Technical Memorandum 970

King County 2012 CSO Control Program Review

CSO Control Alternatives Development

October 2011

King County

Department of Natural Resources and Parks
Wastewater Treatment Division

King Street Center, KSC-NR-0512
201 South Jackson Street
Seattle, WA 98104

For comments or questions, contact:
Karen Huber
King County Wastewater Treatment Division
201 S. Jackson St.
KSC-NR-0512
Seattle, WA 98104-3855
206-684-1246
Karen.Huber@kingcounty.gov

Contents

Appendices

Tables

Figures

Acronyms

AACE	Association for the Advancement of Cost Engineering
BMP	Best management practices
CEPT	Chemically enhanced primary treatment
CSO	Combined sewer overflow
DSN	Discharge serial number
EBI	Elliott Bay Interceptor
Ecology	Washington State Department of Ecology
ENR CCI	Engineering News Record Construction Cost Index
EPA	U.S. Environmental Protection Agency
GIS	Geographic information systems
gpd/sf	Gallons per day per square foot
GSI	Green stormwater infrastructure
LID	Low-impact development
MG	Million-gallon
MGD	Million gallons per day
NPDES	National Pollutant Discharge Elimination System
PLC	Programmable Logic Controller
RWSP	Regional Wastewater Service Plan
SBS	Sodium Bisulfite
SCADA	Supervisory control and data acquisition
SDOT	Seattle Department of Transportation
SPU	Seattle Public Utilities
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

Background

King County's *Combined Sewer Overflow (CSO) Control Plan*, implemented through the County's CSO Control Program, outlines measures for controlling CSO discharges to surface waters, in order to comply with federal and state water quality requirements.

The CSO Control Plan was amended in 1999 as a component of the *Regional Wastewater Services Plan* (RWSP) and is updated regularly as regulations evolve, new information becomes available, and the local region experiences new development. The next update will be prepared for submittal with the National Pollutant Discharge Elimination System permit renewal application for the County's West Point Wastewater Treatment Plant in 2013. To prepare for the next update, the CSO Control Program is undergoing a review—the *2012 CSO Control Program Review*, or "Program Review"—that will identify CSO control measures that are appropriate for the current conditions and information.

The Washington State Department of Ecology (Ecology) requires that CSO sites average no more than one untreated discharge per year. CSO sites that meet this requirement are classified as "controlled." Those that do not are called "uncontrolled" CSO sites. This technical memorandum was prepared to document the process of developing and evaluating control alternatives for King County's uncontrolled CSO sites. The next step will be to develop an implementation schedule and rate/capacity charge analysis for the recommended preferred alternatives. This technical memorandum also summarizes conditions and planned actions to optimize CSO control facilities that have already been built but for which adjustments are still needed to achieve full control.

King County Uncontrolled CSO Sites

King County's combined sewer system includes 38 CSO sites, of which 14 are currently uncontrolled, with no project underway to achieve control. In the RWSP, King County indicated that all remaining uncontrolled CSO sites would be controlled by 2030. The 14 uncontrolled CSO sites for which no control projects are currently underway discharge CSOs to Elliott Bay, the Duwamish River, the Lake Washington Ship Canal, Lake Union, and the Montlake Cut. These CSO sites were grouped into areas for evaluation, so that alternatives could be combined to provide control of all uncontrolled CSO sites in a given area:

- Ship Canal – 11th Ave NW, 3rd Ave W, University, and Montlake
  - 11th Ave NW
  - 3rd Ave W
  - University
  - Montlake
- Middle Elliott Bay Interceptor (EBI) – Hanford #2, Lander St, Kingdome, and King St
  - Hanford #2
  - Lander St

  - Kingdome
  - King St
- Middle EBI – Hanford #1
  - Hanford #1
- South EBI
  - S Michigan St
  - Brandon St
- West Duwamish – W Michigan St and Terminal 115
  - W Michigan St
  - Terminal 115
- West Duwamish – Chelan Ave
  - Chelan Ave

Alternative Evaluation Methodology

The RWSP lists CSO control alternatives for each uncontrolled CSO site. Factors that may result in changed conditions since the preparation of the RWSP were evaluated as part of this Program Review for their impact on the type, size, location, priority, or schedule of the RWSP adopted alternatives. Factors that were evaluated include regulations, CSO control performance, hydraulic modeling, CSO treatment processes, green stormwater infrastructure (GSI) opportunities, site availability, environmental and habitat priorities, receiving water quality, public opinion, and coordination with other projects. Based on the review of factors and changes, a reevaluation of alternatives, priority, and schedule was required for each uncontrolled CSO site.

Alternatives involving collaboration between King County and the City of Seattle were identified and evaluated as part of this Program Review and the City of Seattle's Long-Term Control Plan. These alternatives would contribute to control of CSOs in the combined sewer systems of King County and Seattle Public Utilities. They were incorporated into the process of selecting recommended preferred alternatives for King County's uncontrolled CSO sites.

The following methodology was used in the Program Review to update the CSO control recommendations from the RWSP for the 14 uncontrolled CSO sites:

- An initial assessment prior to the Program Review identified the CSO control approaches that are feasible for each uncontrolled CSO site.
- A set of preliminary alternatives was developed from two sources:
  - The RWSP adopted alternatives
  - New alternatives developed for the Program Review using the identified feasible CSO control approaches; these alternatives were developed based on new modeling results, changes in available siting, newly-identified potential for the use of GSI approaches, or newly-identified potential for collaboration with the City of Seattle on implementation of CSO control projects.

- A screening of the preliminary alternatives was performed, based on technical considerations, relative cost effectiveness, community and public health, environmental impacts, land use and permitting, and operation and maintenance implications. Alternatives that were not screened out moved forward as final alternatives.
- The screened preliminary alternatives, as well as alternative variations identified after the preliminary screening, were further developed into final alternatives by refining the cost, size, and location of the alternatives. A triple-bottom-line analysis of the final alternatives (evaluating environmental, social, and financial metrics) was performed to identify recommended preferred alternatives.
- Recommended preferred alternatives were carried forward into schedule development and rate/capacity charge analysis.

