South Myrtle St. Shoulder Stabilization	Lower Duwamish Waterway	0.024
South Myrtle St. StormFilter Vault	Lower Duwamish Waterway	0.67
South Park WQ Facility	Duwamish Waterway	8.3
Street Sweeping Expansion Arterials	Multiple	Not calculated[a]
Street Sweeping Expansion Residential	Multiple	Not calculated[a]
SW Hinds SD StormFilter Vault	Lower Duwamish Waterway	1.9
U Village Filterras	Lake Washington Ship Canal/ Lake Union	3.2

a. EIVs were not calculated for street sweeping because the receptor factors are based on the outfall location, and runoff from the swept streets would enter many outfalls throughout the city.

Table 7-8. Ecological EIVs for Toxics and Nutrients (Annual)

Candidate project	Receiving water body	Ecological EIV: toxics/nutrients (chronic)
CSO Outfall 99	West Waterway of the Duwamish River	0.0057
CSO Outfall 107	East Waterway of the Duwamish River	0.35
CSO Outfall 111	Duwamish River	0.0038
CSO Outfall 138	Portage Bay	0.039
CSO Outfall 139	Portage Bay	0.0031
CSO Outfall 140	Portage Bay	0.035
Longfellow Cascades	Longfellow Creek	0.61
NDS Partnering: Thornton Creek	Thornton Creek	2.5
NDS Partnering: Piper's Creek	Piper's Creek	0.54
NDS Partnering: Longfellow Creek	Longfellow Creek	0.24
Piper's Cascades	Piper's Creek	1.8
South Myrtle St. Shoulder Stabilization	Lower Duwamish Waterway	0.019
South Myrtle St. StormFilter Vault	Lower Duwamish Waterway	0.14
South Park WQ Facility	Duwamish Waterway	1.9
Street Sweeping Expansion Arterials	Multiple	Not calculated[a]
Street Sweeping Expansion Residential	Multiple	Not calculated[a]
SW Hinds SD StormFilter Vault	Lower Duwamish Waterway	0.36
U Village Filterras	Lake Washington Ship Canal/ Lake Union	0.32

a. EIVs were not calculated for street sweeping because the receptor factors are based on the outfall location, and runoff from the swept streets would enter many outfalls throughout the city.

Figures 7-13 and 7-14 show the three EIVs for each candidate LTCP and stormwater project: Figure 7-13 shows the human-toxics EIVs and Figure 7-14 shows the human-fecal coliform and ecological EIVs. Note that EIV scores should be compared only within each category because the EIVs were calculated differently for each exposure category (i.e., human-toxics, human-fecal coliform, and ecological). Therefore, EIV scores for human-toxics are not directly comparable to EIV scores for human-fecal coliform or ecological receptors.

As indicated in Figures 7-13 and 7-14, most of the candidate LTCP projects have low EIVs compared to the candidate stormwater projects. Several of the stormwater projects have substantially higher EIVs than the LTCP projects.

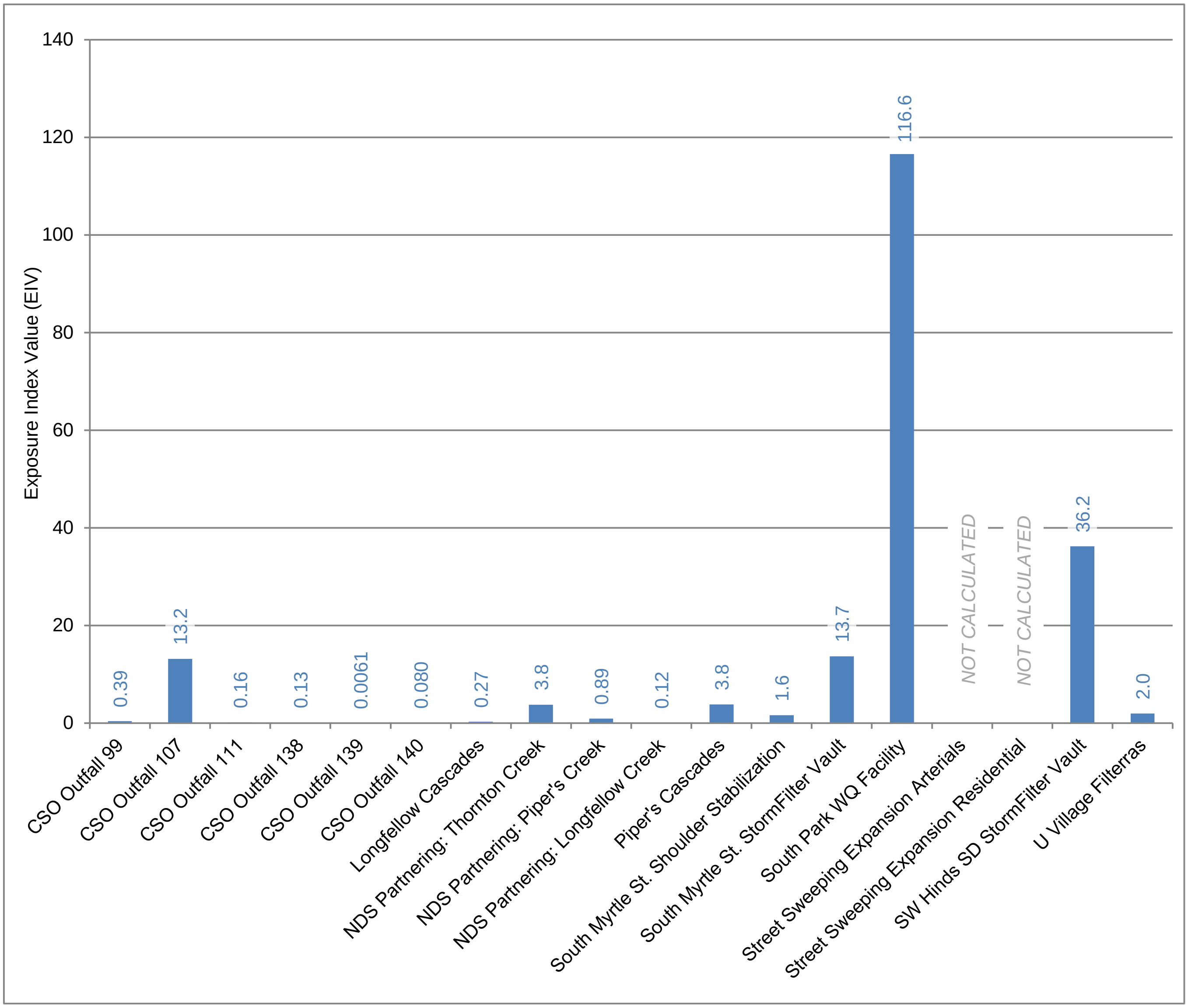

Figure 7-13. EIVs for human receptors: toxics

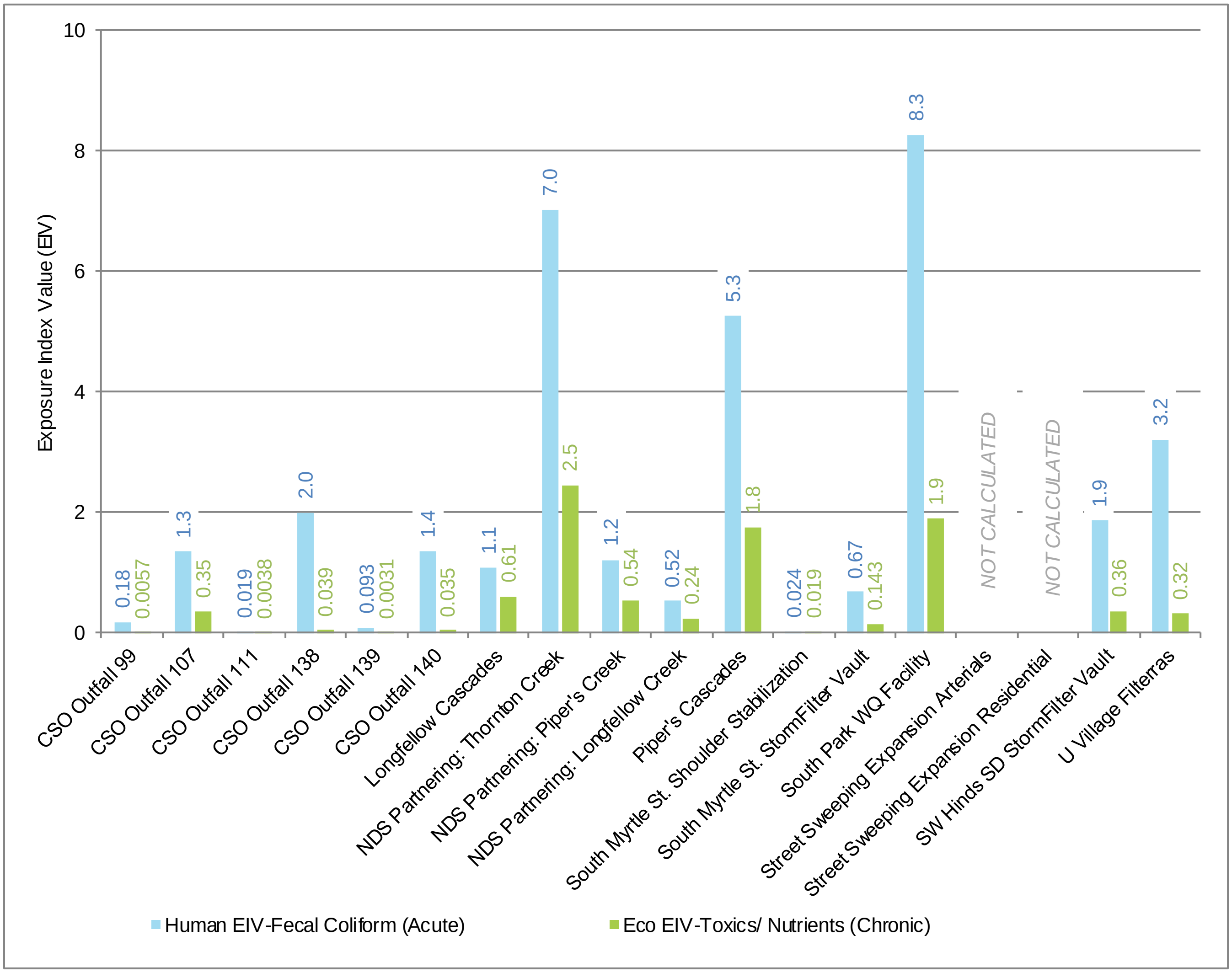

Figure 7-14. EIVs for human receptors: fecal coliform and EIVs for ecological receptors—toxics and nutrients

Figures 7-15 and 7-16 show which RCOCs dominate or drive the human-toxics and ecological EIVs. As shown in Figure 7-15, PCBs drive the human-toxics EIV scores.

Figure 7-16 shows that phosphorus is a key driver for ecological EIVs at most freshwater locations. At the saltwater/brackish locations, a variety of RCOCs contribute to the ecological EIVs.

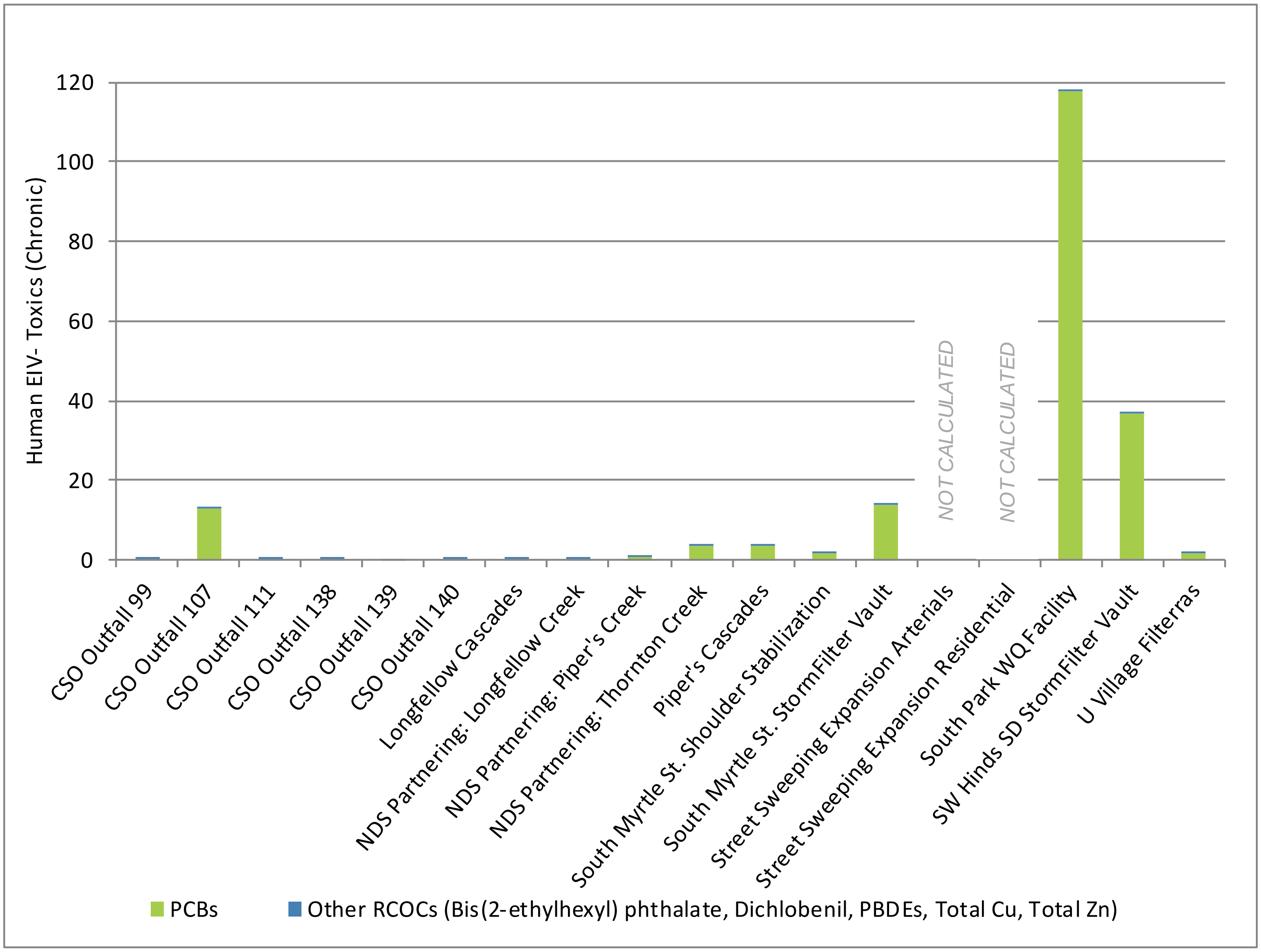

Figure 7-15. Relative contribution of specific RCOCs to human toxics EIVs

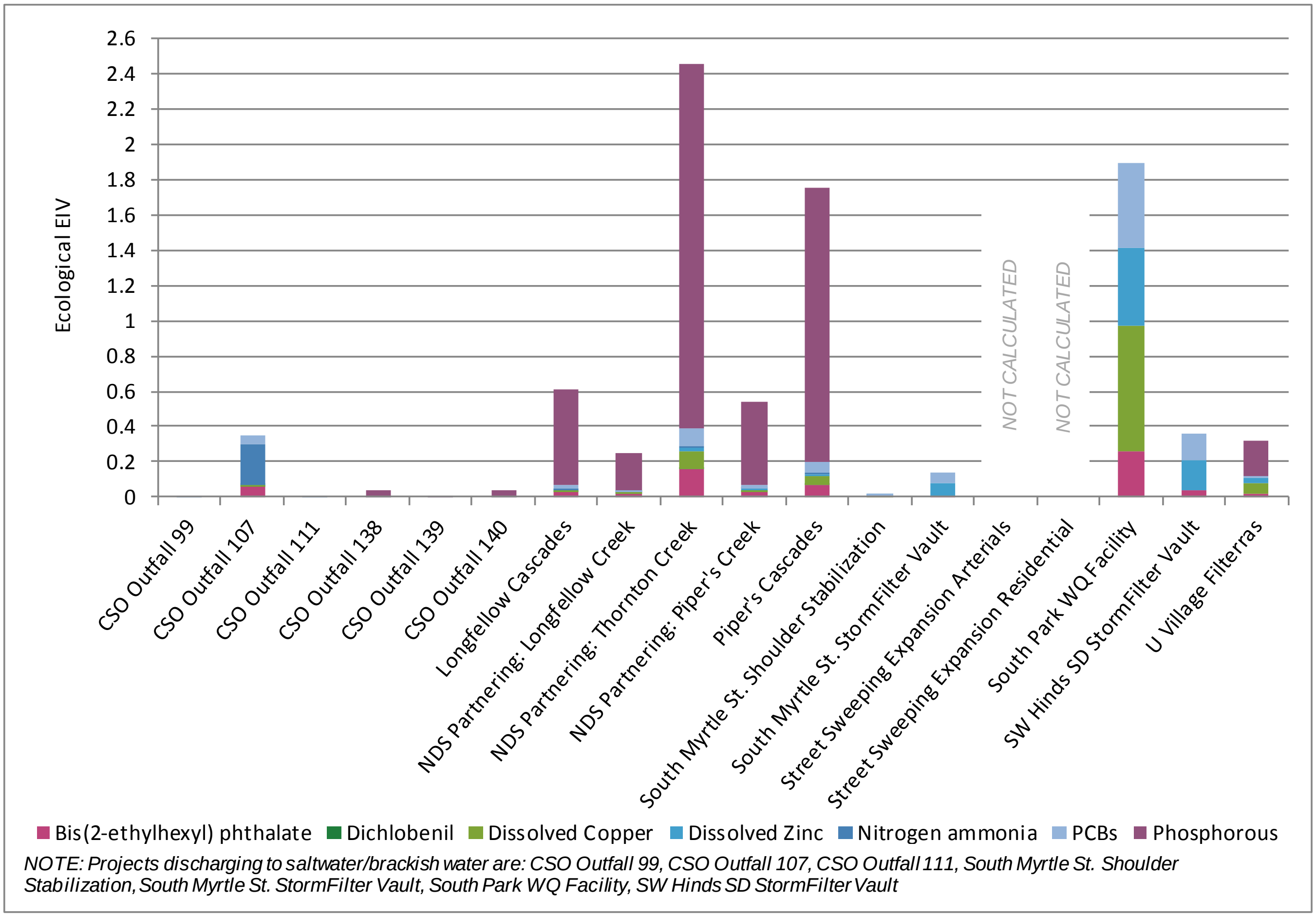

Figure 7-16. Relative contribution of specific RCOCs to ecological EIVs

7.4.1 Relative Exposure Reductions for Candidate Street Sweeping Programs

EIVs were not calculated for the candidate street sweeping programs because the EIV receptor factors are based on the outfall location, and runoff from the swept streets would affect numerous outfalls and water bodies throughout the city. Therefore, a more qualitative approach was used to compare the potential reductions in exposure that would result from the candidate street sweeping programs to the potential exposure reductions from the deferred LTCP projects.