Recommended Preferred Alternatives

Table ES-1 presents the recommended preferred alternatives for each uncontrolled CSO site, along with estimated construction and property acquisition costs, project costs, and life-cycle costs.

Optimizing Existing Facilities

At this time, several County CSO control projects have been completed, but are still being adjusted to achieve full control. This technical memorandum summarizes conditions and planned actions to optimize these CSO control facilities.

Table ES-1. Summary of Recommended Preferred Alternatives

		Costs Allocated to King County (2010 $ millions)		
Alternative Name	Description	Construction & Property Acquisition	Project	Life-Cycle
Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake				
SC-11th Ave NW-KC-Conv	3,200 feet of 84-inch-diameter conveyance pipe	$11.7	$23.7	$22.1
SC-3rd Ave W-Collab-STOR 2	7.23-million-gallon (MG) storage tank north of Ship Canal; with SPU	$27.4	$50.3	$51.5
SC-University-Collab-STOR	5.23-MG storage tank; with SPU	$24.4	$45.2	$53.8
SC-Montlake-Collab-STOR	7.87-MG storage tank; with SPU	$52.1	$95.4	$105.5
	Subtotal	***$116***	***$215***	***$233***
Middle EBI—Hanford #2, Lander St, Kingdome, and King St				
MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications)	151-million-gallon-per-day (MGD) wet-weather treatment facility, with modifications to the EBI	$138	$271	$331
Middle EBI—Hanford #1				
MEBI-Han-Rain-BV-KC-CONV/STOR	0.34-MG storage tank and conveyance improvements to use Bayview Tunnel	$9.5	$19.2	$19.0
South EBI				
SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance)	66-MGD wet-weather treatment facility and new conveyance	$72.3	$140	$168
West Duwamish – W Michigan St and Terminal 115				
WDUW-Cons W Michigan-Term 115-KC-STOR	0.32-MG storage pipe	$7.1	$14.8	$17.0
West Duwamish – Chelan Ave				
WDUW-Chelan-KC-STOR 1	3.85-MG storage tank	$27.2	$51.7	$60.0
	Total	**$370**	**$711**	**$830**

1.0. INTRODUCTION

1.1 Background

King County's *Combined Sewer Overflow (CSO) Control Plan* was amended in 1999 as a component of the *Regional Wastewater Services Plan* (RWSP). The CSO Control Plan, implemented through the CSO Control Program, outlines measures for controlling CSO discharges to surface waters, in order to comply with federal and state water quality requirements.

The CSO Control Plan is updated regularly as regulations evolve, new information becomes available, and the local region experiences new development. The last update was in 2008, in conjunction with the renewal of the National Pollutant Discharge Elimination System (NPDES) permit for King County's West Point Wastewater Treatment Plant. Another update will be prepared for submittal with the next NPDES permit renewal application in 2013. To prepare for the next update, the CSO Control Program is undergoing a review—the *2012 CSO Control Program Review*, or "Program Review"—that will identify CSO control measures that are appropriate for the current conditions and information.

The Washington State Department of Ecology (Ecology) requires that CSO sites average no more than one untreated discharge per year (Washington Administrative Code 173-245-020). The renewed NPDES permit for the West Point Wastewater Treatment Plant, effective July 1, 2009, implemented a new interpretation of the performance standard for CSO control derived from the state regulatory requirements for "greatest reasonable reduction" as specified in WAC 173-245-022(22). The standard of "not more than one untreated discharge event per year per outfall on average" is now based on a 20-year moving average. The number of untreated discharges that occurred over each of the previous 20 years is reported for each CSO site and then averaged. This average will be used each year to assess compliance with the performance standard for CSOs identified as controlled. CSO sites that meet this requirement are classified as "controlled." Those that do not are called "uncontrolled" CSO sites. King County's combined sewer system includes 38 CSO sites, of which 14 are currently uncontrolled, with no project underway to achieve control. Under the RWSP, King County identified that all remaining uncontrolled CSO sites would be controlled by 2030.

1.2 Purpose

Technical Memorandum 970, CSO Control Alternatives Development has been prepared as one product of the 2012 CSO Control Program Review. The Program Review will identify alternative means to control CSOs (alternatives) at King County's uncontrolled CSO sites that optimize and balance environmental, social, and financial goals to meet current needs. CSO control alternatives were developed and evaluated to select a recommended preferred alternative for each uncontrolled CSO site.

The purpose of this technical memorandum is to document the alternative development and evaluation process. Based on the development and evaluation, this technical memorandum presents recommended preferred alternatives for each of the 14 uncontrolled CSO sites. The next step will be to develop an implementation schedule and rate/capacity charge analysis for the recommended preferred alternatives.

1.3 CSO Sites Covered by Program Review

The 14 uncontrolled King County CSO sites for which no control projects are currently underway discharge CSOs to Elliott Bay, the Duwamish River, the Lake Washington Ship Canal, Lake Union, and the Montlake Cut. Each CSO site has an associated CSO outfall (numbered by "Discharge Serial Number" or DSN) and a structure where overflows are diverted to the outfall from the combined sewer system. The area contributing combined sewer flow to each CSO site is referred to as a CSO basin.

For the Program Review, it was recognized that some of the uncontrolled CSO sites, because of their system connections and geographic proximity, might be addressed by projects that control more than one CSO site. These CSO sites were grouped into areas for evaluation. Table 1-1 lists the areas, the CSO sites, the DSN for each CSO site, and the name of the associated overflow diversion facility. Locations are shown on Figure 1-1.