Table 1-1 in Appendix I indicates that the candidate street sweeping programs would provide much larger reductions in PCBs and phosphorus than the candidate LTCP projects. PCBs were found to be the key driver for human-toxics EIVs at all locations. Phosphorus was the key driver for ecological EIVs at freshwater locations, while PCBs were an important contributor to ecological EIVs at several saltwater/brackish locations. These results suggest that the candidate street sweeping programs would provide substantial reductions in human exposure to toxics and ecological exposure to nutrients and toxics as compared to the candidate LTCP projects.

The pollutant loads modeling results (Table 1-1 in Appendix I) indicate that neither of the candidate street sweeping programs would provide as much fecal coliform load reduction as CSO Outfall 107. However, both street sweeping programs would provide more fecal coliform load reduction than any of the other candidate LTCP projects. The loads modeling results also indicate that the candidate street sweeping programs would provide appreciable reductions in human exposure to fecal coliform. Moreover, the loads reductions from sweeping would benefit water bodies throughout the city.

CHAPTER 8

Development of Integrated Plan

This chapter describes the development of the Integrated Plan, which consists of stormwater projects to be implemented by 2025 and LTCP projects to be deferred until after 2025.

8.1 Introduction

The Consent Decree allows the City the opportunity to prepare an Integrated Plan as an alternative to the LTCP. According to Section V.B. paragraph 20 of the Consent Decree, the Integrated Plan must propose water quality improvement project(s) “that will result in significant benefits to water quality beyond those that would be achieved by implementation of the approved CSO Control Measures only.”

The Consent Decree requires that the City describe the benefits of the proposed projects in terms of reductions in pollutant loads and exposure to human and ecological receptors. In addition, the Consent Decree requires a cost-benefit analysis for the proposed projects.

The City developed its Integrated Plan alternative based on these Consent Decree requirements. The City first compared the water quality benefits of the candidate stormwater projects with the water quality benefits of the candidate LTCP projects for potential deferral. This provided the information needed to identify the candidate stormwater projects that would contribute significant benefits to water quality over and above the projected benefits of the deferred LTCP projects. The City also evaluated the candidate stormwater projects based on other factors, such as proximity to other planned stormwater quality projects and level of treatment (pretreatment, basic, or enhanced). Based on these evaluations, the City decided to retain 10 of the candidate stormwater projects for further evaluation.

The City then scored and ranked the candidate stormwater projects using Multiple Objective Decision Analysis (MODA). In keeping with the Consent Decree, MODA gave primary consideration to the expected water quality benefits of each project. MODA also considered other City priorities and community values so that the City could compare the candidate projects based on their overall benefits.

Based on the water quality comparisons and MODA, the City selected a suite of stormwater projects for implementation by 2025 and LTCP projects for deferral until 2028–30. The Integrated Plan comprises these projects.

The City performed a cost-benefit analysis of the Integrated Plan. The City compared the present-value costs of the selected projects to their respective benefits as indicated by MODA scores and costs per unit of pollutant load reduction.

Sections 8.2 and 8.3, respectively, describe the water quality comparisons and MODA. Section 8.4 presents the stormwater and LTCP projects that compose the Integrated Plan, and the significant benefits provided by the Integrated Plan.

8.2 Comparison of Candidate LTCP and Stormwater Projects

The City selected candidate stormwater projects that would take advantage of opportunities in key drainage basins and receiving water bodies, as discussed in Chapter 5. In contrast, the City identified relatively small LTCP projects in the LTCP as potential candidates for deferral. The intent was to identify candidate stormwater projects that would provide significant water quality benefits as compared to the deferred LTCP projects.

Section 8.2.1 compares the estimated pollutant load reductions for the candidate LTCP and stormwater projects. Section 8.2.2 compares the candidate LTCP and stormwater projects based on their relative reductions in exposure to human and ecological receptors. Load and exposure reductions were estimated based on stormwater project conceptual designs that may continue to evolve. Appendix I of this plan contains more detailed information on the estimated load reductions for the candidate stormwater and LTCP projects.

8.2.1 Pollutant Load Reduction

The City compared the projected pollutant load reductions for the candidate stormwater projects with the projected load reductions for the candidate LTCP projects. Table 8-1 lists the estimated annual RCOC load reductions for the candidate projects. For all RCOCs except ammonia-N, the highest-ranked candidate projects are all stormwater projects. CSO Outfall 107 would provide the largest ammonia-N load reduction of the candidate projects, followed by the NDS Partnering, Piper's Cascades, and Longfellow Cascades stormwater projects. The latter are green infrastructure projects that involve infiltration.

Figure 8-1 compares the estimated RCOC load reductions for each candidate stormwater project with the estimated load reductions for the largest of the candidate LTCP projects. As shown in the figure, most of the stormwater projects provide greater load reductions for most RCOCs. The primary reason for this is that these candidate stormwater projects would treat larger volumes than the candidate LTCP projects (see Figure 8-2).

The top-performing candidate stormwater projects provide larger load reductions for the key drivers for human exposure (PCBs and fecal coliform) and ecological exposure (phosphorus and PCBs). In contrast, three stormwater projects (South Myrtle St. Shoulder Stabilization, South Myrtle St. StormFilter Vault, and U Village Filterras projects) provide less load reduction for most RCOCs compared to the largest candidate LTCP project because these stormwater projects treat relatively small volumes of stormwater.

Appendix I contains charts comparing the estimated pollutant loads reductions for each RCOC for the candidate stormwater and LTCP projects.

Table 8-1. Average Pollutant Load Reductions for Candidate LTCP and Stormwater Projects

Candidate project	Volume treated/reduced		Ammonia-N		BOD		Bis(2-ethylhexyl) phthalate		Dichlobenil		Dissolved copper		Dissolved zinc		Fecal coliform		H+		Oil and grease		PBDEs		PCBs		Phosphorus		Total copper		Total suspended solids		Total zinc	
	MG/yr	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (billion CFU/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank	Reduction (kg/yr)	Rank
CSO Outfall 99	0.17	11	0.78	5	12	11	0.0015	12	0.000070	5	0.0032	7	0.012	10	651	11	0.000073	9	2.2	9	0.000038	11	0.000032	12	0.37	11	0.0084	12	20	12	0.026	12
CSO Outfall 107	1.1	10	19	1	82	8	0.035	8	0.00029	4	0.027	6	0.14	9	4,346	6	0.00049	8	15	7	0.00025	8	0.00046	9	6.6	6	0.22	8	494	10	0.57	10
CSO Outfall 111	0.0086	15	0.15	8	0.64	15	0.00027	15	0.000003	9	0.00021	11	0.0011	13	34	15	0.0000038	12	0.11	13	0.0000020	15	0.0000036	15	0.05	15	0.0017	15	4	15	0.0044	15
CSO Outfall 138	0.091	13	0.43	6	6.8	13	0.00081	13	0.000041	6	0.0018	9	0.0067	11	360	12	0.000040	10	1.2	11	0.000021	13	0.000018	13	0.21	12	0.0046	13	11	13	0.015	13
CSO Outfall 139	0.0057	16	0.027	10	0.42	16	0.00005	16	0.000003	10	0.00011	12	0.00042	14	22	16	0.0000025	13	0.075	14	0.0000013	16	0.0000011	16	0.013	16	0.00029	16	0.69	16	0.0009	16
CSO Outfall 140	0.051	14	0.24	7	3.8	14	0.00045	14	0.000023	7	0.0010	10	0.0038	12	201	13	0.000023	11	0.67	12	0.000012	14	0.000010	14	0.12	13	0.0026	14	6	14	0.0081	14
Longfellow Cascades	5.0	7	2.8	4	237	6	0.063	6	0.0019	3	0.12	4	0.71	6	6,212	5	0.00510	5	129	4	0.0010	7	0.00062	7	5.1	8	0.34	7	2,645	7	3.4	7
NDS Partnering	35	4	9.2	2	684	2	0.22	2	0.0048	1	0.46	2	3.2	3	17,910	2	0.015	2	396	2	0.0029	4	0.0018	5	14	4	1.3	4	7,704	4	11	3
Piper's Cascades	8.3	6	4.7	3	370	3	0.11	5	0.0031	2	0.22	3	1.2	5	9,734	4	0.0081	3	204	3	0.0017	5	0.0010	6	8.4	5	0.58	5	4,382	5	6	5
South Myrtle St. Shoulder Stabilization.	0.10	12	0.086	9	8.7	12	0.0021	11	0.000015	8	0.0024	8	0.16	8	125	14	0.00062	7	3.4	8	0.000033	12	0.000069	11	0.09	14	0.027	11	142	11	0.24	11
South Myrtle St. StormFilter	3.1	8	0.0	13	56	10	0.0098	10	0.0	13	0.0	14	1.29	4	3,232	7	0.0064	4	1.3	10	0.00025	9	0.00056	8	1.4	9	0.13	10	1,092	8	1.4	8
South Park WQ Facility	74	3	0.0	13	1,088	1	0.29	1	0.0	13	0.71	1	14	1	52,700	1	0.0	14	702	1	0.0047	3	0.0069	1	46	1	4.5	3	24,741	3	29	1
Street Sweeping Expansion Arterials	1527	1	N/A	N/A	337	5	0.14	4	N/A	N/A	N/A	N/A	N/A	N/A	2,100	9	N/A	N/A	69	6	0.0096	2	0.0033	3	24	3	5.2	2	36,200	2	10	4
Street Sweeping Expansion Residential	986	2	N/A	N/A	366	4	0.16	3	N/A	N/A	N/A	N/A	N/A	N/A	2,560	8	N/A	N/A	84	5	0.011	1	0.0040	2	28	2	6.3	1	41,900	1	12	2
SW Hinds SD/ StormFilter	14	5	0.0	13	213	7	0.045	7	0.0	13	0.0	14	4.1	2	11,496	3	0.021	1	0.0	16	0.0011	6	0.0019	4	6.0	7	0.44	6	4,191	6	5	6
U Village/Filterras	3.0	9	0.0	13	64	9	0.014	9	0.0	13	0.043	5	0.54	7	1,395	10	0.0014	6	0.0	16	0.00022	10	0.00014	10	0.87	10	0.18	9	676	9	1	9

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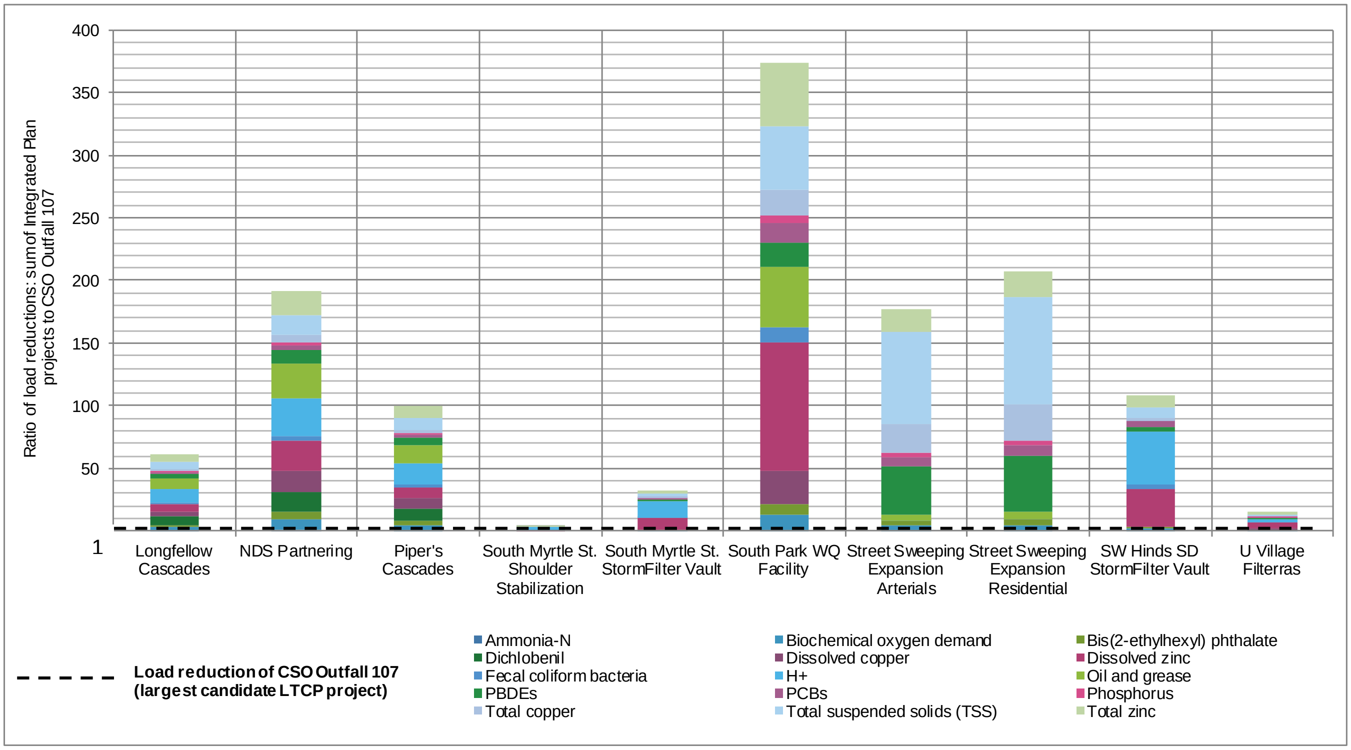


Figure 8-1. Comparison of candidate stormwater projects to largest candidate LTCP project load reductions

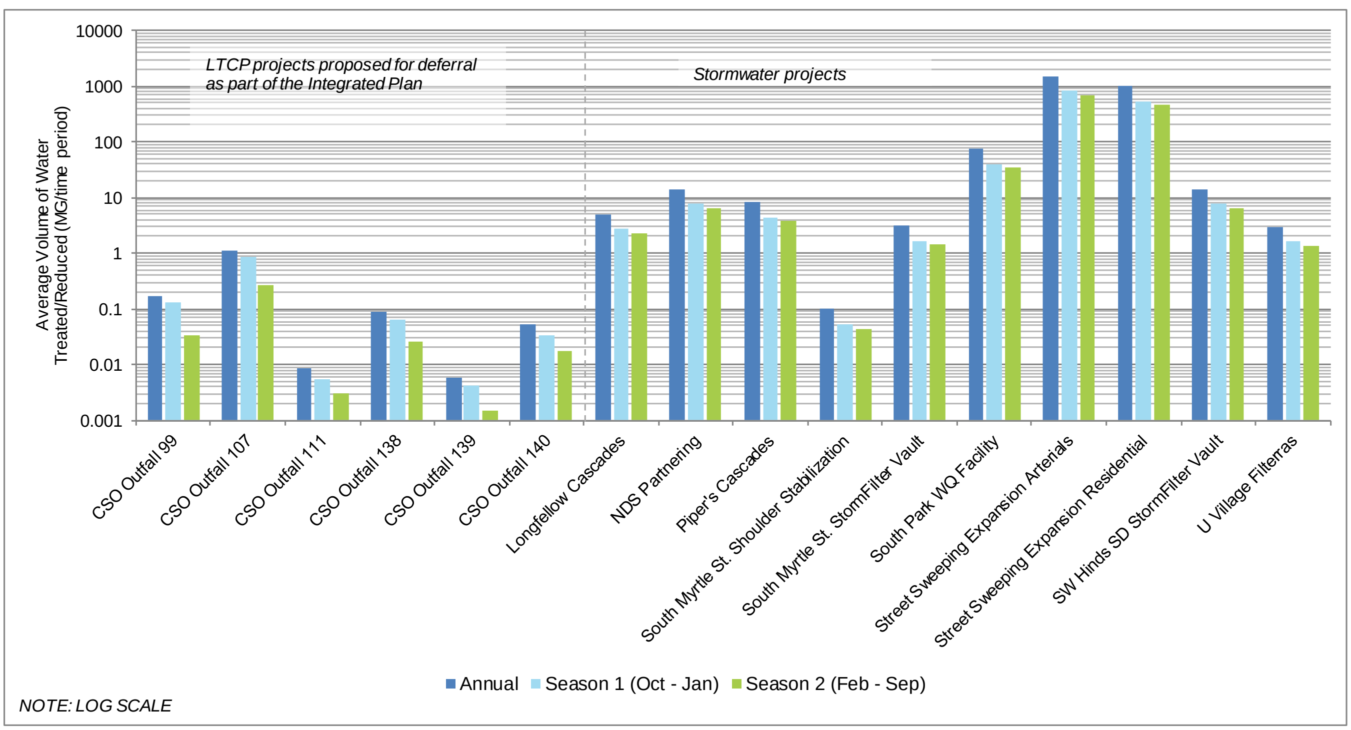


Figure 8-2. Average volumes treated or reduced by candidate LTCP and stormwater projects

8.2.2 Relative Exposure Reductions for Candidate Projects

The City used the pollutant loads reduction results, together with information on local receiving water bodies, to calculate human and ecological exposure index values (EIVs) for the candidate LTCP and structural stormwater projects. The EIVs were calculated to help the City compare the candidate projects and to select the projects to include in the Integrated Plan. Appendix H of this plan provides a detailed description of the EIV methods and results. EIVs were not calculated for the candidate street sweeping programs because the EIV receptor factors are based on the outfall location, and runoff from the swept streets would affect numerous outfalls and water bodies throughout the city. Section 8.2.3 explains the approach used to evaluate the potential reductions in exposure that would result from the candidate street sweeping programs.

Table 8-2 lists the EIVs for the candidate stormwater and LTCP projects. The highest (best) EIVs were associated with candidate stormwater projects. The South Park Water Quality Facility had the highest EIVs for human receptors while the NDS Partnering: Thornton Creek project had the highest EIV for ecological receptors among all of the candidate stormwater and LTCP projects. Note that Table 8-2 lists three sets of EIVs for NDS Partnering because EIVs depend in part on discharge location and NDS Partnering would include projects in three creek basins. Of the LTCP projects, CSO Outfall 107 had the highest human-chronic (toxics) and ecological EIVs, and CSO Outfall 138 had the highest fecal coliform EIV.

Figure 8-3 compares the EIVs for the candidate stormwater projects to the highest EIVs for the candidate CSO projects (CSO Outfall 107 and CSO Outfall 138). As shown in the figure, the human and ecological EIVs for the South Park Water Quality Facility are many times higher than the highest EIVs for the candidate CSO projects. The ecological EIVs for the NDS Partnering: Thornton Creek and Piper's Cascades projects were several times higher than the ecological EIVs for the highest candidate CSO project (CSO Outfall 107).