Table 1-1. Uncontrolled CSO Sites and Facilities in King County

Area	Uncontrolled CSO Site	DSN	Overflow Diversion Facility	Receiving Water Body
Ship Canal – 11th Ave NW, 3rd Ave W, University, and Montlake	11th Ave NW	004	11th Ave NW Overflow Structure	Lake Washington Ship Canal
	3rd Ave W	008	3rd Ave W Overflow Structure	
	University	015	University Regulator Station	
	Montlake	014	Montlake Regulator Station	
Middle Elliott Bay Interceptor (EBI) – Hanford #2, Lander St, Kingdome, and King St	Hanford #2	032	Hanford St Regulator Station	Duwamish River – East Waterway
	Lander St	030	Lander St Regulator Station	Elliott Bay
	Kingdome	029	Kingdome Regulator Station	Elliott Bay
	King St	028	King St Regulator Station	Elliott Bay
Middle EBI – Hanford #1	Hanford #1	031	Hanford@Rainier, Bayview North, and Bayview South Overflow Structures	Duwamish River via Diagonal Storm Drain
South EBI	S Michigan St	039	S Michigan St Regulator Station	Duwamish River
	Brandon St	041	Brandon St Regulator Station	Duwamish River
West Duwamish – W Michigan St and Terminal 115	W Michigan St	042	W Michigan St Regulator Station	Duwamish River
	Terminal 115	038	Terminal 115 Overflow Structure	Duwamish River
West Duwamish – Chelan Ave	Chelan Ave	036	Chelan Ave Regulator Station	Duwamish River – West Waterway

King County
Department of
Natural Resources and Parks
Wastewater Treatment
Division

The information included on this map has been compiled from a variety of sources and is subject to change without notice. King County makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information. This document is not intended for use as a survey product. King County shall not be liable for any general, special, indirect, incidential, or consequential damages including, but not limited to, lost revenues or lost profits resulting from the use or misuse of the information contained on this map. Any sale of this map or information on this map is prohibited except by written permission of King County.

File Name:

Data Source:

Figure 1-1.
King County CSO Site and Program Review Areas
TM 970, CSO Control Alternatives Development

1.4 Methodology

1.4.1 Terminology

Through multiple levels of evaluation performed for the Program Review, alternatives were grouped and defined in a variety of ways. The following are definitions for the alternatives terminology used in this technical memorandum:

- **RWSP adopted alternatives** are the final recommended CSO control projects for each CSO site from the RWSP.
- **CSO control approaches** are general types of technology used for CSO control; feasible CSO control approaches were identified for each uncontrolled CSO site evaluated in this Program Review.
- **Preliminary alternatives** are all of the RWSP adopted alternatives plus new alternatives developed for this Program Review based on updated conditions since the RWSP was adopted. The new preliminary alternatives use the CSO control approaches identified as feasible for each uncontrolled CSO site.
- **Final alternatives** are all preliminary alternatives that were advanced through the initial screening. Each was further developed to define size, location, and cost.
- **Area alternatives** are combinations of site and consolidated final alternatives that provide control of all uncontrolled CSO sites in a given area. For areas consisting of only a single CSO site, each site alternative is an area alternative. For areas with multiple CSO sites, an area alternative may be a combination of site alternatives for each uncontrolled CSO site in the area, a single consolidated alternative that controls all uncontrolled CSO sites in the area, or a combination of site and consolidated alternatives that together provide control for all uncontrolled CSO sites in the area.
- **Recommended preferred alternatives** are the final alternatives identified as the best combination of CSO control projects to provide control for all uncontrolled CSO sites evaluated in this Program Review.
- Preliminary, final, and recommended preferred alternatives consist of several types of alternatives:
  - **Site alternatives** are those that would control a single CSO site.
  - **Consolidated alternatives** are those that would control multiple CSO sites.
  - **Independent alternatives** are site or consolidated alternatives that would contribute to control of CSOs in the King County combined sewer system or the Seattle Public Utilities (SPU) system only.
  - **Collaborative alternatives** are site or consolidated alternatives that would contribute to control of CSOs in the King County combined sewer system as well as the SPU system.
  - **Green Stormwater Infrastructure (GSI) alternatives** are low-impact measures, such as bioretention swales, rain gardens, roof drain disconnects, cisterns, green roof retrofits and permeable paving, implemented to reduce stormwater runoff throughout

a neighborhood or area. The Program Review evaluated the GSI approach separately from the evaluation of alternatives developed from other CSO control approaches. Where GSI is predicted to reduce the size of a CSO control facility, the facility size is not reduced in this Program Review. Future evaluations, including enhanced monitoring and modeling, will verify the benefit of GSI techniques prior to final facility sizing during development of preferred alternatives.

1.4.2 Evaluation Process

The following methodology was used in the Program Review to update the CSO control recommendations from the RWSP for the 14 uncontrolled CSO sites:

- An initial assessment prior to the Program Review identified the CSO control approaches that are feasible for each uncontrolled CSO site.
- A set of preliminary alternatives was developed from two sources:
  - The RWSP adopted alternatives
  - New alternatives developed for the Program Review using the identified feasible CSO control approaches; these alternatives were developed based on new modeling results, changes in available siting, newly-identified potential for the use of green stormwater infrastructure approaches, or newly-identified potential for collaboration with SPU on implementation of CSO control projects.
- A screening of the preliminary alternatives was performed, based on technical considerations, relative cost effectiveness, community and public health, environmental impacts, land use and permitting, and operation and maintenance implications. Alternatives that were not screened out moved forward as final alternatives.
- The screened preliminary alternatives, as well as additional alternatives identified after the preliminary screening, were further developed into final alternatives by refining the cost, size, and location of the alternative. A triple-bottom-line analysis of the final alternatives, which assesses environmental, social, and financial metrics, was performed to identify recommended preferred alternatives to control the 14 uncontrolled CSO sites.