Table 8-2. Comparison of EIVs for Candidate LTCP and Stormwater Projects, by Project

Candidate project	Receiving water body	Human				Ecological	
		Toxics		Fecal coliform		Toxics/nutrients	
		EIV	Rank	EIV	Rank	EIV	Rank
CSO Outfall 99	West Waterway of the Duwamish River	0.39	10	0.18	13	0.0057	14
CSO Outfall 107	East Waterway of the Duwamish River	13.2	4	1.3	8	0.35	7
CSO Outfall 111	Duwamish River	0.16	12	0.019	16	0.0038	15
CSO Outfall 138	Portage Bay	0.13	13	2.0	5	0.039	11
CSO Outfall 139	Portage Bay	0.0061	16	0.093	14	0.0031	16
CSO Outfall 140	Portage Bay	0.080	15	1.4	7	0.035	12
Longfellow Cascades	Longfellow Creek	0.27	11	1.1	10	0.61	4
NDS Partnering: Thornton Creek	Thornton Creek	3.8	6	7.0	2	2.5	1
NDS Partnering: Piper's Creek	Piper's Creek	0.89	9	1.2	9	0.54	5
NDS Partnering: Longfellow Creek	Longfellow Creek	0.12	14	0.52	12	0.24	9

Table 8-2. Comparison of EIVs for Candidate LTCP and Stormwater Projects, by Project

Candidate project	Receiving water body	Human				Ecological	
		Toxics		Fecal coliform		Toxics/nutrients	
		EIV	Rank	EIV	Rank	EIV	Rank
Piper's Cascades	Piper's Creek	3.8	5	5.3	3	1.8	3
South Myrtle St. Shoulder Stabilization	Duwamish Waterway	1.6	8	0.024	15	0.019	13
South Myrtle St. StormFilter Vault	Duwamish Waterway	13.7	3	0.67	11	0.14	10
South Park WQ Facility	Duwamish Waterway	116.6	1	8.3	1	1.9	2
Street Sweeping Expansion Arterials	Multiple	N/A[a]					
Street Sweeping Expansion Residential	Multiple	N/A[a]					
SW Hinds SD StormFilter Vault	Duwamish Waterway	36.2	2	1.9	6	0.36	6
U Village Filterras	Union Bay/Lake Washington	2.0	7	3.2	4	0.32	8

a. EIVs were not calculated for street sweeping because the receptor factors are based on the outfall location, and runoff from the swept streets would enter >100 outfalls throughout the city.

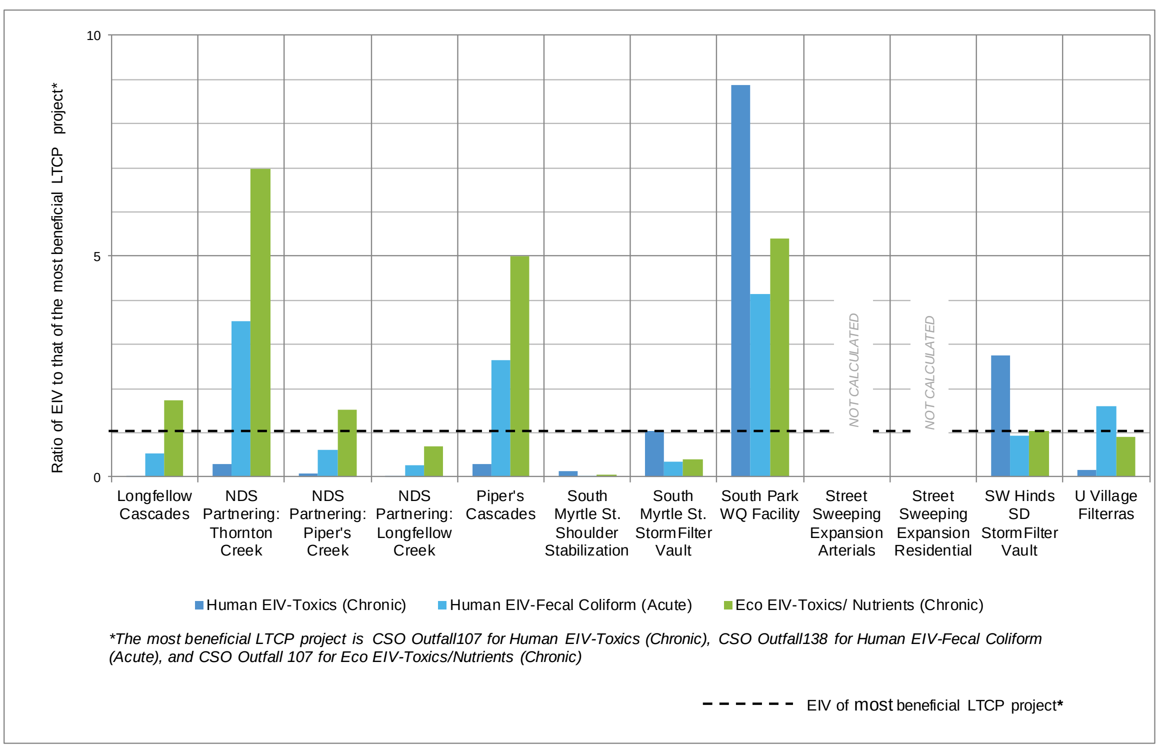


Figure 8-3. Ratio of candidate stormwater project EIVs to most beneficial candidate LTCP project EIVs

8.2.3 Relative Exposure Reductions for Candidate Street Sweeping Programs

EIVs were not calculated for the candidate street sweeping programs because the EIV receptor factors are based on the outfall location, and runoff from the swept streets would affect numerous outfalls and water bodies throughout the city. Therefore, a more qualitative approach was used to evaluate the potential reductions in exposure that would result from the candidate street sweeping programs.

Table 8-1 above and Figures 1-3 and 1-6 in Appendix I show that the candidate street sweeping programs would provide much larger reductions in PCBs and phosphorus than the candidate LTCP projects. PCBs were found to be the key driver for human-toxics EIVs at all locations, as shown in Figure 7-15 above. Phosphorus was the key driver for ecological EIVs at freshwater locations, while PCBs were an important contributor to ecological EIVs at several saltwater/brackish locations (see Figure 7-16). These results suggest that the candidate sweeping programs would provide substantial reductions in human exposure to toxics and ecological exposure to nutrients and toxics as compared to the candidate LTCP projects.

The pollutant loads modeling results indicate that neither of the candidate street sweeping programs would provide as much fecal coliform load reduction as CSO Outfall 107. However, both sweeping programs would provide more fecal coliform load reduction than any of the other candidate LTCP projects. The pollutant loads modeling results also indicate that the candidate sweeping programs would provide appreciable reductions in human exposure to fecal coliform. Moreover, the loads reductions from sweeping would benefit water bodies throughout the city.

8.3 Multiple Objective Decision Analysis

The pollutant loads modeling and exposure assessments described above indicated that multiple combinations of the candidate stormwater projects and programs could provide significantly greater water quality benefits beyond those that would be achieved by implementation of the combined six CSO reduction projects alone. Therefore, the City believes that it is appropriate to defer all six CSO reduction projects. Implementation of the preferred option for the LTCP and the candidate stormwater projects by 2025, and the remaining six CSO reduction projects by 2030, will result in significant benefits to the receiving water bodies in and around Seattle beyond what could be achieved with the six CSO reduction projects alone. Therefore, the City decided that the Integrated Plan should include deferral of all six of the candidate LTCP projects.

To help select the candidate stormwater projects for the Integrated Plan, the City used MODA to compare the candidate stormwater projects and programs for potential inclusion in the Integrated Plan. This section summarizes the MODA methods and results.

8.3.1 Methodology Overview

The City often uses MODA to help make decisions regarding projects or programs. For the Integrated Plan, the City used MODA to compare candidate stormwater projects based on their expected water quality benefits as well as other criteria important to the community.

The MODA methodology for the Integrated Plan involved the following steps:

1. Establish evaluation criteria
2. Develop measurement scales and assign draft scores
3. Establish relative value weights

4. Normalize scores and calculate results
5. Perform sensitivity analysis

These steps are described below. Appendix I contains additional details on the MODA process.

8.3.2 Establish Evaluation Criteria

The Integrated Plan team developed evaluation criteria during a series of workshops facilitated by the same MODA specialists who supported the LTCP decision-making process. Through these workshops the team developed criteria that represent the City values and objectives relevant to making decisions about the Integrated Plan. The MODA criteria used to rank the candidate stormwater projects are summarized below. Appendix I contains additional details on these criteria and their measurement scales.

1. **Performance risk:** *How flexible is the project in terms of responding to varying flow and pollutant characteristics above and below the project location?*
2. **Flexibility:** What are the intervention opportunities to address under-performance, changes in rainfall patterns, and/or increases in temperature and drought situations?
3. **Relationship with other agencies (tribes, King County):** *To what extent does the project enhance long-term relationships with Puget Sound area tribes and King County Wastewater Treatment Division (WTD)?*
4. **Water quality:** *To what extent does the candidate project contribute water quality benefits beyond those that would be achieved by the deferred LTCP projects? As described in Appendix I, the project score for this criterion was calculated based on pre-project RCOC concentrations, relevant water quality criteria, and estimated load reductions.*
5. **Other positive environmental outcomes:** *Does the project help meet the City's Green Goal by reducing stream flow rates, and/or does the project add green space and habitat?*
6. **Construction impacts (short-term):** *What level of disruption will occur during project construction?*
7. **Community impacts (long-term):** *What lasting impact will the project and its operations and maintenance (O&M) activities have on the neighborhood, either positive (culturally relevant, sidewalks, water access, bike paths, traffic calming, visual appeal), or negative (odor, noise, visual)? Note: This is not meant to include construction impacts.*
8. **Environmental/social justice:** *Who and where? Will the location of the project address the historical inequity (e.g., address problems that were historically "underreported")? Will the project protect a current use by socioeconomic class (e.g., fishing in Duwamish/Green Lake)? Will facility siting affect an already heavily impacted area (e.g., South Park has transfer station)?*
9. **Ease of operations and maintenance (O&M) and safety:** *The score for this criterion was the average of the scores given for three sub-criteria: operations, maintenance, and safety.*

8.3.3 Develop Measurement Scales and Assign Draft Scores

A measurement scale describes the extent to which a project meets each evaluation criterion. The Integrated Plan team developed measurement scales of 1 to 5 for each criterion (except water quality). The worst potential outcome was given a score of 1 and the best possible outcome was given a score of 5. The MODA team then assigned scores for each criterion (except water quality) using the 1–5 measurement scale. Scores for each criterion (except water quality) were assigned based on each team member's knowledge of the project.

The water quality score for each candidate stormwater project was calculated based on estimated pre-project (i.e., existing) concentrations and the estimated load reductions that would result from implementation of the project. The existing concentrations were used to indicate the potency of the existing discharge and the load reductions were used to account for the magnitude of change. The water quality score was calculated as described below.

First, a weight was calculated as the ratio of the pre-project concentration to the water quality criteria for each RCOC:

$$Weight_{RCOC} = \frac{Pre\text{-}project\ concentration_{RCOC}}{Water\ quality\ criteria_{RCOC}}$$

Next, the load reduction for each RCOC was normalized to the largest LTCP project (CSO Outfall 107):

$$Normalized\ load\ reduction_{RCOC} = \frac{Load\ reduction\ project_{RCOC}}{Load\ reduction\ LTCP\ NPDES\ 107_{RCOC}}$$

The weight was then multiplied by the normalized load reduction and summed to provide the water quality score for the candidate project or program.

$$Water\ quality\ score_{project} = \sum (weight * normalized\ load\ reduction)_{RCOC}$$

Appendix I provides more details on the evaluation criteria, measurement scales, and scoring rationales.

8.3.4 Establish Relative Value Weights

The City assigned weights to each criterion to reflect the relative value of each criterion within the context of the decision being made. Weights were determined at a MODA team meeting where a trained facilitator led City senior managers using a modified Delphi process in which managers provided weights, the weights were shown to the group, and the differences were discussed. Weights were assigned based on the relative importance of the criterion and the extent to which the scores for the criterion varied among the candidate projects. The discussion resulted in a consensus set of weights that were used in the evaluation. Table 8-3 presents the consensus weights used for the MODA evaluation of the candidate stormwater projects. The water quality criterion was given the greatest weight.

Table 8-3. Criteria Weights

Evaluation criterion	Relative value weight	Percent of total
1. Performance risk	18	10%
2. Flexibility	12	7%
3. Relationship with other agencies	4	2%
4. Water quality	100	54%
5. Other positive environmental outcomes	8	4%
6. Construction impacts (short-term)	8	4%
7. Community impacts (longer-term)	8	4%
8. Environmental/social justice	8	4%
9. Ease of O&M and safety	18	10%

8.3.5 MODA Results

Total MODA scores ranged from 0 to 100. All scores were normalized to a 0–1 scale using linear transformation. The normalized scores were multiplied by the relative value weight for each criterion, then multiplied by 100 (a scalar for presentation), and summed over all criteria, resulting in a total value score for each project.

Table 8-4 lists the MODA scores and ranks for the candidate stormwater projects. The results of the analysis are also shown on Figure 8-4 as a stacked bar chart where each bar represents the contribution to the score from each criterion. As shown, the South Park WQ Facility provides the highest overall score. Water quality and performance risk impacts contributed the most value to the South Park WQ Facility project.

Table 8-4. MODA Results

Candidate project/program	Total score	Rank
South Park WQ Facility	79	1
Street Sweeping Expansion Arterials	64	2
Street Sweeping Expansion Residential	57	3
NDS Partnering	41	4
SW Hinds SD StormFilter Vault	40	5
Piper's Cascades	37	6
Longfellow Cascades	35	7
U Village Filterras	30	8
South Myrtle St. StormFilter Vault	30	9
South Myrtle St. Shoulder Stabilization	27	10

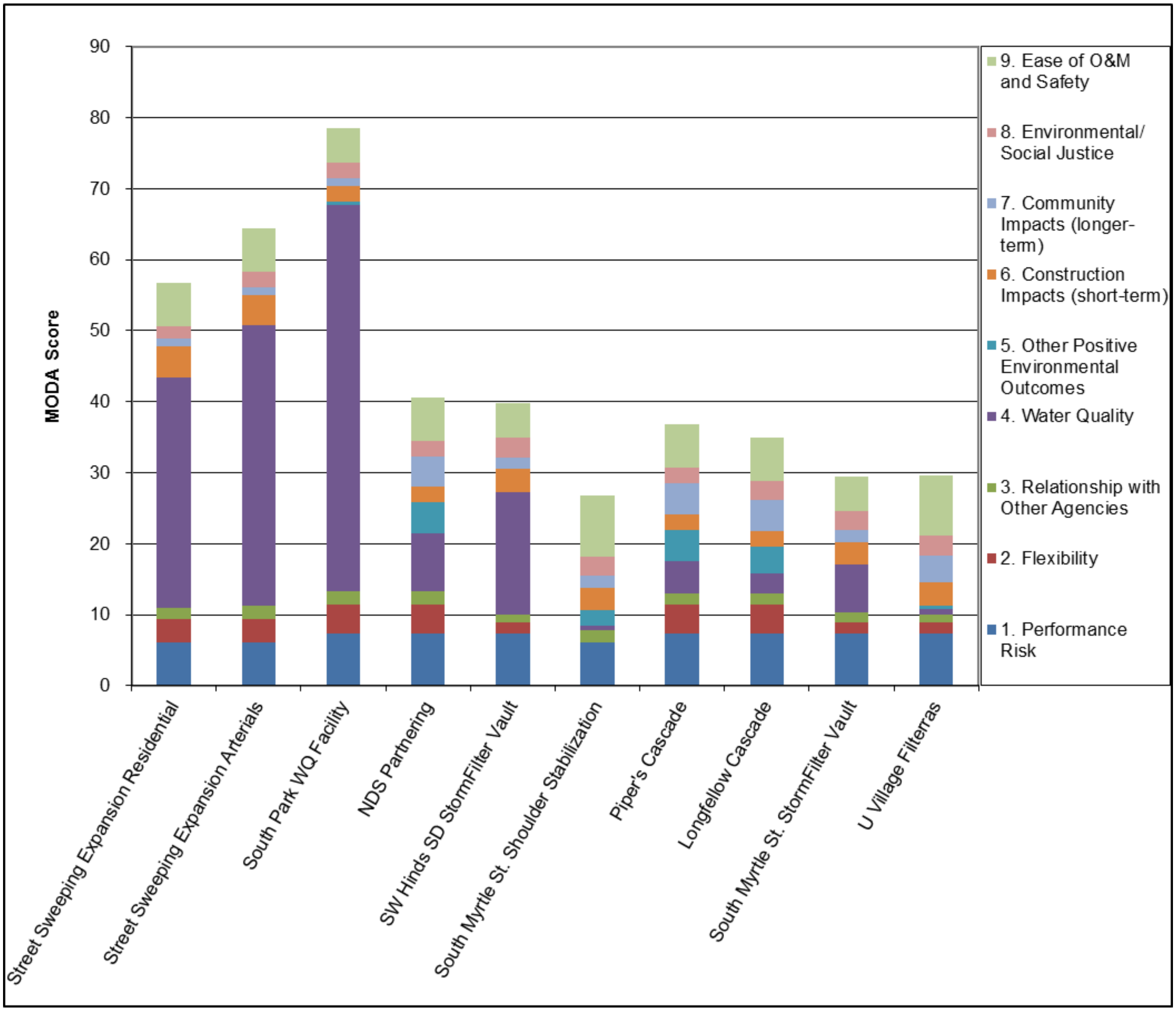


Figure 8-4. MODA results

8.4 Integrated Plan Projects

In keeping with the Consent Decree requirements, the City selected projects for the Integrated Plan based on their anticipated pollutant load reductions, human and ecological exposure reductions, and overall benefits to water bodies with special circumstances. The City added the MODA evaluations to the selection process to acknowledge the economic, social, and environmental benefits of the projects beyond the Consent Decree requirements.

The City found that a number of the candidate stormwater projects would provide significant benefits beyond those of the LTCP projects alone, as described in Sections 8.1 through 8.3 above. The City ultimately selected three of these candidate stormwater projects for the Integrated Plan based on their significant water quality benefits, high value per the MODA evaluations, and life-cycle costs. The City selected the South Park Water

Quality Facility project, Street Sweeping Expansion Arterials and NDS Partnering project for implementation under the Integrated Plan alternative.

The South Park Water Quality Facility received the highest significant benefits and MODA score of the candidate stormwater projects. Street Sweeping Expansion Arterials received the fourth-highest significant benefit score and the second-highest MODA score. NDS Partnering received the second-highest significant benefit score and the fourth-highest MODA score. The City selected NDS Partnering instead of the third-ranked project (Street Sweeping Expansion Residential) in order to have a combination of green, gray, and programmatic stormwater measures in the Integrated Plan, consistent with EPA's "Integrated Municipal Stormwater and Wastewater Planning Approach Framework." Moreover, the residential sweeping program would have required development and enforcement of a no-parking program in areas with little or no off-street parking.