Figure 1-2 provides a flow schematic of the methodology used to select recommended preferred alternatives.

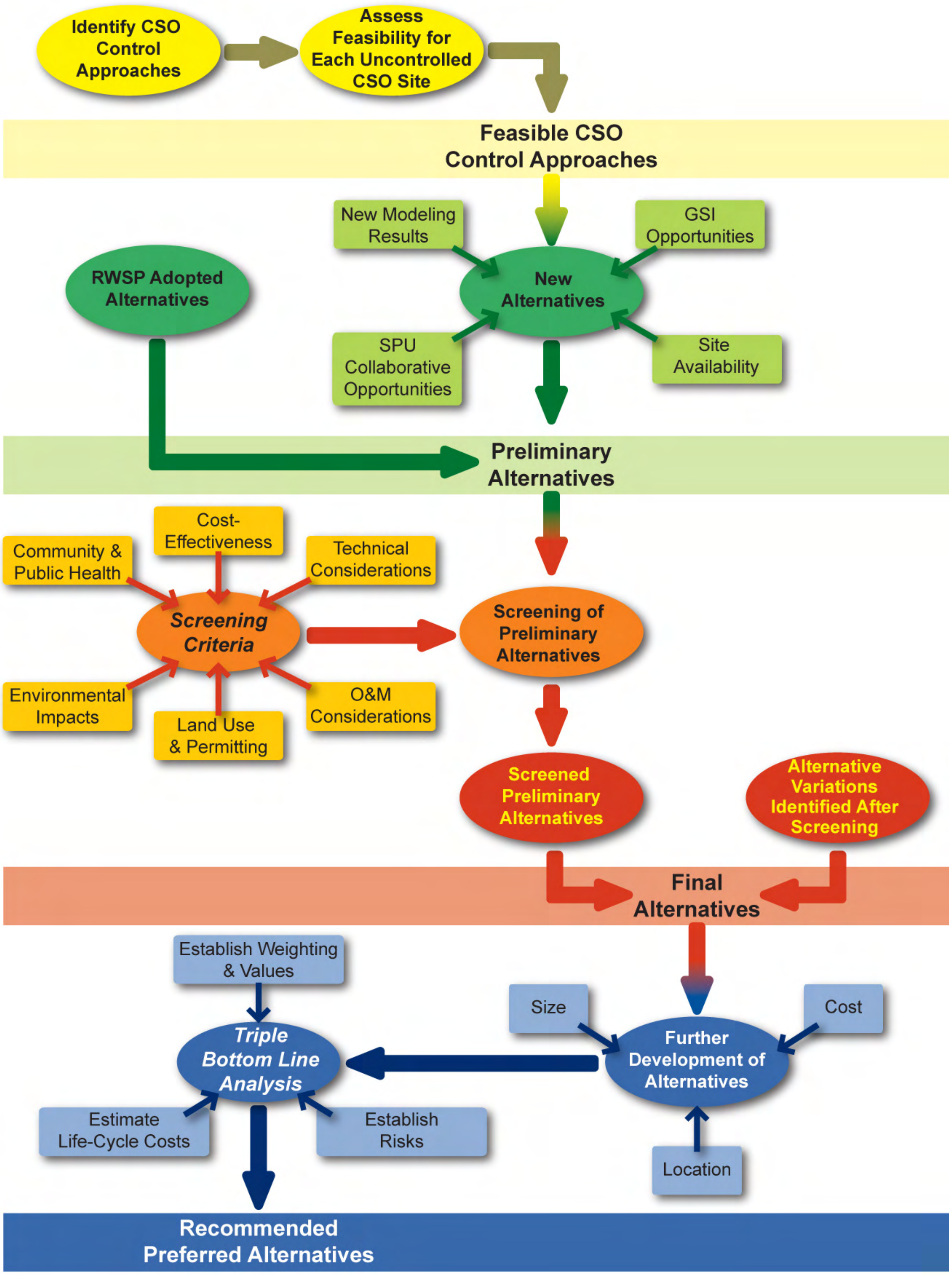

Figure 1-2. Identification and Evaluation of CSO Control Alternatives

1.5 History of Collaboration with the City of Seattle on CSO Control Planning

King County and the City of Seattle have coordinated over the years to explore CSO control projects that benefit both agencies, the environment, and the communities served. This coordination has acknowledged that the County and the City are distinct governments with different legislative bodies, responsibilities, regulatory requirements, and financial requirements.

King County serves 34 cities and sewer districts (local agencies). By contractual agreement with the local agencies, King County owns and operates the regional conveyance facilities that are downstream of local agency sewer basins that, when added together, serve a total area of 1,000 acres or more. King County conveys these local agency flows through its regional interceptor system to one of its wastewater treatment/reclamation plants. Local agencies, such as the City of Seattle, own the sewer collection and conveyance systems in the basins contributing to the regional system. Since King County's and the local agencies' conveyance systems are connected, one agency's system may impact another's system, but the systems can hydraulically function in very different ways. This is particularly true with the City of Seattle because a large part of the City's system is combined sewer, with highly variable wet-weather flows that require complex flow control facilities and operations.

King County and the City of Seattle recognize that they must work together to serve citizens and protect the region's water quality. The history of collaboration between King County and the City of Seattle, including recent efforts to collaborate on CSO control, is summarized below.

1.5.1 Collaboration Efforts between 1960 and 1994

From 1960 to 1994, Seattle's mayors and council members were voting members of the Seattle Metropolitan Council (Metro). As members of the council, they made decisions about all Metro plans and projects.

In 1979, the first local CSO control plan was published as part of the Clean Water Act Section 201 facility planning. It was published jointly by Metro, the City of Seattle, the Environmental Protection Agency, and Ecology. It assessed whole system needs and identified 30 CSO control projects. These projects were assigned to the agency owning the parts of the system involved – 9 projects to Metro and 11 projects to the City of Seattle.