The three stormwater projects would provide citywide source control (Street Sweeping Expansion Arterials Program), active treatment of stormwater runoff to the high-priority Lower Duwamish Waterway (South Park WQ Facility Project), and green infrastructure to reduce flows and pollutants discharging into salmon-bearing streams (NDS Partnering Project). These stormwater projects would be fully implemented by 2025.

The City selected six LTCP CSO control projects for deferral under the Integrated Plan alternative. Projects to control CSO Outfalls 99, 107, 111, 138, 139, and 140 would be constructed by 2030 instead of 2025. As discussed in Sections 8.1 through 8.3 above, the six deferred LTCP projects would provide much smaller water quality benefits than the three selected stormwater projects.

8.4.1 Selected Stormwater Projects

This section provides a brief summary of the three stormwater projects selected for the Integrated Plan. Appendix J contains detailed fact sheets for these projects.

8.4.1.1 NDS Partnering Project

The NDS Partnering project is a regional green infrastructure project that would construct bioretention facilities (i.e., engineered rain gardens) in separated storm sewer system basins that drain to Piper's, Thornton, and Longfellow creeks. These would entail modifications to about 4 miles of rights-of-way to manage flow and provide water quality treatment for stormwater runoff. Attachment J, Figures J-1 through J-3 show the general project locations and receiving water bodies.

The bioretention facilities would be designed to reduce geomorphically significant flows and loads of PCBs, metals, bacteria, and other pollutants to Piper's, Thornton, and Longfellow creeks. Two types of bioretention facilities would be constructed depending on site-specific conditions. In areas with low infiltration rates, the facilities would be equipped with underdrains (perforated pipes) to collect stormwater that passes through the bioretention media but does not infiltrate into the underlying soil within an acceptable time frame. The underdrains would convey the treated stormwater to a City stormwater conveyance system or an engineered underground injection control (UIC) structure, such as a pit drain (<12 feet deep), a vertically drilled drain (25-35 deep), or a gravity injection well (35-80 feet deep). Injection wells would be used only where pit drains and drilled drains are found to be infeasible based on geotechnical analysis and groundwater monitoring.

The City recently completed a GIS study to map the areas within each watershed that appear feasible for NDS projects. The NDS Partnering project would require only about 4 percent of the potentially feasible area within the Piper's, Thornton, and Longfellow creek watersheds. Thus, the City should have significant flexibility in finding bioretention facility locations with appropriate site conditions and community support.

The City will select specific NDS project sites using a "partnering" approach. The City will work in partnership with local residents and community groups to identify candidate blocks within areas deemed potentially feasible for bioretention. To encourage local partnerships, the NDS Partnering project will include community amenities such as mobility, traffic calming, and beautification. The City anticipates that most of the candidate blocks will be in areas that currently lack curbs and gutters. In addition to providing water quality, flow control, and community benefits, NDS Partnering project should also increase community awareness of urban stormwater quality issues.

NDS Partnering locations will be prioritized based primarily on stormwater management goals, but factors such as community support and overlapping City priorities will be included in the site prioritization. The site selection process will involve information exchange with neighborhood groups and other public agencies about the program, and selection of project sites based on input from these groups.

8.4.1.2 South Park WQ Facility Project

As briefly described in Section 5.3.2, the South Park WQ Facility would treat runoff in the 7th Avenue S drainage system. The current South Park drainage area is approximately 238 acres, about 145 acres (61 percent) of which is impervious. In the future, the drainage area could be expanded to encompass up to 278 acres including approximately 219 acres of impervious surfaces (SPU, 2014b) The South Park project would involve installation of a basic, active treatment system, such as a CESF system, near the outlet to the 7th Avenue S drainage system. The facility would treat runoff prior to discharge into the Duwamish Waterway. The treatment facility would be designed in conjunction with a new stormwater pump station that the City plans to build in order to reduce flooding in the 7th Avenue S drainage basin. The proposed project would take advantage of the opportunity to integrate water quality treatment with flood control.

The primary objective of this project would be to reduce loads of total PCBs, metals, bacteria, and other pollutants to the Duwamish Waterway. This project would be designed to treat an average annual runoff volume of approximately 74 MG/yr and remove about 80 percent of the TSS load (approximately 24,741 kg) in an average year. See Appendix J for additional information on this project.

8.4.1.3 Street Sweeping Expansion Arterials Program

The Street Sweeping Expansion Arterials program would focus on the separated storm sewer system basins. It would entail increased sweeping of arterials to remove potential stormwater pollutants from a tributary area of approximately 1,736 acres (10,600 annual curb-miles), including streets and adjacent sidewalks. This program includes the following three expansions:

- increase the route coverage from 83 percent to approximately 85 percent of curbed arterials (for a total 10,600 curb-miles), by adding 1 route, for a total of 25 routes
- increase the sweeping season from 40 to 48 weeks per year
- increase the sweeping frequency from biweekly to weekly for some routes: 21 routes would be swept on a weekly basis and 4 routes would be swept on a biweekly basis

The primary objective of this program would be to reduce loads of TSS, PCBs, metals, bacteria, and other particulate-bound pollutants to multiple receiving water bodies. This program would remove pollutants from approximately 1,736 acres with an average annual runoff volume of approximately 1,527 MG/yr. See Appendix J for additional information on this program.

8.4.2 Selected LTCP Projects

The City selected six LTCP projects (those that would control CSO Outfalls 99, 107, 111, 138, 139, and 140) for deferral under the Integrated Plan. These six projects were selected for deferral because (1) they are located in CSO basins that the LTCP team deemed lower priority based on ranking per EPA guidelines and consideration of potential partnering opportunities with King County, and (2) the projects would provide considerably smaller reductions in pollutant loads and exposures than the selected stormwater projects. The LTCP (Volume 2) provides additional details regarding the six LTCP projects to be deferred.

Figure 8-5 shows the locations of the stormwater projects/programs that would be implemented and the LTCP projects that would be deferred under the Integrated Plan alternative. Table 8-5 summarizes the stormwater projects/programs to be implemented and the LTCP projects to be deferred.

Table 8-5. Integrated Plan Alternative

Project name	Project type	Receiving water body	Average existing discharge frequency (average events/yr)[a,b]	Average volume treated or removed (MG/yr)[c]	Life-cycle cost[d] (M$)	Construction completed (yr)
LTCP projects to be completed during 2028–30[e]						
CSO Outfall 99	Offline storage pipe	West Waterway of the Duwamish River	1.5	0.17	$8.2	2030
CSO Outfall 107	Offline storage tank	East Waterway of the Duwamish River	4.6	1.1	$24.2	2030
CSO Outfall 111	Offline storage pipes	Duwamish River	1.7	0.01	$7.3	2030
CSO Outfall 138	Offline storage tank	Portage Bay	1.4	0.09	$7.5	2030
CSO Outfall 139	Offline storage pipes	Portage Bay	1.2	0.01	$1.9	2030
CSO Outfall 140	Offline storage pipes	Portage Bay	3.7	0.05	$4.4	2030
Stormwater projects/programs to be implemented by 2025[f]						
NDS Partnering	Bioretention	Longfellow Creek, Piper's Creek, Thornton Creek	119	35	$27.2	2025
South Park WQ Facility	Basic, active treatment (e.g., CESF[g])	Duwamish Waterway	119	74	$34.8	2025
Street Sweeping Expansion Arterials	Street sweeping (weekly arterial sweeping)	Multiple	119	1,527[h]	$26.1	N/A[i]

a. *For stormwater projects, the existing discharge frequency was estimated using data from 10 years' worth of recorded rainfall data from a City rain gauge. A discharge event was considered as an "event" if, on that particular day, the precipitation depth was at a minimum of 0.03 inch. Based on collected flow monitoring data, a rainfall depth of 0.03 inch generates flow in the storm sewer system.*

b. *The existing discharge frequencies for the candidate LTCP projects can be found in the 2012 Annual CSO Report.*

c. *The estimated average volume removed for the candidate LTCP projects was calculated using the moving 20-year average simulated volumes, without the consideration of climate change. This means that the precipitation data used for modeling was not modified to account for potential effects of climate change on rain; therefore, a scaling factor of 1 was assumed. See the LTCP Hydraulic Monitoring Reports for a more detailed discussion of the hydraulic modeling conducted.*

d. *Present value in 2014 dollars assuming 100-year project life and 3% discount rate based on current IP schedule.*

e. *Prior to 2025, SPU will implement Sewer System Improvements (SSI) designed to reduce oveflows from the CSO outfalls associated with the six deferred LTCP Neighborhood Storage projects. After the SSI have been completed, SPU will monitor the six affected outfalls to assess compliance with the state CSO control standard. SPU will then determine whether some or all of the deferred LTCP Neighborhood Storage projects can be downsized or eliminated.*

f. SPU anticipates that the South Park and NDS Partnering projects will have a life span of 50 years. Street Sweeping Expansion for the Integrated Plan will be conducted up to 2030 or until all six of the deferred CSOs have been controlled. At that time, SPU will determine whether to continue the Street Sweeping Expansion program.*CESF is chitosan-enhanced sand filtration.*

g. *Volume is based on estimated runoff from swept streets.*

h. *The Street Sweeping Expansion Arterials program will begin in 2015. The purchase of sweepers and program implementation will be complete by 2016. Post-Construction Monitoring will occur between 2016 and 2018.*

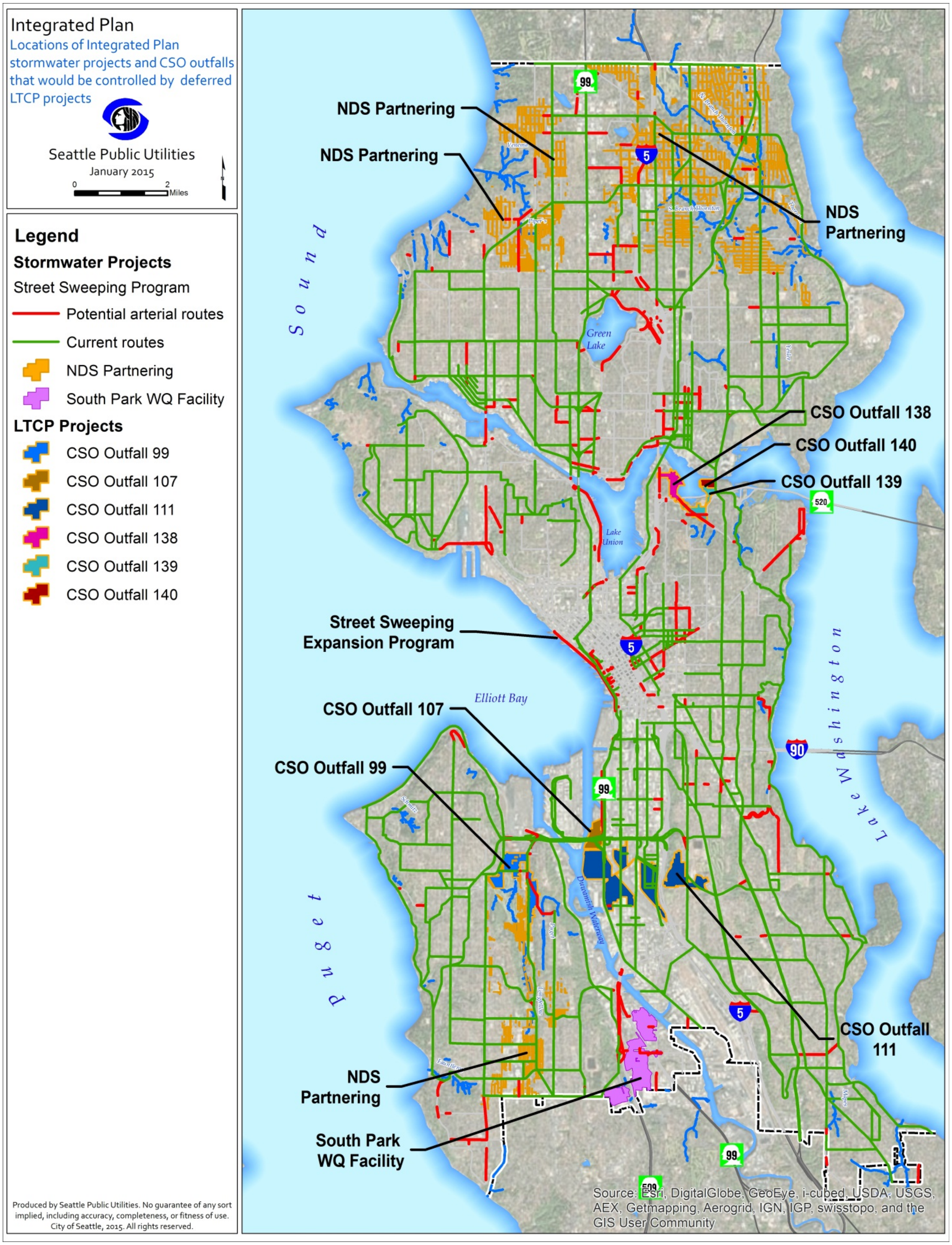


Figure 8-5. Locations of Integrated Plan stormwater projects and CSO outfalls that would be controlled by

deferred LTCP projects

8.4.3 Water Quality Benefits of the Integrated Plan

The Consent Decree requires that the Integrated Plan must result in significant water quality benefits beyond the benefits that would be achieved by implementing the LTCP control measure projects alone. This section summarizes the additional water quality benefits of the Integrated Plan.

8.4.3.1 Pollutant Load Reduction Benefits

Table 8-6 shows that the three stormwater projects selected for the Integrated Plan would result in substantially greater load reductions than the deferred LTCP projects for all RCOCs except ammonia-N. For the RCOCs aside from ammonia-N, the Integrated Plan stormwater projects would achieve load reductions from 10 to more than 100 times greater than the six deferred LTCP projects and the LTCP projects not deferred (see Figure 8-6).

Table 8-6. Average Annual Pollutant Load Reductions for Preferred Alternative for the Integrated Plan

Project	Ammonia-N (kg)	Biochemical oxygen demand (kg)	Bis(2-ethylhexyl) phthalate (kg)	Dichlobenil (kg)	Dissolved copper (kg)	Dissolved zinc (kg)	Fecal coliform bacteria (billion CFU)	H+ (kg)	Oil and grease (kg)	PBDEs (kg)	PCBs (kg)	Phosphorus (kg)	Total copper (kg)	Total suspended solids (TSS) (kg)	Total zinc (kg)
LTCP projects to be completed during 2028–30															
CSO Outfall 99	0.78	12	0.0015	0.000070	0.0032	0.012	651	0.000073	2.2	0.000038	0.000032	0.37	0.0084	20	0.026
CSO Outfall 107	19	82	0.035	0.00029	0.027	0.14	4346	0.00049	15	0.00025	0.00046	6.6	0.22	494	0.57
CSO Outfall 111	0.15	0.64	0.00027	0.000003	0.00021	0.0011	34	0.0000038	0.11	0.0000020	0.0000036	0.05	0.0017	4	0.0044
CSO Outfall 138	0.43	6.8	0.00081	0.000041	0.0018	0.0067	360	0.000040	1.2	0.000021	0.000018	0.21	0.0046	11	0.015
CSO Outfall 139	0.027	0.42	0.000050	0.000003	0.00011	0.00042	22	0.0000025	0.075	0.0000013	0.0000011	0.013	0.00029	0.69	0.00090
CSO Outfall 140	0.24	3.8	0.00045	0.000023	0.0010	0.0038	201	0.000023	0.67	0.000012	0.000010	0.12	0.0026	6	0.0081
Total load reduction	**21**	**106**	**0.038**	**0.00043**	**0.034**	**0.16**	**5,614**	**0.00063**	**19**	**0.00032**	**0.00053**	**7.3**	**0.24**	**536**	**0.63**
Stormwater projects/programs to be implemented by 2025															
NDS Partnering	9.2	684	0.22	0.0048	0.46	3.2	17,910	0.015	396	0.0029	0.0018	14	1.3	7,704	11
South Park WQ Facility	0.0	1,088	0.29	0.0	0.71	14	52,700	0.0	702	0.0047	0.0069	46	4.5	24,741	29
Street Sweeping Expansion Arterials	N/A	337	0.14	N/A	N/A	N/A	2,100	N/A	69	0.0096	0.0033	24	5.2	36,200	10
Total load reduction	**9.2**	**2,109**	**0.64**	**0.0048**	**1.17**	**17**	**72,710**	**0.015**	**1,167**	**0.017**	**0.012**	**83**	**10.9**	**68,645**	**51**

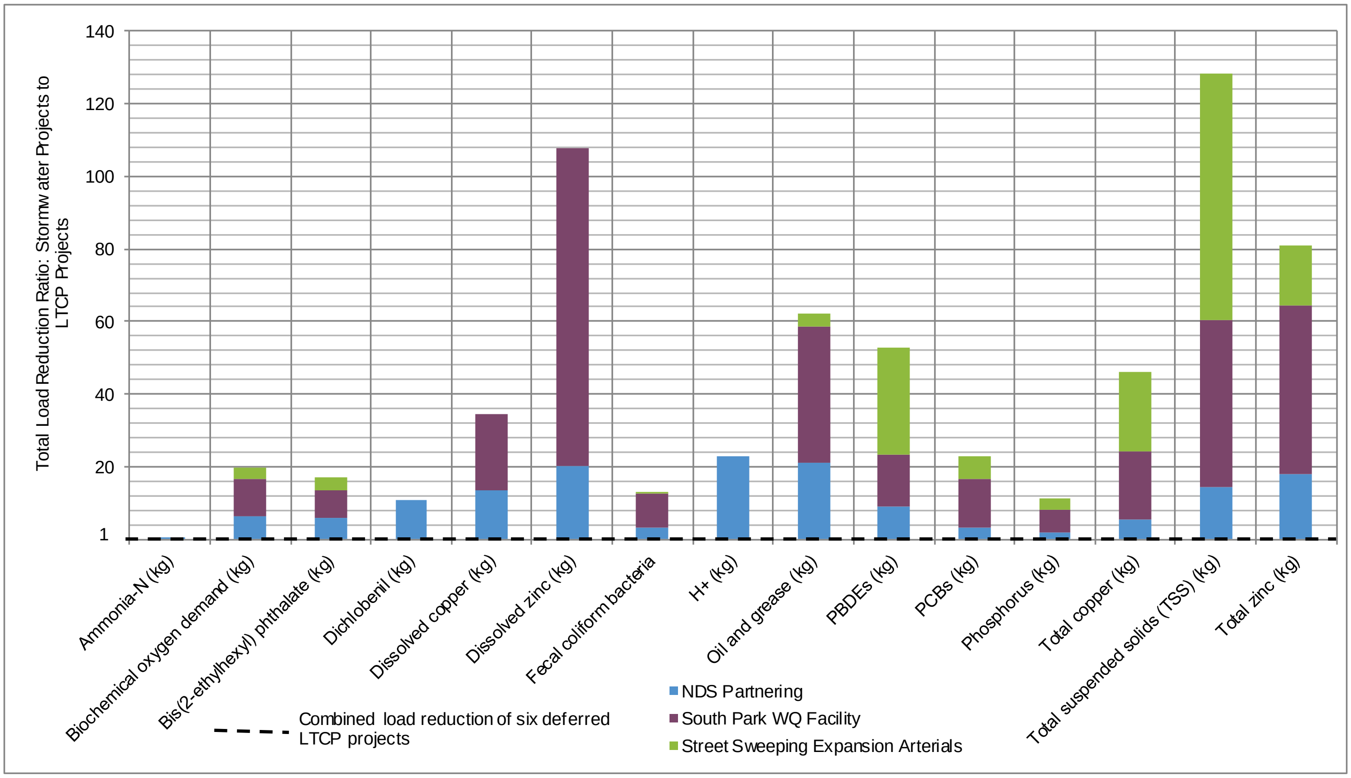


Figure 8-6. Significant pollutant load reduction benefits of Integrated Plan stormwater projects

The bars show how much more estimated pollutant load reduction would be provided by the proposed stormwater projects than by the six deferred LTCP projects, which is represented by the black dashed line.

The six LTCP projects listed in Table 8-5 would be deferred but not eliminated under the Integrated Plan. After the deferred LTCP projects are completed during 2028–30, their water quality benefits will add to the water quality benefits of the stormwater projects. The Integrated Plan stormwater and LTCP projects are long-term measures (100-year life cycle). Consequently, the Integrated Plan will result in significantly greater long-term water quality benefits compared to the deferred LTCP projects alone.

Figures 8-7, 8-8, and 8-9 show the long-term load reductions for TSS, PCBs, and fecal coliform, respectively, with and without the Integrated Plan. As shown in these figures, the Integrated Plan would result in much larger reductions in TSS, PCBs, and fecal coliform loads than the deferred LTCP projects.

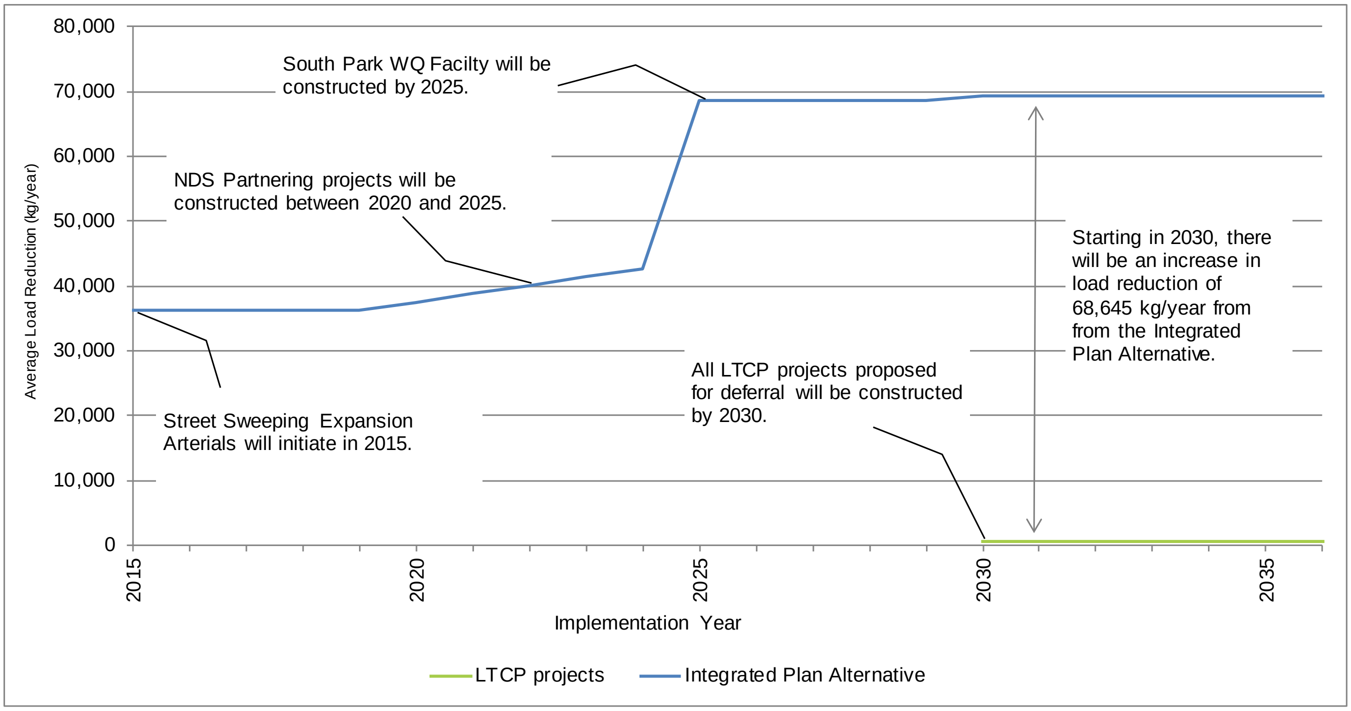


Figure 8-7. Cumulative water quality benefits of the Integrated Plan: TSS load reduction

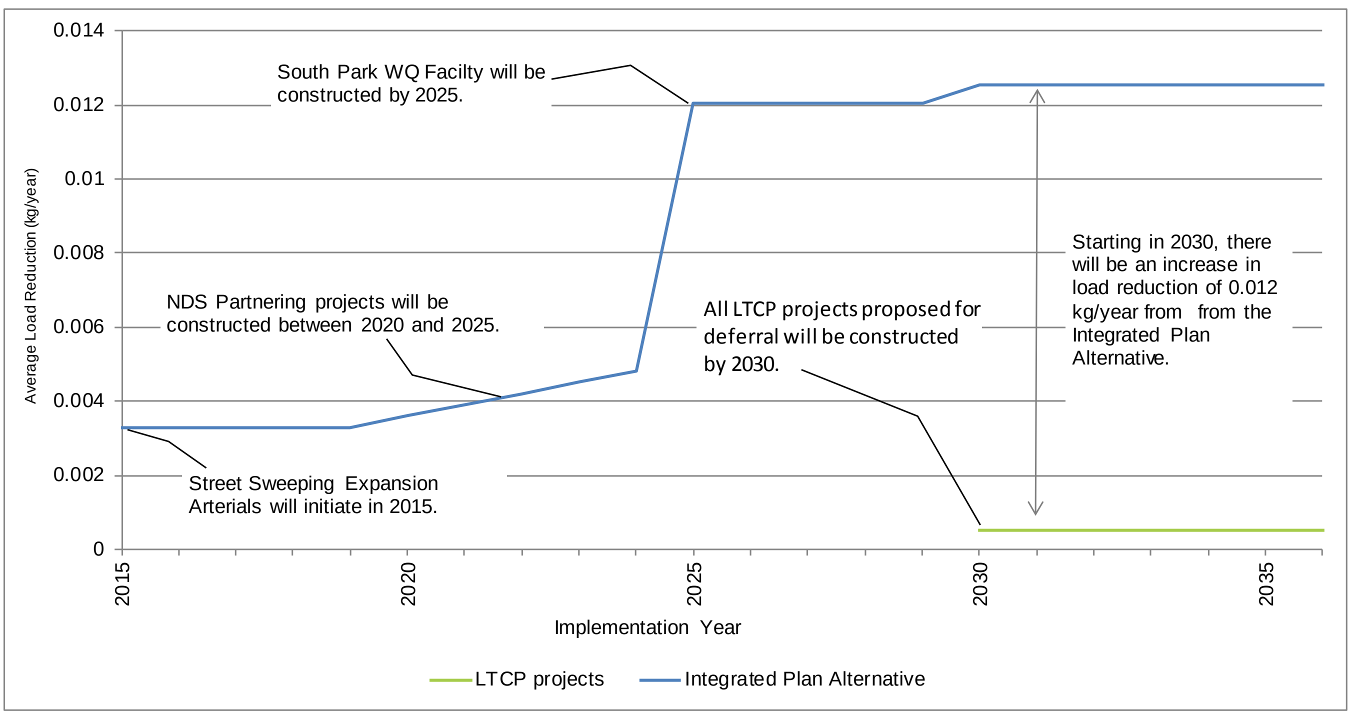


Figure 8-8. Cumulative water quality benefits of the Integrated Plan: PCBs load reduction

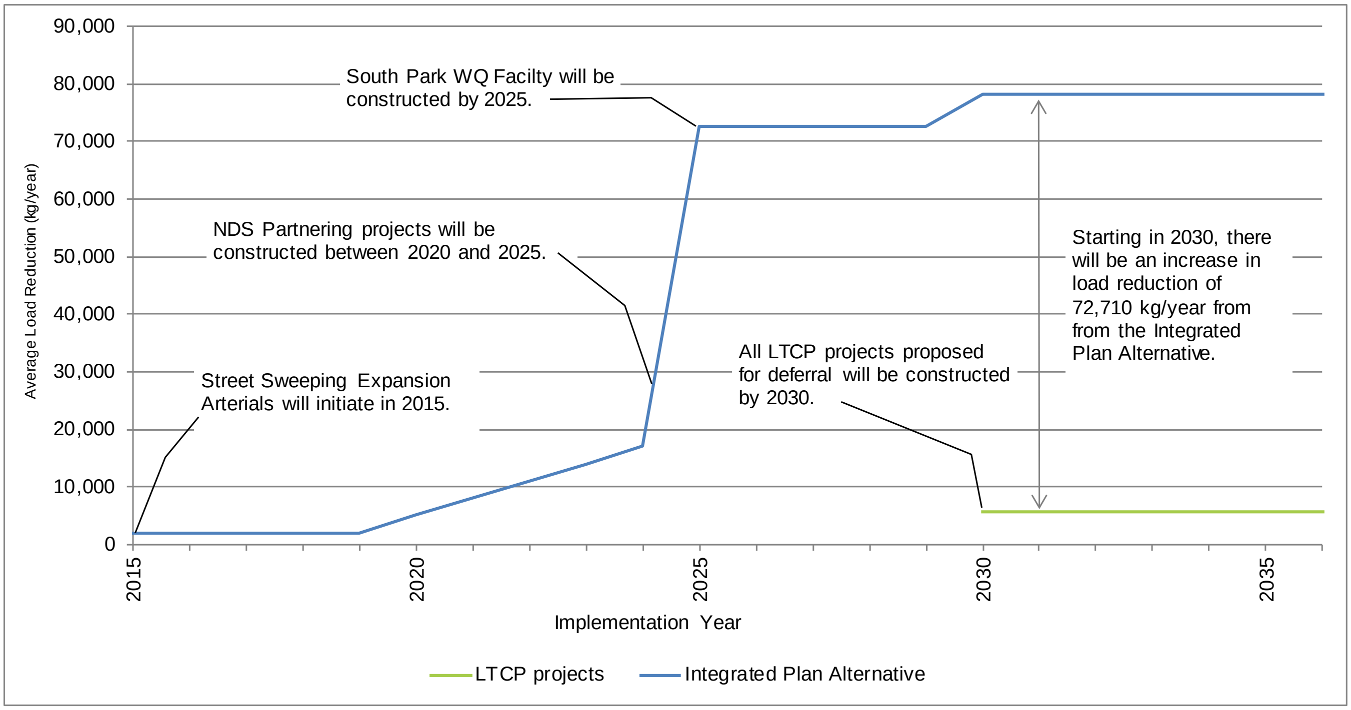


Figure 8-9. Cumulative water quality benefits of the Integrated Plan: fecal coliform load reduction

Under the Integrated Plan, both the stormwater projects and the deferred LTCP projects would reduce pollutant loads to water bodies listed as impaired, water bodies with contaminated sediments, water bodies with spawning grounds, and water bodies where listed species may be present (see Table 8-7). However, the deferred LTCP projects would benefit only the Duwamish Waterway and the Ship Canal while the stormwater projects would benefit additional water bodies throughout the city.

8.4.3.2 Exposure Reduction Benefits

The Integrated Plan would reduce pollutant exposures for human and ecological receptors beyond the reductions that would occur due to the deferred LTCP projects alone. The reduced exposures would result from reductions in the following four factors:

- pollutant loads
- discharge frequency
- discharges when human and ecological receptors are more likely to be present
- geomorphically significant flows to creeks

The following paragraphs discuss each factor.

Pollutant Loads

The Integrated Plan would result in substantially larger reductions in pollutant loads than the LTCP projects alone. These large reductions in loads should bring large reductions in pollutant exposures for human and ecological receptors, including threatened or endangered species.

The exposure assessment (Section 7.4) indicated that PCBs were by far the most important driver for human-toxics EIVs at all locations, as well as an important contributor to ecological EIVs at several locations. PCBs are also a key concern with regard to recontamination of sediments in the Duwamish Waterway. As shown in Figure 8-6 above, the Integrated Plan stormwater projects would result in PCB load reductions more than 20 times larger than the deferred LTCP projects. Human and ecological exposure to PCBs will be further reduced after the deferred LTCP projects are completed in 2028–30.

Human exposure to fecal pathogens is a key concern for CSOs as well as stormwater discharges. The Integrated Plan stormwater projects would result in fecal coliform load reductions more than 10 times greater than the deferred LTCP projects (see Figure 8-6 above). After the deferred LTCP projects are completed in 2028–30, fecal coliform loads and potential exposure will be further reduced.

The exposure assessment indicated that phosphorus, copper, and zinc were important contributors to the ecological EIVs, while dichlobenil, bis(2-ethylhexyl)phthalate, and ammonia-N also contributed to the EIVs. Figure 8-6 shows that the Integrated Plan stormwater projects should provide 10 to 100 times the deferred LTCP load reductions for all of those pollutants except ammonia-N.

As noted in Table 8-7, due to its relatively large load reductions for PCBs and other key pollutants, the human and ecological EIVs for the South Park WQ Facility project are far higher (better) than the EIVs for any of the deferred LTCP projects. The human-fecal coliform and ecological EIVs for the NDS Partnering project are higher than the respective EIVs for the deferred LTCP projects. Although EIVs were not calculated for the candidate street sweeping programs, the pollutant load modeling results suggest that the Street Sweeping Expansion Arterials program would provide substantial reductions in human exposure to toxics and ecological exposure to nutrients and toxics as compared to the candidate LTCP projects. The exposure reduction benefits of the Integrated Plan will increase when the deferred LTCP projects are completed in 2028–30.

Discharge Frequency

The Integrated Plan stormwater projects would treat discharges that are far more frequent than the existing discharges from the deferred LTCP projects. As noted in Table 8-7, the stormwater projects would treat more than 100 runoff events in an average year. The City selected the deferred LTCP projects largely because these LTCP basins are already close to meeting the one discharge per outfall per year standard. The current average discharge frequencies for the outfalls that would be controlled by the deferred LTCP projects range from 1.4 to 5 times per year. Because the stormwater discharges are much more frequent, they are more likely to affect human and ecological receptors.

Discharge Timing

The stormwater projects would treat flows that occur during much of the year. The deferred LTCP projects would control CSOs that discharge primarily during October through January. As shown in Figure 8-10, human and ecological receptors are less likely to be present in the affected receiving water bodies during the peak CSO discharge season. Therefore, the Integrated Plan should reduce exposures beyond the reductions that would be achieved by the deferred LTCP projects alone.

Geomorphically Significant Flows

The Integrated Plan includes the NDS Partnering project, which will increase stormwater infiltration and reduce direct stormwater discharges to Piper's, Thornton, and Longfellow creeks in addition to providing water quality benefits. Initial modeling indicates that NDS Partnering would reduce stormwater discharges in the Piper's, Thornton, and Longfellow basins by about 3, 12, and 2 MG/yr, respectively. These flow reductions should incrementally reduce the frequency and duration of channel-disturbing flows and could increase base flows in the creeks.

Numerous creeks in the Puget Sound lowlands have been adversely affected by hydrologic changes associated with urban development. Urbanization involves replacing native vegetation and topsoil with impervious surfaces, which reduces infiltration and evapotranspiration, and construction of artificial drainage networks designed to quickly convey runoff to receiving water bodies. These landscape alterations can reduce base flows and increase the frequency and duration of geomorphically significant flows, stream channel erosion, down-cutting, and instability problems, particularly in small streams.

The Integrated Plan would also defer six LTCP projects that discharge directly into the Duwamish Waterway and the Lake Washington Ship Canal. The small flow reductions resulting from the deferred LTCP projects are unlikely to affect channel morphology or physical habitat conditions in those large water bodies.