Between 1979 and 1986, Metro's facility planning evolved into an integrated "Secondary/CSO Control" set of plans. After these plans were first published in 1985, the City requested that Metro evaluate a non-West Point secondary plant alternative. That, and its associated CSO control configuration, was included in a new set of facility plans published in 1986. The Secondary/CSO control plan was adopted by the Metro Council in 1986.

Between 1987 and 1988, Ecology promulgated new CSO control regulations that required both Metro and the City of Seattle to establish new CSO control plans meeting these regulations. The agencies were stakeholders and participants in each other's processes.

1.5.2 Collaboration Efforts between 1990 and 1999

During the 1990s, Metro/King County and the City of Seattle implemented several joint CSO control projects, including the following:

- In the Hanford/Lander/Bayview separation and storage project, Metro reactivated the City's abandoned Bayview Tunnel. In 1992, a memorandum of agreement was developed for Lander separated stormwater responsibilities.
- The City of Seattle allowed Metro to use its abandoned pipeline for the Carkeek flow transfer project.
- A CSO Public Notification Plan was developed between King County, the City of Seattle, and the King County-Seattle Public Health Department. The City of Seattle and King County both fund the Health Department's CSO activities.

In 1994, King County assumed responsibility for Metro's wastewater system. The City of Seattle became a member of the King County Regional Water Quality Committee, with two voting members, providing advice to the King County Council on all plans and policies governing the wastewater system, including CSO control.

From 1994 to 1999, the City participated in the following planning efforts led by King County:

- The RWSP was developed on the understanding that City of Seattle CSOs were largely controlled. The City provided input on the County's CSO control priorities and participated in many workshops and meetings for the CSO component of the plan, as well as for the whole RWSP.
- The City of Seattle was a stakeholder and participant in an advisory panel for the County's *1998 CSO Water Quality Assessment Study for the Duwamish River and Elliott Bay*.
- When the City identified CSO control needs in the Henderson area, where the County was in advanced stages of design for the Henderson/MLK CSO control project, the County committed to evaluating the Henderson system capacity after several years of operation to determine if any of the City's CSOs could be reduced through transfer of flow to the Henderson facilities. (This has occurred in the current planning process.)
- The City of Seattle participated in King County's *2000 CSO Control Plan Update* workshop, and King County participated in the consultant selection panel, team meetings, and workshops for the City's *2001 CSO Control Plan Amendment*. The City shared its on-line flow monitoring data with King County.
- The Denny Way/Lake Union CSO Control Project was a joint effort of King County and the City of Seattle to control CSOs into Lake Union and Elliott Bay. After 12 years of planning and more than 4 years of construction, the project was completed in May 2005.

1.5.3 Collaboration Efforts between 2000 and 2008

Since 2000, King County and the City of Seattle have implemented several joint CSO control projects or planning efforts, including the following:

- Joint Carkeek Flow Reduction Study
- Joint sediment remediation projects at Norfolk and Diagonal/Duwamish outfalls

- Joint (King County, City of Seattle, Boeing and Port of Seattle) response to the Superfund listing of the Duwamish Waterway, including development of the remedial investigation, feasibility study, and other required studies and documentation
- County population and flow forecasts for the entire system and the City of Seattle, including eight major workshops specifically for SPU managers and staff
- The City's Madison Valley stormwater management alternative analysis and 2006 flooding investigation
- The County's 2005/2008 CSO Control Plan Update and technologies assessments
- The City's Wastewater/Water Comprehensive Plan
- Joint Slip 4 sediment remediation.

1.5.4 Recent Collaboration Efforts, King County 2012 Program Review and City of Seattle Long-Term Control Plan

In the last three years, collaboration has increased significantly, with regular meetings and planning efforts occurring at least monthly, and with at least weekly staff communication. Both agencies have provided information relevant to each other's project areas – the City's waterfront, Diagonal, Windermere, Genesee, and Henderson projects, and the County's Puget Sound Beach projects – including geographic information system data (GIS), rain gauge data, supervisory control and data acquisition (SCADA) data, portable flow monitoring results, and pump station performance data. Each agency has allowed the other to place meters at its facilities. Significant time has been spent sharing and translating hydraulic modeling efforts and supporting the City's development of its system model. The City has shared its experience with green stormwater infrastructure to support the County's Puget Sound Beach projects. In 2011, the County incorporated the City of Seattle's real-time data into its on-line notification website to provide the public more comprehensive information.

Through all of this coordination, it became clear that a more systematic analysis of potential collaborative CSO control projects would benefit both agencies. In early 2009, the County proposed a collaborative CSO control alternatives analysis effort. A first meeting occurred to outline the process on May 27, 2009. The County proposed a process that involved the parallel development of independent and collaborative alternatives. The collaborative process would proceed in steps, with decisions to proceed occurring at key process milestones. Viable collaborative alternatives would then be compared with independent alternatives, so each agency could develop an optimal implementation plan. A decision to advance collaborative alternatives into schedule development would be made jointly by each agency's management. Recommended collaborative alternatives would be planned to integrate with each agency's independent project schedules, and those schedules would be assessed for rate impacts by each agency. If schedules meeting each agency's regulatory and financial goals were identified, then the collaborative alternatives and schedules would be incorporated into each agency's CSO control plans.

As part of King County's Program Review and the City's Long-Term Control Plan development, collaborative alternatives have been identified and evaluated. Collaborative alternatives have been incorporated into King County's process to select recommended preferred alternatives to control its uncontrolled CSO sites.

This page left blank intentionally.

2.0. RWSP ADOPTED ALTERNATIVES AND CHANGES TO ASSUMPTIONS

2.1 RWSP Adopted Alternatives

The *RWSP Executive's Preferred Plan* (King County, 1998) outlined CSO control projects for each King County CSO site that was uncontrolled at that time; these projects are referred to in this Program Review as the RWSP adopted alternatives. The adopted alternatives define the type and size of CSO control facility, potential locations, and projected year of control.

From the original list of RWSP adopted alternatives, the following CSO sites have been controlled based on hydraulic modeling and CSO monitoring or are anticipated to be controlled with projects that are currently underway:

- Ballard (DSN 003) - Project underway as part of the Ballard Siphon Replacement Project
- Magnolia (DSN 006) – Project underway
- 8th Ave S/W Marginal Way (DSN 040) – Determined to be controlled
- North Beach (DSN 048) – Project underway
- SW Alaska St (DSN 055) – Determined to be controlled
- Murray Ave (DSN 056) – Project underway
- Barton St (DSN 057) – Project underway.

The RWSP adopted alternatives for the 14 remaining uncontrolled CSO sites are as follows:

- **11th Ave NW (DSN 004)—**Includes a 2.0-million-gallon (MG) storage tank. The projected year of control is 2030. Potential sites identified in the RWSP for the storage tank are a segment of NW 45th Street or adjacent private properties, including storage yards, an abandoned warehouse, and a former petroleum company tank farm.
- **3rd Ave W (DSN 008)—**Includes a 5.5-MG storage tank. The projected year of control is 2029. The potential site identified in the RWSP is an extension of W Ewing Street, east of 3rd Avenue W and adjacent to the Ship Canal.
- **Montlake (DSN 014) and University (DSN 015)—**Includes one to six storage tanks with a total volume of 7.5 MG to control both CSO sites. The projected year of control is 2015. Six potential sites were identified:
  - The parking lot south of the Husky stadium
  - Two sites on the Montlake parking lot or intramural fields north of the Intramural Building
  - University parking area E2 at the intersection of Montlake Boulevard and NE 45th Street
  - A site beneath a possible extension of Ravenna Creek adjacent to the University Village shopping center

– A site associated with a redevelopment of the University of Washington's southwest campus plan (known as the Portage Vista) extending southwest from the new Physics Building at NE Pacific Street and 15th Avenue NE.

- **King St (DSN 028) and Kingdome (DSN 029)—**Includes conveyance of flows to a 2.2-MG storage/treatment tank near the Kingdome Regulator Station to control both CSO sites. The storage/treatment tank would consist of a rectangular primary sedimentation tank with the top of the walls 7 feet above grade, to be loaded at a surface overflow rate of 4,000 gallons per day per square foot (gpd/sf). The projected year of control is 2026. Potential sites identified in the RWSP for the storage/treatment tank were the Kingdome parking areas that existed at that time on the north or south side of S Royal Brougham Way or beneath what was at the time of the RWSP a potential new stadium in the vicinity of the Kingdome.
- **Lander St (DSN 030)—**Includes a 1.5-MG storage/treatment tank near the Hanford St Regulator Station. The storage/treatment tank would consist of a rectangular primary sedimentation tank with the top of the walls 7 feet above grade, to be loaded at a surface overflow rate of 4,000 gpd/sf. The projected year of control for the Lander St Regulator Station is 2019. The potential site identified in the RWSP is industrial property at the corner of Occidental Avenue S and Lander Street. It was anticipated that this would be consolidated with the Hanford #2 facility.
- **Hanford #1 (DSN 031)—**Includes a 0.6-MG storage tank. The projected year of control for the Hanford@Rainier Overflow Structure is 2026. Potential sites identified in the RWSP include a ball field adjacent to the intersection of Rainier Avenue S and S Winthrop Street or pipe storage in Rainier Avenue from S Hanford Street to S Bayview Street.
- **Hanford #2 (DSN 032)—**Includes a 3.3-MG storage/treatment tank. The storage/treatment tank would consist of a rectangular primary sedimentation tank with the top of the walls 7 feet above grade, to be loaded at a surface overflow rate of 4,000 gpd/sf. The projected year of control is 2017. The potential site identified in the RWSP is industrial property at the corner of Occidental Avenue S and Lander Street. It was anticipated that this would be consolidated with the Lander facility.
- **Chelan Ave (DSN 036)—**Includes a 4.0-MG storage facility (two 90-foot-diameter caissons that are 70 feet deep). This storage size assumes there is no available capacity in the West Seattle Tunnel. The projected year of control is 2024. The potential site identified in the RWSP is adjacent to the West Seattle Pump Station. Flows from the Chelan Ave Regulator Station would be conveyed to the existing Harbor CSO Pipeline via an abandoned 72-inch-diameter storm drain and a short section of 54-inch-diameter pipe.
- **Terminal 115 (DSN 038)—**Includes a 0.5-MG storage tank. The projected year of control is 2027. Potential sites identified in the RWSP are an industrial facility parking lot east of W Marginal Way S or the site of an old building on the east side of W Marginal Way S.
- **S Michigan St (DSN 039)—**Includes a 2.2-MG storage/treatment tank. The storage/treatment tank would consist of a rectangular primary sedimentation tank with the

top of the walls 7 feet above grade, to be loaded at a surface overflow rate of 4,000 gpd/sf. The projected year of control is 2022. The potential site identified in the RWSP is a private property north of S Michigan Street and east of 5th Avenue S.

- **Brandon St (DSN 041)—**Includes a 0.8-MG storage/treatment tank. The storage/ treatment tank would consist of a rectangular primary sedimentation tank with the top of the walls 7 feet above grade, to be loaded at a surface overflow rate of 4,000 gpd/sf. The projected year of control is 2022. The potential site identified in the RWSP is a private property south of S Brandon Street and west of 1st Avenue S.
- **W Michigan St (DSN 042)—**Includes a conveyance upgrade. The projected year of control is 2027. The conveyance upgrade includes decommissioning the existing 24-inch-diameter outfall gate and upgrading the diversion pipe that routes flows to the West Duwamish Interceptor (Section 2) from 10 inches to 30 inches in diameter. The upgrade also includes constructing a new junction chamber upstream of the W Michigan St Regulator Station and rebuilding the existing diversion manhole. These improvements would transfer the flow for control at the Terminal 115 facility.