Table 8-7. Summary of Stormwater and LTCP Projects Included in the Integrated Plan

Project	Receiving water body	Receiving water conditions				Average existing discharge frequency (average events/yr)[a,b]	Average volume treated or removed (MG/yr)[c]	Exposure index value		
		303(d)/ impairments	Contaminated sediments	Spawning grounds	T&E species			Human EIV: toxics (chronic)	Human EIV: fecal coliform (acute)	Eco EIV: toxics/ nutrients (chronic)
LTCP projects to be completed during 2028–30										
CSO Outfall 99	West Waterway of the Duwamish River	✓	✓		✓	1.5	0.17	0.39	0.18	0.0057
CSO Outfall 107	East Waterway of the Duwamish River	✓	✓		✓	4.6	1.1	13	1.3	0.35
CSO Outfall 111	Duwamish River	✓	✓		✓	1.7	0.01	0.16	0.019	0.0038
CSO Outfall 138	Portage Bay					1.4	0.09	0.13	2.0	0.039
CSO Outfall 139	Portage Bay	✓	✓		✓	1.2	0.01	0.0061	0.093	0.0031
CSO Outfall 140	Portage Bay	✓	✓		✓	3.7	0.05	0.080	1.4	0.035
Stormwater projects/programs to be implemented by 2025										
NDS Partnering	Thornton Creek	✓			✓	119	24 (12)[d]	3.8	7.0	2.5
	Piper's Creek	✓		✓		119	6 (3)[d]	0.89	1.2	0.54
	Longfellow Creek	✓		✓		119	5 (3)[d]	0.12	0.52	0.24
South Park WQ Facility	Duwamish Waterway	✓	✓		✓	119	74	117	8.3	1.9
Street Sweeping Expansion Arterials	Multiple	✓				119	1,527	N/A[e]	N/A[e]	N/A[e]

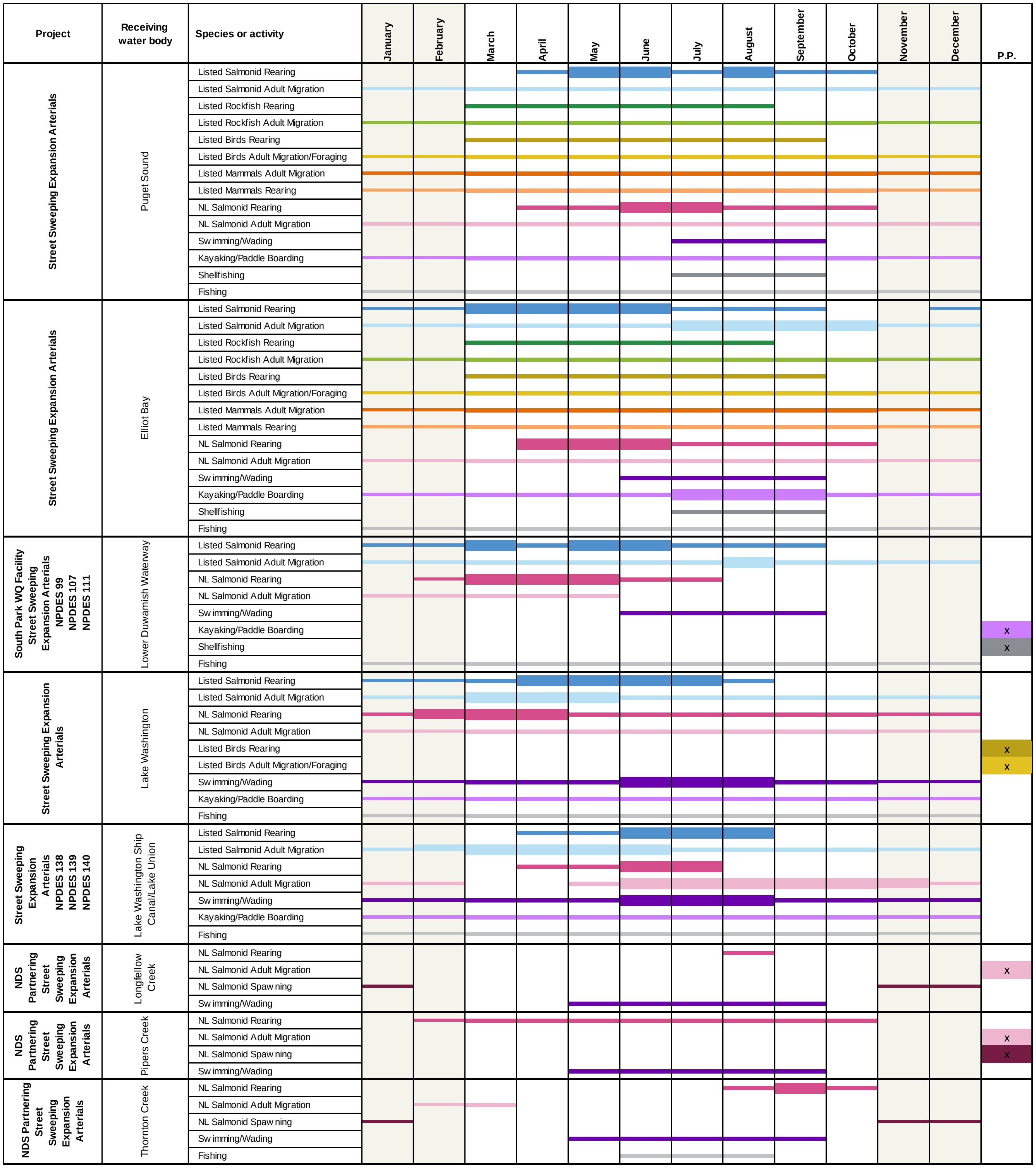
a. For stormwater projects, the existing discharge frequency was estimated from a 10-year rainfall record from a City rain gauge, where a discharge event was any day on which precipitation depth was at least 0.03 inch. Based on flow monitoring data, a rainfall depth of 0.03 inch generates flow in the storm sewer system.

b. The existing discharge frequencies for the deferred LTCP neighborhood storage projects are those reported in the 2012 Annual CSO Report.

c. The volume removed for the deferred LTCP neighborhood storage projects is the moving 20-year average simulated volumes without climate change (scaling factor = 1).

d. Numbers in parentheses are volumes infiltrated.

e. EIVs were not calculated for street sweeping because the receptor factors are based on the outfall location, and runoff from the swept streets would enter >100 outfalls throughout the city.



Species are lumped together in listed or non-listed groups. Some or all of the species may be observed in the receiving waters at any given time.
Listed species may include: Salmonids: Chinook salmon, Steelhead trout, Bull trout; Rockfish: three species; Birds: Marbled murrelet; Mammals: Killer whale, Steller sea lion, Humpback whale.
Non-listed species may include: Salmonids: Coho salmon, Sockeye salmon, Chum salmon, Pink salmon, Cutthroat trout, Rainbow trout.
NL: non-listed.
P.P.: presumed present.
X: Activity or species is presumed present (P.P.) but no specific date range was available.
Thicker bar: Indicates peak timing for the species and associated life history use or human activities.
Shading: November to February is peak timing for discharges from CSO basins.

Figure 8-10. Human and ecological receptors at each discharge location

8.4.4 Cost-Benefit Analysis

This section presents the cost-benefit analysis of the Integrated Plan in accordance with the Consent Decree requirement that the plan shall include "a cost-benefit analysis for implementation of the Integrated Plan". The City prepared this analysis consistent with generally accepted guidance applicable to the Integrated Plan, using readily available, relevant data.

A cost-benefit analysis is an analytical tool for comparing the positive and negative effects of a proposed action on the value of goods and services available to society for other uses. A cost is a reduction in value; a benefit is an increase in value. Either may involve a change (decrease or increase, respectively) in the supply of a good or service, a change in its per-unit value, or both.

This analysis compares two scenarios. One describes what the conditions are expected to be with the implementation of the Integrated Plan. The other, the baseline scenario, reflects what the conditions are expected to be without it. The difference between the two provides the basis for identifying the costs and benefits attributable solely to the Integrated Plan. For the purposes of this analysis, the baseline scenario is defined as construction by 2025 of the six LTCP projects summarized in Table 8-5 above. The Integrated Plan scenario consists of implementing the three stormwater projects listed in Table 8-5 by 2025 and completing the six deferred LTCP projects by 2030.

The comparison of the two scenarios considers both the costs and benefits that would accrue to the City through its implementation of the Integrated Plan, and the external costs and benefits that would accrue to others. Readily available data were sufficient to estimate, in monetary terms, the City's costs to implement the Integrated Plan. For other costs and all the benefits, the City determined that the available information is not sufficiently robust and reliable to support a monetized description. In some instances suitable information was available to describe costs and benefits quantitatively.

8.4.4.1 Costs

The City developed planning-level cost estimates for the selected projects. The estimates for the selected stormwater projects are based on the conceptual designs contained in Appendix J. Estimates for the LTCP projects selected for deferral are described in the LTCP.

Table 8-8 lists the City's estimated costs for the six deferred LTCP projects and the three stormwater projects that comprise the Integrated Plan. The costs are expressed in present-value terms. In each case, the present value is a single amount that is economically equivalent to the stream of costs the City would incur over the study period. The present value is calculated through a process known as discounting, using a real (adjusted for inflation) discount rate of 3 percent per year. The City assumes a 3 percent discount rate for its CSO program.

Implementation of the Integrated Plan also may result in external costs, such as traffic delays associated with street sweeping. Insufficient information currently exists to quantify or monetize the external costs. Therefore, external costs were considered qualitatively in the MODA.

Table 8-8. Estimated Costs for the Integrated Plan Projects

Project name	Capital	O&M[a]	Total
LTCP projects to be completed during 2028-30[b]			
CSO Outfall 99	$5.5	$2.7	$8.2
CSO Outfall 107	$21.4	$2.8	$24.2
CSO Outfall 111	$3.7	$3.6	$7.3
CSO Outfall 138	$5.9	$1.6	$7.5
CSO Outfall 139	$1.2	$0.7	$1.9
CSO Outfall 140	$2.7	$1.7	$4.4
Stormwater projects/programs to be implemented by 2025			
NDS Partnering	$24.5	$2.8	$27.2
South Park WQ Facility	$24.3	$10.5	$34.8
Street Sweeping Expansion Arterials	$0.6	$25.5	$26.1

a. Present value costs in 2014 dollars (in $ million over 100 years at 3%).

8.4.4.2 Benefits

The primary benefit of the Integrated Plan projects/program includes not only the significant improvement in water quality, relative to what would occur under the LTCP, but also the time frame in which these benefits would occur. Benefits would be seen sooner because of the advancing of the Integrated Plan water quality improvement projects. The approach to illustrating water quality benefits was to quantify and compare the reduction in the discharge of those pollutants that impact the established human and environmental beneficial uses and the reduction in human and environmental exposure risk. Section 8.4.3 above summarizes the expected water quality benefits of the Integrated Plan relative to the LTCP.

The City has determined that insufficient information exists to monetize the increased value of goods and services that will result from the significant improvements in water quality, but sufficient information exists to quantify some of them in non-monetary terms. The water quality improvements are expected to result in increased value for numerous goods and services associated with an improved aquatic environment, such as better fish habitat, larger fish populations, improved water-related recreation, and reduced water-related illnesses for exposed humans and animals. Other benefits of the Integrated Plan include enhanced protection of sediment cleanup sites from recontamination, improved pedestrian safety and aesthetics associated with green infrastructure (i.e., NDS Partnering), and improved aesthetics due to street sweeping.

8.4.4.3 Comparison of Costs and Benefits

Table 8-9 lists the estimated costs per unit of annual pollutant reduction for the Integrated Plan stormwater projects and the deferred LTCP projects. The table shows that the stormwater projects would provide substantially greater load reductions benefits per dollar of life-cycle cost for all pollutants except ammonia-N.

Table 8-9. Pollutant Load Reduction Costs for Integrated Plan

Pollutant	Stormwater projects ($/kg load reduction/yr)	Deferred LTCP projects ($/kg load reduction/yr)
Ammonia-N	$304,598	$80,777
BOD	$1,322	$16,041
Bis(2-ethylhexyl)phthalate	$4,327,907	$45,074,610
Dichlobenil	$584,610,939	$3,919,536,310
Dissolved copper	$2,390,588	$50,412,115
Dissolved zinc	$161,791	$10,600,399
Fecal coliform	$38	$302
H+	$190,869,894	$2,679,223,587
Oil and grease	$2,389	$90,271
PBDEs	$162,279,211	$5,221,649,390
PCBs	$231,842,571	$3,221,987,276
Phosphorus	$33,434	$230,839
Total copper	$254,900	$7,129,600
TSS	$41	$3,160
Total zinc	$55,150	$2,706,974

Although the Integrated Plan stormwater projects would be very cost-effective relative to the deferred LTCP projects, the City's overall costs would be higher under the Integrated Plan. The Integrated Plan costs would be higher because the stormwater projects would be completed in addition to the deferred and the non-deferred LTCP projects. Nevertheless, the City has concluded that the additional benefits resulting from the Integrated Plan outweigh the additional costs. The City reached this conclusion based on the results of the MODA process described in Section 8.3. This process weighed the costs and benefits using expert opinion and considering all available information, and concluded that the benefits would outweigh the costs. Relying on MODA to complete the comparison of costs and benefits was necessitated because insufficient information exists to support a monetized, quantitative comparison. The City frequently relies on the MODA process to conduct a cost-benefit analysis of investment decisions that considers contributions to positive environmental outcomes, social good for the community, and the City's financial strength.

8.4.5 Compliance Assurance

The Consent Decree allows the City to develop an Integrated Plan as an alternative to the LTCP. An approved Integrated Plan would allow the City to defer implementation of selected LTCP projects and implement stormwater projects that would provide significant benefits to water quality beyond those that would be achieved by implementing the LTCP projects alone. This language indicates that the "significant benefits" of the stormwater projects should be determined relative to the deferred LTCP projects. Therefore, the City compared the candidate LTCP and stormwater projects in terms of pollutant load reductions and other factors relevant to water quality benefits. The City selected three stormwater projects that would meet the "significant benefits" criterion by providing the following benefits:

- substantially larger pollutant load reductions than the six LTCP projects proposed for deferral
- substantially greater long-term environmental benefits than the LTCP projects alone, because the deferred LTCP projects will be operational by 2030 and add to the water quality benefits of the stormwater projects
- greater reductions in pollutant loads to water bodies with impairments and special circumstances compared to the LTCP projects proposed for deferral
- greater reductions in discharges of PCBs and other toxic organic compounds to the Duwamish Waterway, where sediments are listed under CERCLA and MTCA, compared to the LTCP projects proposed for deferral
- reductions in pollutant loads to a number of water bodies, such as Piper's Creek, Thornton Creek, and Elliott Bay, that would not benefit from the LTCP projects
- reductions in geomorphically significant flows to Piper's, Thornton, and Longfellow creeks, which will help to protect spawning grounds and improve aquatic habitat in these water bodies

Although the City used the best available data and robust evaluation methods to estimate pollutant load reductions for the LTCP and stormwater projects, the City recognizes that there is uncertainty associated with the estimates. Figures 8-11 through 8-16 below show the upper and lower confidence limits for the proposed stormwater projects. As shown in these figures, the lower confidence limits (LCLs) for the stormwater projects are much higher than the upper confidence limits (UCLs) for the deferred LTCP projects. Moreover, the stormwater load reductions will continue for many years after the deferred LTCP projects have been completed. The figures show that the proposed stormwater projects clearly meet the "significant benefit" criterion of the Consent Decree.

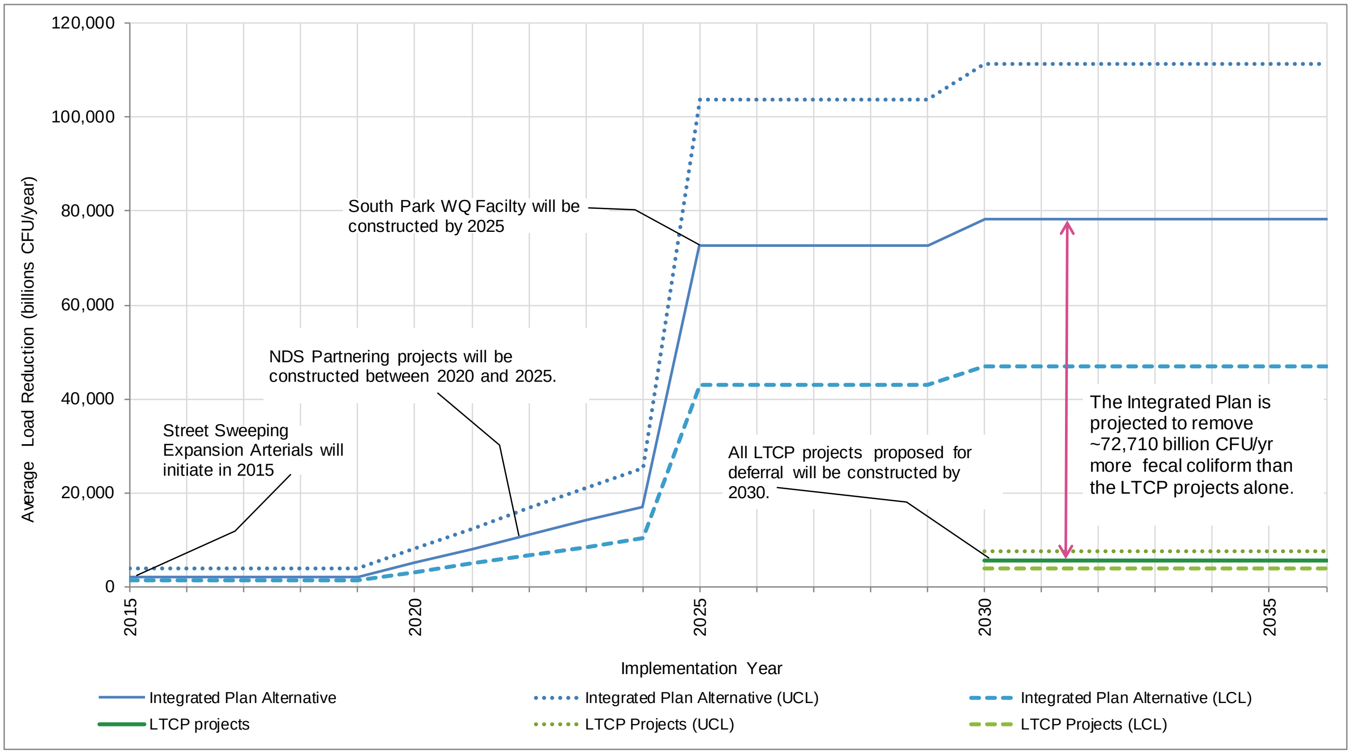


Figure 8-11. Estimated fecal coliform load reduction benefits of the Integrated Plan