2.2 Potential Changes Requiring Reevaluation of CSO Control Alternatives

Changes in conditions since 1998 may impact the type, size, or location of the CSO control facility, the priority, or the schedule for the RWSP adopted alternatives for the remaining 14 uncontrolled CSO sites. These changes are described in this section and in Appendix A.1. The following changes that could impact alternatives were reviewed for this Program Review:

- **Regulations—**Do regulatory changes require a change in control target?
- **CSO Control Performance—**Has the performance of existing CSO controls indicated a need for improvements of future facilities?
- **Size of Facility Based on Hydraulic Modeling—**Has the size of CSO control facility changed significantly (greater than 10 percent) based on hydraulic modeling?
- **Type of Facility Based on Hydraulic Modeling—**Has the type of CSO control facility (e.g., storage, treatment, etc.) changed based on new model control volume needs?
- **CSO Treatment Process—**Has the CSO treatment process changed based on review?
  - The latest information on CSO treatment processes has been reviewed, design and operations issues associated with CSO treatment processes have been defined, and two CSO treatment processes are recommended for alternatives development in the Program Review (see *Technical Memorandum 700, Treatment Technology Selection*).
- **Green Stormwater Infrastructure Opportunities—**Have green stormwater infrastructure opportunities been identified in the CSO basin? Can these reduce the size of CSO control facilities needed for the basin?
  - Green stormwater infrastructure opportunities have been evaluated as part of the Program Review as described in *Technical Memorandum 800, Green Stormwater Infrastructure Feasibility Evaluation*, which is included in Appendix C.

- **Site Availability—**Are the sites proposed in the RWSP unavailable or impractical? Have any new sites become available?
- **Environmental and Habitat Priorities—**Have environmental factors (climate change, habitat restoration projects, and human health considerations) changed CSO control priority or schedule for the CSO basin?
  - The RWSP identified project priorities based on protecting public health, endangered species, and the environment. As a result, CSO control projects were prioritized and scheduled in the following order from first to last: the Puget Sound Beach projects, East Ship Canal projects, Duwamish River projects, and West Ship Canal projects.
  - The Program Review included a review of environmental science and developments since the RWSP and any habitat improvement projects being considered near CSO sites. The review included existing studies by King County and other entities covering a variety of subjects related to ecological and human health in the Puget Sound region, including sediment quality, water quality, threatened and endangered species, climate change, and habitat improvement. Findings and recommendations of this review are documented in *Technical Memorandum 540, Environmental and Habitat Priorities*. These were considered in reviewing CSO control project prioritization, control targets, and technology improvements.
- **Receiving Water Quality—**Are there any changes in the water quality of the receiving water body?
  - Receiving water quality is addressed in the environmental review that is documented in *Technical Memorandum 540, Environmental and Habitat Priorities*.
- **Public Opinion—**Has public opinion changed in the area?
  - Public involvement activities for the Program Review are ongoing. The assessment of public opinion related to the King County CSO Control Program is not summarized in this technical memorandum but will be discussed in the future summary of technical memorandums for the 2012 CSO Control Program Review.
- **Coordination with King County or Other Agency Projects—**Have opportunities for coordination with other King County projects or other agency projects (e.g., SPU control needs) been identified?

Based on the review of changes, a reevaluation of alternatives, priority, and schedule is required for each uncontrolled CSO site. The RWSP Change Matrix in Appendix A.1 identifies which changes triggered the need for a reevaluation for each uncontrolled CSO site. The matrix also includes a brief description for each site of the RWSP adopted alternative, the RWSP projected year of control, the RWSP CSO control volume, the RWSP CSO peak flow rate, and updated CSO control volume and CSO peak flow rate from recent hydraulic modeling, which is described further in Section 3.0.

3.0. HYDRAULIC MODELING UPDATE

3.1 Overview of Hydraulic Modeling

King County uses flow monitors and a supervisory control and data acquisition (SCADA) system to continuously monitor the frequency and volume of CSO events at locations in the wastewater system where flow control occurs, such as at regulator stations or pump stations. Monitoring consists of directly measuring overflows with flow meters or measuring the depth or flow level in a pipe with a known geometry and then using the data to calculate flow values. Portable monitors, which must be manually downloaded at set time intervals, are used at a few other locations. Monitoring data are used to determine compliance with Ecology regulations.

The King County Wastewater Treatment Division uses the monitoring data and other information, such as rainfall patterns, to predict system behavior and to plan for future CSO control facilities. A computer model uses the data to estimate the frequency and volume of overflows that would occur in response to various rainfall events. The model is continually updated and refined with updated software and as more monitoring data becomes available. Modeled flow responses are compared to actual rainfall and flow monitoring data, and the model is calibrated (adjusted) to further refine model predictions.

For the RWSP, the types and sizes of CSO control projects were determined using a storm scenario (“design storm”) to predict average CSO frequencies and volumes. The design storm represented a storm of a specified volume, duration, and intensity that occurs once per year on average. King County currently uses a “continuous simulation model” that is based on historical long-term rainfall patterns. The continuous simulation model more realistically simulates rainfall variability than previous “event-based” models and provides better long-term predictions of combined sewer overflows.

See Appendix B.1 for details related to the models used for King County CSO control planning.

3.2 October 2010 Modeling Run and Results

King County completed a 32-year continuous-simulation model run of its combined sewer system for the Program Review in October 2010. The work associated with the Program Review and October 2010 model run is described in Appendix B.1 and summarized below.