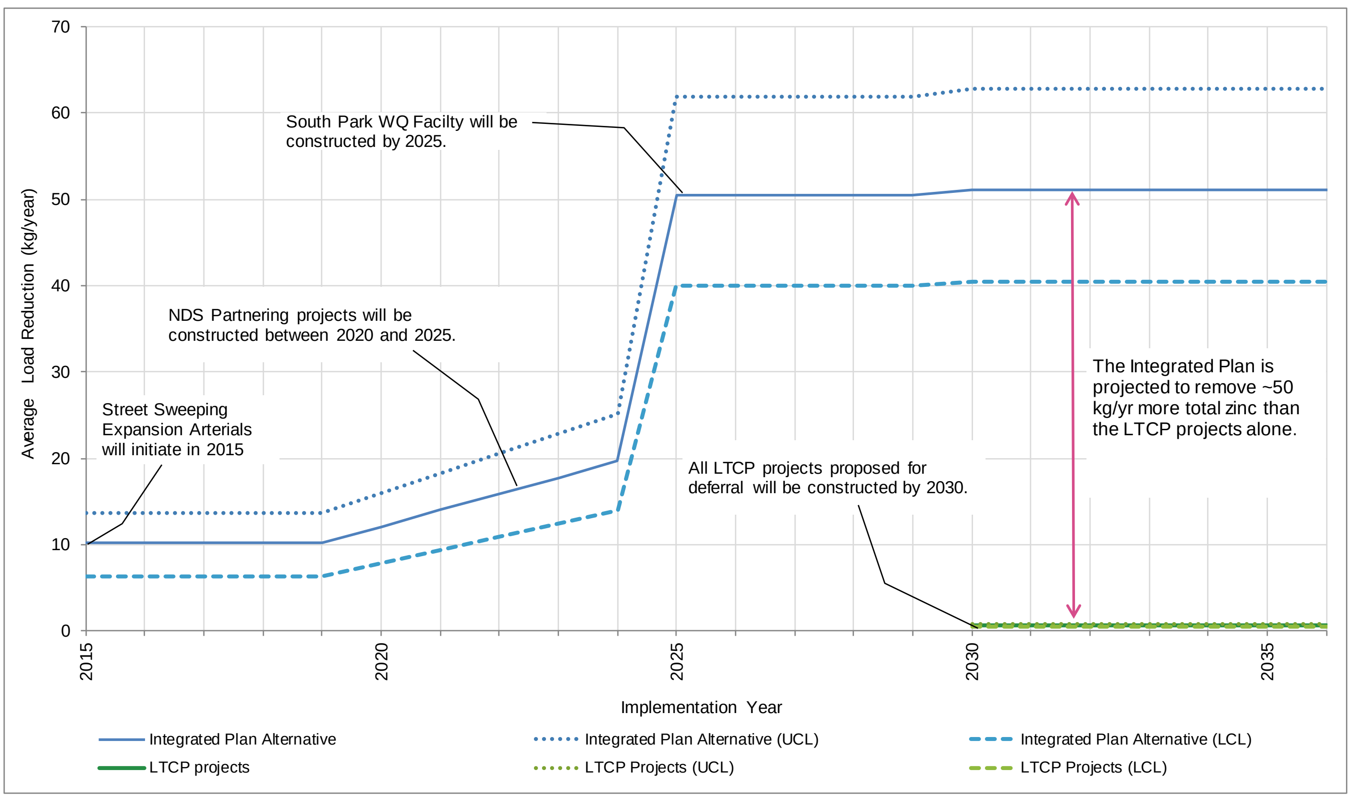


Figure 8-12. Estimated total zinc load reduction benefits of the Integrated Plan

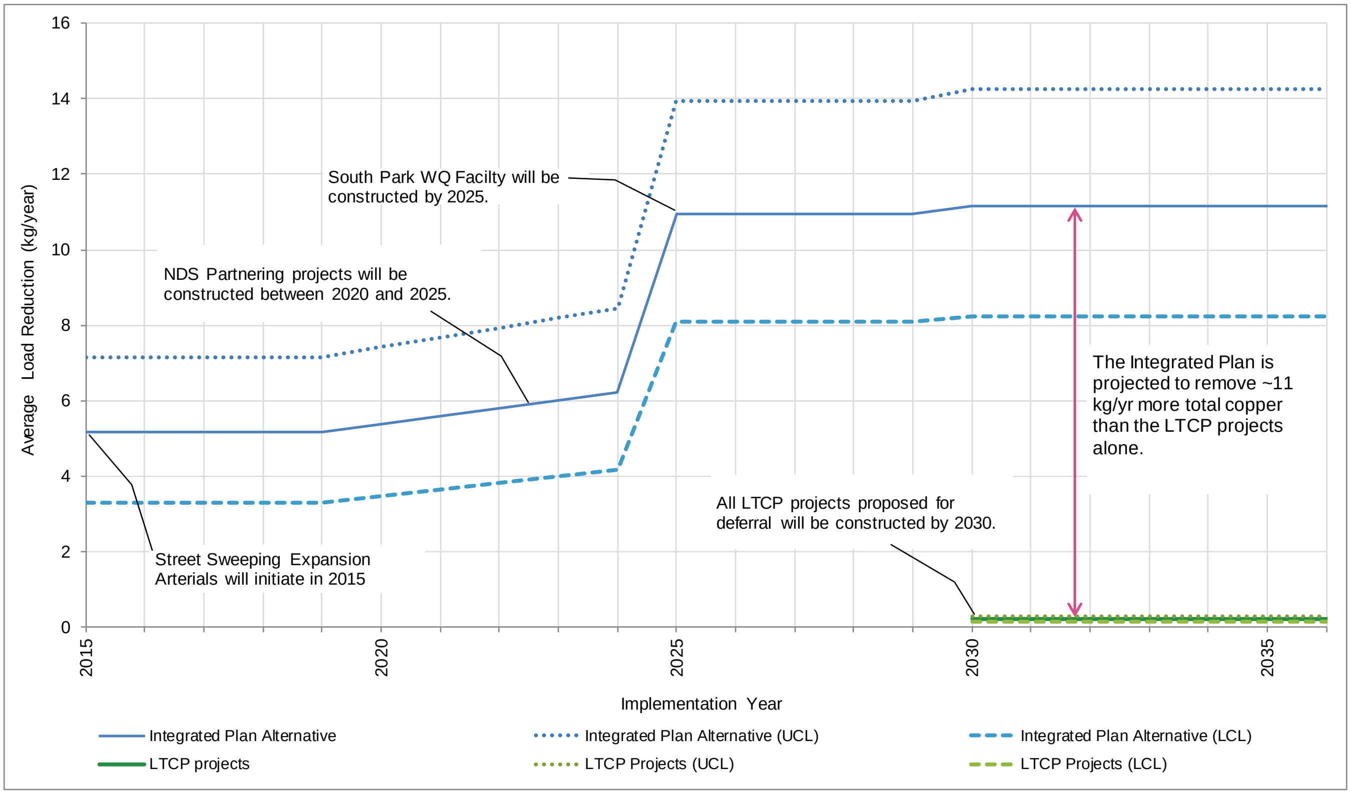


Figure 8-13. Estimated total copper load reduction benefits of the Integrated Plan

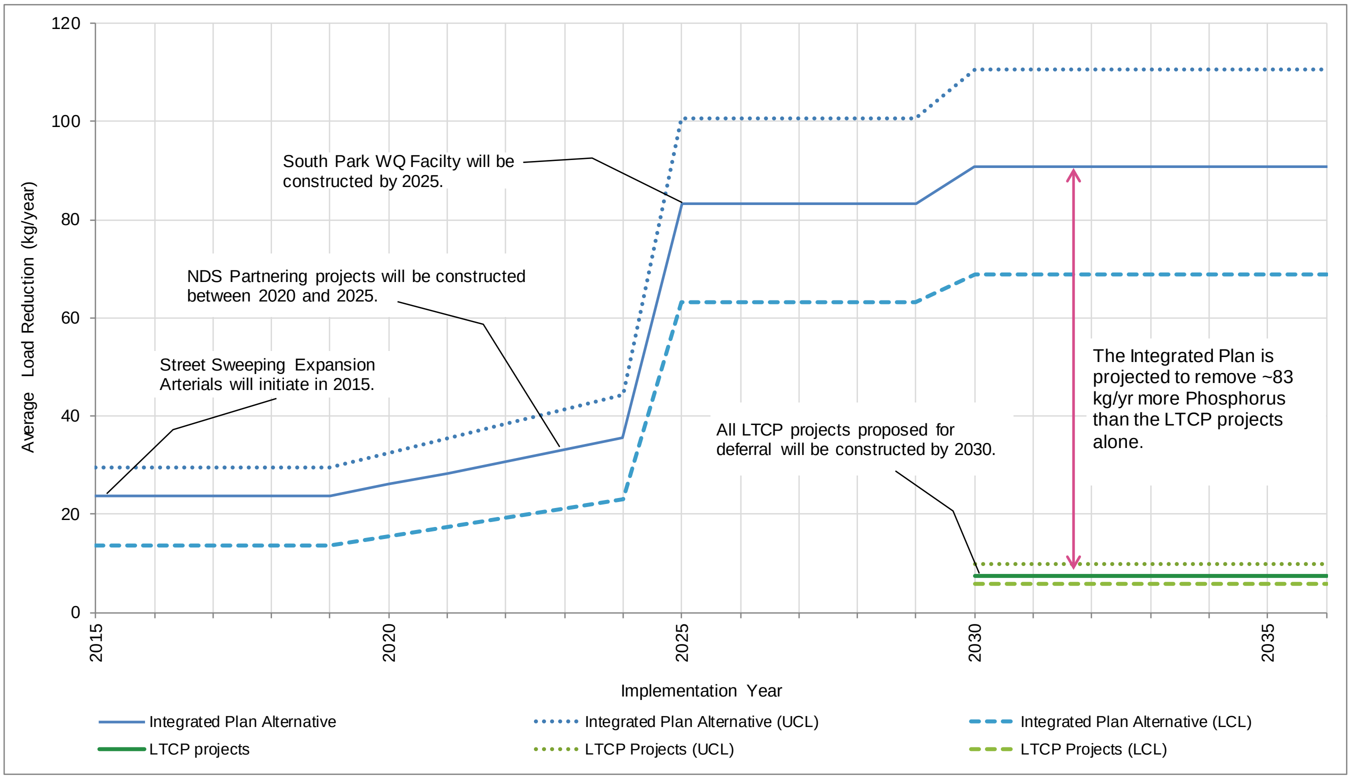


Figure 8-14. Estimated phosphorus load reduction benefits of the Integrated Plan

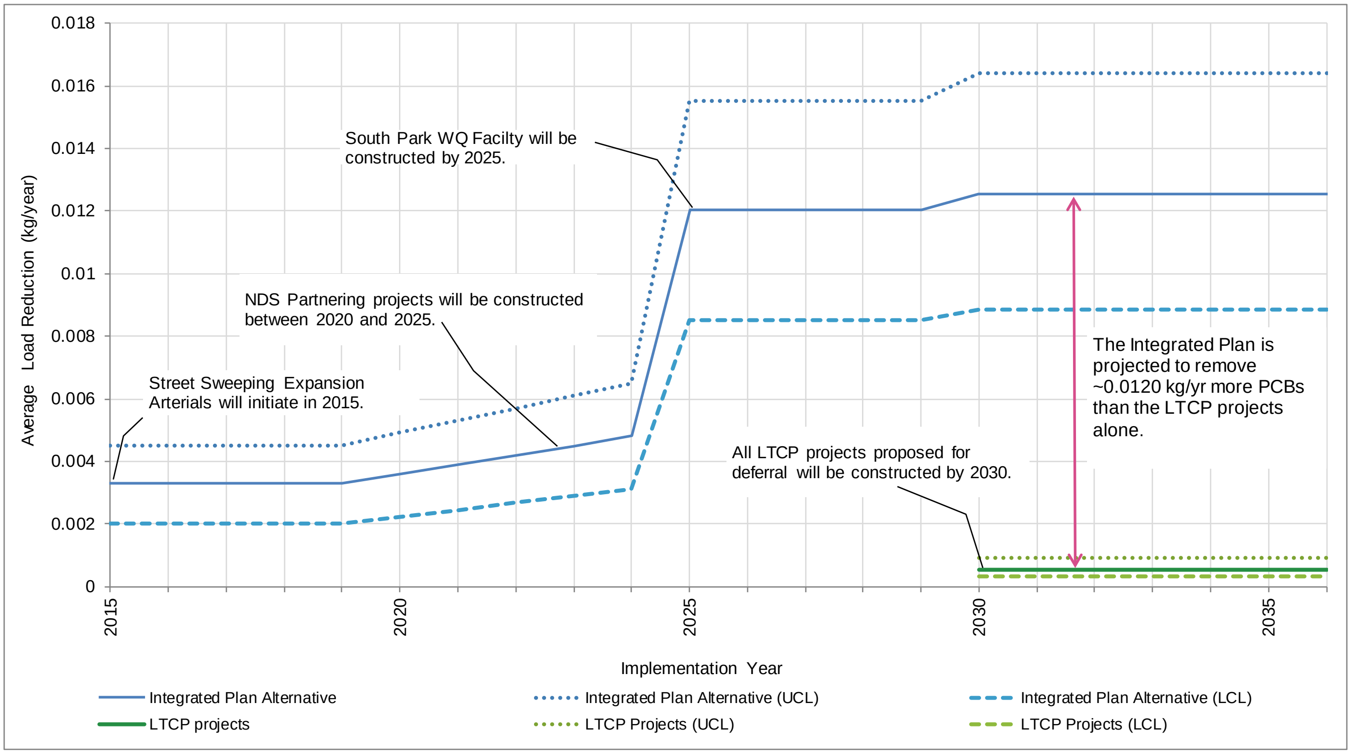


Figure 8-15. Estimated PCB load reduction benefits of the Integrated Plan

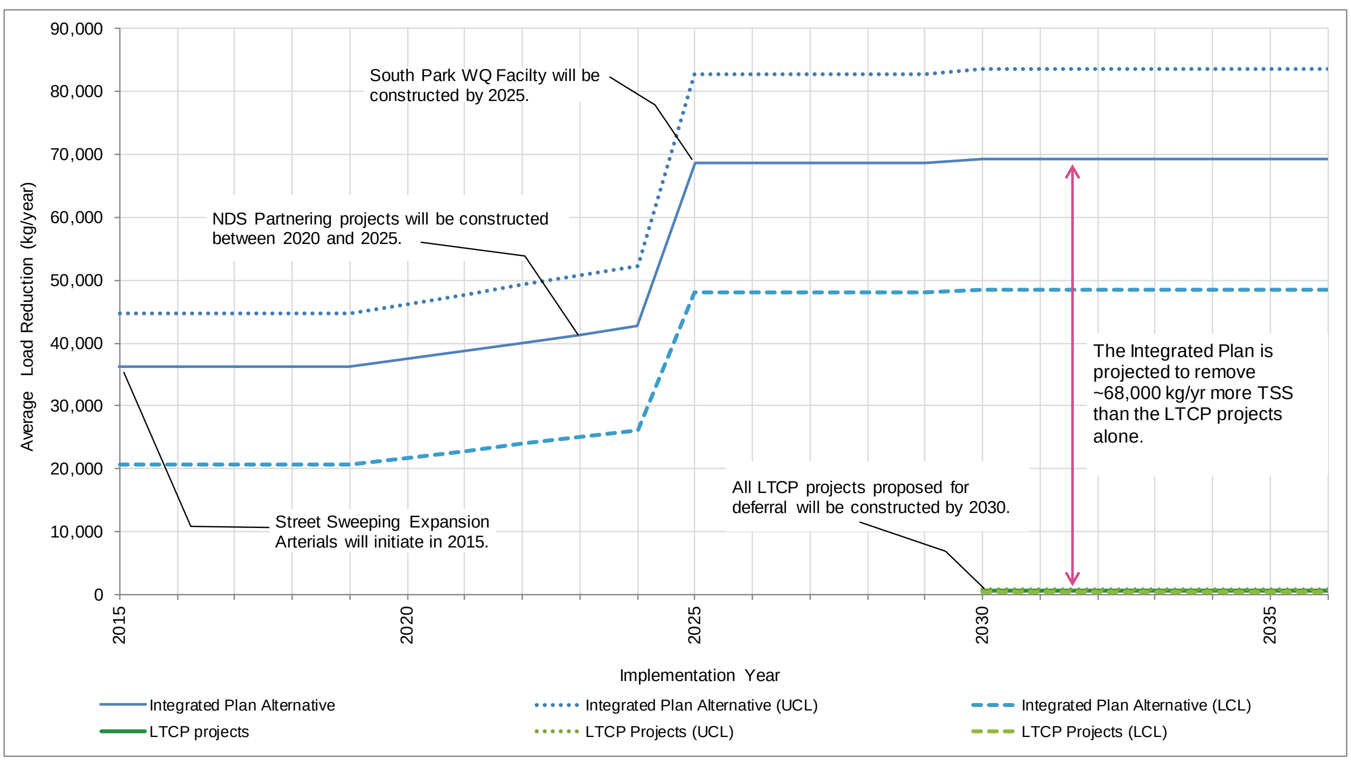


Figure 8-16. Estimated TSS load reduction benefits of the Integrated Plan

The City proposes to set a performance goal for measuring the success of the Integrated Plan stormwater projects. The performance goal is based on the LCLs for the estimated fecal coliform, total zinc, total copper, phosphorus, PCB, and TSS load reductions. TSS was selected because it is commonly used to measure stormwater project performance. The other pollutants were selected based on the exposure assessment performed for the Integrated Plan.

The individual stormwater projects will be monitored as described in Chapter 10 of this plan and summarized below:

- The Street Sweeping Expansion Arterials project monitoring will consist of measuring the curb-miles swept and the dry tons of material removed. The monitoring data will be used to calculate pollutant load removals using the City's existing robust data set collected by the Seattle street sweeping program over the past 2 years.
- The NDS Partnering project monitoring will involve monitoring flow and water quality at representative swales in each of the basins (Thornton, Piper's, and Longfellow creeks). At each representative swale the City will measure inflow and bypass flow (and underdrain flow if present). The City will also collect samples of inflow and outflow (and underdrain flow if present) for RCOC analysis. The flow and water quality measurements will be used to calculate pollutant load reductions for each of the monitored NDS facilities. The City will extrapolate these results to the rest of the NDS Partnering project swales using flow simulations from hydrologic models, which will be developed during facility design and calibrated based on flow data collected at the representative swales.
- The South Park WQ Facility project monitoring will involve measuring the volume of stormwater managed by the project. These data will be used to re-calculate the pollutant load removals.

Following completion of all post-construction monitoring for the three stormwater projects/programs, the City will evaluate the monitoring results in light of the performance goal, as described in Chapter 10. The City will report the results to EPA and Ecology and if necessary develop a Supplemental Compliance Plan as described in Appendix C, Section D, Paragraph 2 of the Consent Decree.

CHAPTER 9

Implementation Schedule

Table 9-1 presents the implementation schedule for the Integrated Plan.

Table 9-1. Implementation Schedule

Project name	Draft engineering report	Final engineering report	Draft plans and specs	Final plans and specs	Construction start	Construction completion/ project completion[a]	Achieve controlled status/ post-construction monitoring completed[b]
LTCP projects to be completed during 2028-30							
CSO Outfall 99	6/30/2017	12/31/2026	6/30/2018	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 107	6/30/2017	12/31/2024	6/30/2019	12/31/2026	7/1/2027	9/30/2030	9/30/2031
CSO Outfall 111	6/30/2021	12/31/2026	6/30/2022	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 138	6/30/2016	12/31/2026	6/30/2017	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 139	6/30/2016	12/31/2026	6/30/2017	12/31/2027	7/1/2028	9/30/2030	9/30/2031
CSO Outfall 140	6/30/2016	12/31/2026	6/30/2017	12/31/2027	7/1/2028	9/30/2030	9/30/2031
Stormwater projects/programs to be implemented by 2025							
NDS Partnering	NA	NA	NA	NA	7/17/2019	12/28/2025	9/30/2029
South Park WQ Facility	NA	NA	NA	NA	12/31/2023	12/31/2025	9/30/2028
Street Sweeping Expansion Arterials	NA	NA	NA	NA	2015[c]	N/A	9/30/2019

a. "Construction Completion" dates apply to the LTCP projects and that "Project Completion" dates apply to the Stormwater projects/programs.

b. "Achieve Controlled Status" dates apply to the LTCP projects and that "Post-Construction Monitoring Completed" dates apply to the Stormwater projects/programs.

c. The "Construction Start" for Street Sweeping Expansion Arterials is the notice to proceed date for SDOT to initiate the program.

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CHAPTER 10

Post-Construction Monitoring Plan

This chapter discusses the methods SPU will use to perform post-construction monitoring of the three stormwater projects included in the Integrated Plan.

10.1 Introduction

In accordance with the Consent Decree, the City will conduct post-construction monitoring of the Integrated Plan stormwater projects to assess whether their anticipated water quality benefits have been achieved.

As discussed in Chapter 8, the pollutant load modeling performed for this Integrated Plan indicates that the stormwater projects should provide substantially greater load reductions for key pollutants than the deferred CSO projects. The City used the pollutant loads modeling results to establish performance goals for the Integrated Plan stormwater projects. The performance goals are listed in Table 10-1. The goals are based on the LCLs for the estimated load reductions for fecal coliform, PCBs, total phosphorus, total copper, TSS, and total zinc. TSS was selected because it is commonly used as a general indicator of stormwater project performance. Fecal coliform, PCBs, total phosphorus, total copper, and total zinc were selected because they were identified as important parameters by the exposure assessment performed for the Integrated Plan. As noted in Section 8.4.5 above, the stormwater project LCLs for these pollutants are considerably higher than the UCLs for the six LTCP projects to be deferred.

Table 10-1. Integrated Plan Performance Monitoring Goals

Project name	Average volume treated or removed (MG/yr)	Fecal coliform bacteria (billion CFU/yr)[a]	PCBs (g/yr)[a]	Total phosphorus (kg/yr)[a]	Total copper (kg/yr)[a]	TSS (kg/yr)[a]	Total zinc (kg/yr)[a]
NDS Partnering	32[a]	10,649	1.3	11	1.1	6,478	9.2
South Park WQ Facility	67[a]	31,000	5.2	38	3.8	20,935	25
Street Sweeping Expansion Arterials	1,477[a,b]	1,380	2.0	14	3.3	20,700	6.3
Total	**1,576**	**43,029**	**8.5**	**63**	**8.1**	**48,113**	**40**

a. These values represent the 95% lower confidence limits (LCL) from the pollutant load model (PLM) results.
b. Volume of runoff from swept streets.

The City will monitor the influent and effluent concentrations and volumes of the stormwater managed by the NDS Partnering Project and the South Park Water Quality Facility for 2 years after these projects become operational. Similarly, the City will monitor the mass of material collected data during the first 2 years of its expanded arterial street sweeping program. After monitoring has been completed for all three projects, the results will be used to calculate the total pollutant load reductions for the three projects combined and compared to the total load reduction goals listed in Table 10-1 above.

Chapter 9 contains the implementation schedules for the three stormwater projects. Table 10-2 summarizes the proposed post-construction monitoring schedule for each project. Sections 10.2, 10.3, and 10.4, respectively, describe the monitoring methods for the NDS Partnering, South Park Water Quality Facility, and Street Sweeping Expansion Arterials projects. Section 10.5 describes how the post-construction monitoring data will be evaluated against the Integrated Plan performance targets and how the findings will be reported. Appendix J provides additional details for each project, including the estimated long-term average pollutant load reductions for the constituents included in the post-construction monitoring program.

Table 10-2. Proposed Integrated Plan Stormwater Projects Monitoring Summary

Project name	Construction completed (year)[a]	Post-construction monitoring completed (year)	Water years of monitoring	Facilities to be monitored
NDS Partnering[b]	2025	2029	2 per facility	2/watershed; 6 total
South Park WQ Facility	2025	2028	2	1
Street Sweeping Expansion Arterials	2016[c]	2019	2	2[d]

a. SPU will submit monitoring Quality Assurance Project Plans (QAPP) for Ecology review for each project prior to construction completion.

b. NDS Partnering monitoring will begin 1 full year following construction completion in each basin.

c. Start of Street Sweeping Expansion Arterials program.

d. Street sweepings collected across Seattle are deposited at two collection facilities depending on the area where they are collected.

10.2 NDS Partnering

This section provides an overview and monitoring summary of the NDS Partnering project.

10.2.1 Overview

The NDS Partnering project will use bioretention in the form of engineered rain gardens to manage stormwater in the basins that drain to Longfellow, Piper's, and Thornton creeks. The NDS facilities will be small distributed bioretention cells designed to capture and treat stormwater from a street block or set of street blocks. Two types of rain gardens will be constructed: (1) shallow infiltration rain gardens with no underdrains and (2) rain gardens with underdrains (perforated pipes) to collect stormwater that passes through the bioretention media but does not infiltrate in an acceptable time frame. The underdrains will collect the portion of the treated stormwater that does not infiltrate and convey it to a City stormwater conveyance system or UIC structure. The remainder of the treated stormwater (assumed to be less than 80 percent of the inflow volume) will be infiltrated as the soil and other conditions allow. Collectively, the NDS facilities will be designed to allow for 50 percent of the captured volume to be infiltrated into native soils while the remaining 50 percent will be discharged after treatment via an underdrain. Hydrologic models will be used to size the facilities based on basin characteristics.

For the purposes of monitoring, an NDS bioretention "facility" is defined as a contiguous rain garden (which may consist of several individual cells) on one side of a project street block.

10.2.2 Monitoring Summary

The monitoring approach for the NDS Partnering bioretention facilities will involve the four steps described below.

Step 1: Monitor Flow. In each of the three watersheds, the City will monitor two NDS bioretention facilities, one without an underdrain and a second with or without an underdrain, depending on the final design and relative number of each type of facility constructed in each basin. (Note that underdrains may not be installed in all of the basins or only in limited cases). Thus, a total of six NDS facilities will be monitored.

The NDS facilities to be monitored will be designed to have a single inflow location, if feasible. If this is not feasible (i.e., the NDS facility requires multiple inflow points), one representative inlet may be used as a surrogate for all of the influent stormwater. The runoff volume entering each facility will be monitored by level sensors and data loggers upstream or at the inlet(s) to each facility.

Overflow volumes will be measured at the overflow out of a facility (if present) or downstream curb cuts (if acting as an overflow structure). Bypass flows will be measured at the point where any runoff externally that bypasses the NDS facility inlets discharges back into the stormwater conveyance system via a roadway storm drain inlet.

For monitored facilities with underdrains, the underdrain flow will be measured by level sensors and volumetric weirs installed at the point where the underdrains discharge back into the local stormwater conveyance system (or other suitable location). The type and location of the monitoring instrumentation will be dependent on the configuration of the facility and the corresponding conveyance system. The flow measurements will be continuous over the 2 years each facility is monitored.

Step 2: Monitor Water Quality. Flow-proportioned composite and discrete, instantaneous grab samples will be collected on untreated influent (roadway runoff) and treated effluent (underdrain flow). Automatic water quality samplers will be paced by the flow monitoring equipment to collect flow-proportioned sample aliquots throughout the duration of each event monitored. The aliquots will be combined for analysis (flow-weighted composite sample). Influent and effluent grab samples (for bacteria analysis) will be collected once during each event. Six influent/effluent sample pairs will be collected each year for a sample total of 12 sample pairs per each facility monitored over 2 full water years of monitoring.

Table 10-3 lists the storm event criteria for storm event parameters and sampling goals for the NDS Partnering project. Storm events of various sizes and antecedent conditions will be targeted.

Table 10-3. NDS Partnering Storm Event and Sampling Criteria

Criterion	Requirement
Target storm depth	A minimum of 0.15 inch of precipitation over a 24-hour period
Rainfall duration	Target storms must have a duration of at least 1 hour
Antecedent dry period	A period of at least 6 hours preceding the event with less than 0.04 inch of precipitation
Storm capture coverage	75% (for storms longer than 24 hours, 75% of first 24 hours)
End of storm	A continuous 6-hour period with less than 0.04 inch of precipitation

Table 10-4 lists the water quality parameters to be sampled and sample collection methods to be used for the NDS Partnering project.

Table 10-4. Water Quality Parameters and Sample Collection Method

Parameter	Collection method
PCBs	Composite
Total phosphorus	Composite
Total copper and zinc	Composite
TSS	Composite
Fecal coliform	Grab

Step 3: Model Flow Volumes. The 2 years of continuous monitored flow data will be used to calibrate the hydrologic models (e.g., HSPF or EPA SWMM) that the City developed to design each of the NDS facilities. The calibrated models will be used to estimate the flows managed by the NDS facilities that were not directly monitored for 2 years after construction. Volumes will be aggregated across all the facilities in each basin to generate the total flow volume managed by the NDS facilities within each basin.

Step 4: Calculate Pollutant Load Reductions. Data from Step 2 will be averaged across the two monitored facilities in each basin to generate mean influent and treated effluent concentrations, which will be used to represent concentrations for all of the NDS facilities within each respective basin. These concentrations will be multiplied by the volumes from Step 3 to generate pollutant load reduction estimates for each basin per year. Pollutant load reductions will be summed across basins to generate a total NDS project pollutant load reduction estimate for each of the 2 years monitored. The load reductions will be averaged over the 2 years to generate the average annual pollutant load removed by the project and used to evaluate performance as discussed in Section 10.5 below.

10.3 South Park WQ Facility

This section provides an overview and monitoring summary of the South Park WQ Facility project.

10.3.1 Overview

The South Park WQ facility will be a basic, active treatment system, such as a CESF system. The specific treatment technology will be selected and designed after the Integrated Plan has been approved by EPA and Ecology. The treatment facility will have built-in flow monitors; inline sensors to measure parameters such as turbidity, conductivity, and pH; and water quality sample collection ports. The South Park WQ facility will treat the stormwater but will not reduce flow volume, so inflow volume will equal outflow volume. These factors will simplify water quality monitoring and load reduction calculation.

10.3.2 Monitoring Summary

The monitoring approach for the South Park WQ facility will consist of the four steps described below.

Step 1: Monitor Flow. The total flow volume treated by the facility will be measured by built-in, in-line flow monitors. Flow measurements will be continuous over a 2-year period.

Step 2: Monitor Water Quality. Flow-proportioned composite and discrete, instantaneous grab stormwater samples will be collected on untreated stormwater influent and treated effluent. Automatic water quality samplers will be paced by in-line flow monitoring equipment to collect one flow-proportioned influent and one effluent composite sample per event. Influent and effluent grab samples will be collected once during each event monitored. Paired influent and effluent samples from six stormwater events per water year will be sampled per year for a total 12 pair samples over 2 years of monitoring.

Table 10-5 lists the storm event criteria and sampling goals for the South Park WQ facility. Storm events of various sizes and antecedent conditions will be targeted.

Table 10-5. South Park WQ Facility Storm Event and Sampling Criteria

Criterion	Requirement
Target storm rainfall amount	A minimum of 0.15 inch of precipitation over a 24-hour period
Rainfall duration	Storms must have a duration of at least 1 hour
Antecedent dry period	A period of at least 6 hours preceding the event with less than 0.04 inch of precipitation in total
Minimum storm capture coverage	75% (for storms longer than 24 hours, 75% of first 24 hours)
End of storm	A continuous 6-hour period with less than 0.04 inch of precipitation in total

Table 10-6 lists the water quality parameters to be sampled and sample collection methods to be used for the South Park facility.

Table 10-6. South Park WQ Facility Water Quality Parameters and Sample Collection Method

Parameter	Collection method
PCBs	Composite
Total phosphorus	Composite
Total copper and zinc	Composite
TSS	Composite
Fecal coliform	Grab

Step 3: Calculate Pollutant Load Reduction. Water quality concentration data from Step 2 will be averaged across the monitored storms within each water year to generate one mean influent and effluent concentration for the facility for the respective water year. These mean annual concentrations will be multiplied by the annual flow volumes from Step 1 to generate pollutant load reduction estimates for each year monitored.

The project pollutant load reduction calculated above will be averaged over the 2 years of monitoring and used to evaluate performance as discussed in Section 10.5 below.

10.4 Street Sweeping Expansion Arterials

This section provides an overview and monitoring summary of the Street Sweeping Expansion Arterials project.

10.4.1 Overview

The Street Sweeping Expansion Arterials project will augment SPU's current Street Sweeping for Water Quality (SS4WQ) program by increasing the extent of arterials swept from 83 to 85 percent, increasing sweeping frequency from every 2 weeks to weekly for some routes, and extending the sweeping season from 40 to 48 weeks per year. The project goal is to sweep an additional 10, 700 curb-miles of arterials per year, which is predicted to remove an additional 400 short dry tons (sdt) of sweepings material per year.

The City will perform post-construction monitoring for the Integrated Plan to quantify the pollutant load removed by the Street Sweeping Expansion Arterials program. The monitoring will compare the pollutant load reductions from the pre-Integrated Plan sweeping program (baseline) to the load reductions from the expanded (baseline plus Expansion Arterials project) sweeping program to estimate the load removed by the Expansion Arterials project only.

Street sweepings (solid material removed from roadways by sweepers) are collected by the sweepers into built-in hoppers on the sweeper equipment. The sweeper operators empty the hoppers into two temporary storage bins. Sweepings collected on arterials located in the northern portion of Seattle are emptied into a bin at the Haller Lake maintenance facility and sweepings collected on arterials in the southern portion of Seattle are emptied into a bin at the Charles Street facility. Bins are emptied periodically, at intervals ranging from 2 weeks to 2 months, and solids material is disposed of at a waste disposal facility.

The SS4WQ program has been tracking wet and dry sweepings load removed since mid-2011 and analyzing pollutant concentrations since December 2011. Analysis of the fine particulate matter (PM) fraction and additional pollutants on both the whole samples and fine PM fraction began in fall 2012. At least 2 full years of pollutant concentration data for the fine PM will be available before the program is expanded in 2016. The pre-Integrated Plan concentration and load data will be used as baseline data. The baseline load removal data will then be compared to load removal data collected after the Expansion Arterials program has been implemented in order to estimate the additional load reduction associated with the Expansion Arterials program. Table 10-7 presents the annual baseline load removed by the current (baseline) street sweeping program for fecal coliform, total zinc, total copper, PCBs, and TSS equivalent.

Table 10-7. Annual Baseline Load Removed by Current Street Sweeping Program

Fecal coliform bacteria (billion CFU/yr)	PCBs (g/yr)	Total phosphorus (kg/yr)	Total copper (kg/yr)	Total suspended solids equivalent (washoff load) (kg/yr)	Total zinc (kg/yr)
5,700	9	60	14	90,000	28

10.4.2 Monitoring Summary

The monitoring approach for the Street Sweeping Expansion Arterials project will consist of calculating the total annual pollutant load removed by the augmented SS4WQ program after it is expanded in 2016 and subtracting the load removed by the program before it was expanded (listed in Table 10-7) to calculate the additional load removed by the Expansion Arterials project.

Specifically, the monitoring approach will consist of the following steps: (1) measuring the curb-miles swept annually for 2 water years, (2) measuring the wet solids weight of the street sweepings collected annually for 2 water years, (3) collecting 30 solids samples per year for 2 years (for a total of 60 samples) and analyzing for chemical parameters and total solids, (4) calculating the dry weight of sweepings collected using the wet solids weight and total solids concentration, and (5) using data collected in the steps above and the existing Street Sweeping Pollutant reduction model, calculating the pollutant load removed.

Step 1: Measure Curb Miles. Curb miles swept for the Street Sweeping program are calculated by an Automated Vehicle Location (AVL) system. The AVL system reports time and distance each sweeper truck travels and is sweeping using a global positioning system on each sweeper truck and monitors connected to the sweeper brooms. These data are broken down by the system software to determine the distance and time of actions performed (e.g., miles traveled, total miles swept, miles swept in an MS4 basin, miles swept in a non-MS4 or unspecified route, vehicle speed when sweeping, etc.).

Step 2: Measure Wet Solids Weight. Wet weight of sweeping will be measured when material is disposed of at the waste disposal facility using truck scale readings.

Step 3: Collect and Analyze Solids Samples. Street sweeping samples will be collected from the two bins during periods of sweeping operations (i.e., 46 to 48 weeks per year) over a 2-year period, beginning the second year of the expansion (2017). A minimum of 30 (15 from each bin) samples per year, or 60 (30 from each bin) over the 2-year monitoring period, will be collected.

Table 10-8 lists solids parameters to be analyzed on both the whole grain solids and fine PM portion of each sweepings sample and sample collection methods to be used for the Street Sweeping Expansions Arterials project.

Table 10-8. Street Sweeping Solids Parameters and Sample Collection Method

Parameter	Collection method
PCBs	Composite
Phosphorus	Composite
Total copper and zinc	Composite
Total solids	Composite
Fecal coliform	Composite

Step 4: Calculate Dry Solids Mass. The average monthly dry solids mass of sweepings will be calculated by multiplying the average monthly wet solids mass by the corresponding monthly total solids concentration. The monthly dry solids mass will be segregated by dry and wet season and then summed to produce seasonal totals.

Step 5: Calculate Pollutant Loads Removed. The information collected in the preceding steps will be inputted into the existing Street Sweeping Pollutant reduction model (detailed in Appendix G) to calculate the total pollutant load removed by the augmented SS4WQ program over the 2 years of monitoring.

The annual baseline load for each parameter removed by the pre-Integrated Plan (baseline) Street Sweeping program (listed in Table 10-3) will be subtracted from the average annual load removed by the augmented SS4WQ program (baseline plus Expansion Arterials project) to determine the load removed by the Expansion

Arterials project only for fecal coliform, total zinc, total copper, total phosphorus, PCBs, and TSS. This pollutant load reduced by the Expansion Arterials project will be as discussed in Section 10.5 below.

10.5 Post-Construction Monitoring Reporting

The post-construction monitoring results for the three stormwater projects will be included in the CSO Reduction Program Annual Report, which will document the activities that occurred in the prior calendar year. Due to the lag time between sample collection, laboratory analysis, data delivery, data analysis, and reporting, the Annual Report will present post-construction monitoring results for the stormwater projects for the prior water year (not calendar year), which begins on October 1 and ends on September 30.

Annual pollutant load removed by each stormwater project will be presented in the annual CSO report following the end of the first water year for which data are collected for each stormwater project. However, the post-construction monitoring results will not be compared to the performance monitoring goals until monitoring has been completed for all three stormwater projects because the goals are based on the total load reductions for the three projects combined.

After all of the post-construction monitoring has been completed for the three stormwater projects, the median load reductions will be compared to the total load reduction goals listed in Table 10-1. If all of the post-construction median load reductions meet or exceed the total load reductions for all constituents listed in Table 10-1, the Integrated Plan will have clearly met the performance goals. If the post-construction monitoring results indicate that load reductions for one or more constituents were smaller than the value(s) listed in Table 10-1, the City will evaluate the cumulative load reductions for the three stormwater projects in light of the UCLs for the deferred LTCP projects. The performance goals listed in Table 10-1 are substantially higher than the corresponding UCLs for the deferred LTCP projects. Consequently, stormwater project pollutant load reductions that fall short of the goals listed in Table 10-1 could still meet the significant benefits criterion of the Consent Decree. In the event that this occurs, the City will meet with Ecology and EPA to discuss the post-construction monitoring results and the need for adaptive management actions. If additional action is deemed necessary, the City will develop a Supplemental Compliance Plan as described in Appendix C, Section D, Paragraph 2 of the Consent Decree.

CHAPTER 11

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