The work associated with the October 2010 model run included recalibration of selected basins and associated pipe systems using DHI MOUSE/Mike Urban. This recalibration was performed in some areas where King County has large CSOs to control. In addition, SPU has calibrated basin/pipe models in areas where the City has CSO concerns, which sometimes overlap areas where the County has CSOs. SPU has been moving from the Infoworks model to the EPA SWMM model for its work.

Basins were recalibrated based on flow data from in-station meters and portable flow meters provided by the County and SPU.

The County method for recalibrating basins consisted of building up a basin and pipe model, providing a dry-weather flow pattern based on dry-weather meter data, and then using a calibration tool called PEST (5th edition). PEST, a model-independent parameter estimation computer optimization code, was used to change selected basin parameters until model output was as close as possible to the meter data for selected storms.

The County models were run using City of Seattle rain gauge information and applying County quality assurance/quality control procedures. The City models utilized similar data, but applied City processing procedures. This rain data was available and formed the 32-year continuous-simulation model period from January 1, 1978 to January 1, 2010. CSO statistics were then generated for that period.

The October 2010 32-year continuous-simulation model run provided the following:

- **CSO Control Volume—**Overflow volume with 1-year recurrence frequency. CSO Control Volume is used to size storage facilities, so that CSO sites average no more than one untreated discharge per year.
- **CSO Peak Flow Rate—**Overflow rate with 1-year recurrence frequency. CSO Peak Flow Rate is used to size wet-weather treatment facilities and conveyance facilities, so that CSO sites average no more than one untreated discharge per year.
- **Maximum Peak Overflow Rate—**Maximum peak overflow rate of events less than and equal to 1-year recurrence frequency by volume. Maximum Peak Overflow Rate is used to size conveyance to storage facilities, so that wet-weather flows can be conveyed to storage facilities, and CSO sites average no more than one untreated discharge per year.

These values are summarized in Table 3-1 for each uncontrolled CSO site.

Table 3-1. Key Results from October 2010 Modeling Run

Uncontrolled CSO Site	CSO Control Volume (MG)	CSO Peak Flow Rate (MGD)[a]	Maximum Peak Overflow Rate (MGD)
11th Ave NW (DSN 004)			
Existing Conveyance	1.85	32.2	N/A
Increased Conveyance to Ballard Siphon[b]	0.00	0.3	0.3
3rd Ave W (DSN 008)	4.18	29.3	61.3
Montlake (DSN 014)	6.6	93.5	148.5
University (DSN 015)	2.94	74.9	94.7
King St (DSN 028)	2.63	29.6	56.0
Kingdome (DSN 029)	34.22	87.0	227.4
Lander St (DSN 030)	17.69	47.9	324.7
Hanford #1 (DSN 031)			
Hanford@Rainier Overflow Structure	1.02	17.8	31.0
Bayview North Overflow Structure	0.77	28.9	55.5
Bayview South Overflow Structure	0.0	0.0	0.0
Hanford #2 (DSN 032)	43.78	94.9	188.0
Chelan Ave (DSN 036)	3.85	25.7	38.4
Terminal 115 (DSN 038)	0.05	3.8	4.6

Table 3-1. Key Results from October 2010 Modeling Run

Uncontrolled CSO Site	CSO Control Volume (MG)	CSO Peak Flow Rate (MGD)[a]	Maximum Peak Overflow Rate (MGD)
S Michigan St (DSN 039)	18.6	66.1	161.4
Brandon St (DSN 041)	6.52	35.2	106.5
W Michigan St (DSN 042)	0.27	3.0	3.6

a. MGD = million gallons/day

b. A scenario with increased conveyance to the Ballard Siphon was modeled for the 11th Ave NW site to assess whether conveyance improvement alone could control this site; the work was performed as part of the screening of preliminary alternatives described in Section 5.3.

3.3 Site-Specific Modeling Evaluations

Additional modeling evaluations were completed for the Program Review to refine alternatives for specific CSO sites. The goals of these evaluations were to maximize the use of existing facilities and minimize the construction and operation of new facilities. Summaries of the site-specific modeling evaluations are provided in the following sections.

3.3.1 Optimization of Duwamish CSO Control

Under the RWSP adopted alternatives, most CSO sites in the Middle and South EBI areas would be controlled by building wet-weather treatment facilities. To avoid construction of many such facilities that go unused most of the year, and to minimize impacts on businesses and community in these areas east of the Duwamish River, the County evaluated three alternatives that would allow multiple CSO sites to be controlled with construction of consolidated treatment facilities. The following sections describe the East Duwamish wet-weather treatment facility consolidation evaluations.

Upstream Diversions to Treatment at Pump Stations

Modeling evaluations were completed to determine if upstream diversions to a wet-weather treatment facility at the Duwamish or East Marginal Pump Station (see Figure 1-1) could reduce downstream CSOs. The following evaluations were performed:

- Diversion at the Duwamish Pump Station to a wet-weather treatment facility to provide downstream system capacity and reduce the size of or eliminate the proposed wet-weather treatment facilities at the Hanford #2 and Lander St CSO sites
- Diversion at the Duwamish Pump Station to a wet-weather treatment facility to provide downstream system capacity and reduce the size of or eliminate the proposed CSO control facilities at the Hanford #2, Lander St, Kingdome, and King St CSO sites
- Diversion at the East Marginal Pump Station to a wet-weather treatment facility to provide downstream system capacity and reduce the size of or eliminate the proposed wet-weather treatment facilities at the S Michigan St and Brandon St CSO sites.

The findings of the evaluations indicated that it is possible to divert flows from the two pump stations and reduce downstream CSOs, reducing the required sizes of the proposed CSO control facilities at the downstream CSO sites but not eliminating those facilities. Because these diversions did not eliminate facilities but increased the number of required facilities, flow diversions at the pump stations were not incorporated into the alternatives developed and evaluated for the Program Review.

See Appendix B.2 for the memorandum that discusses the methodology, limitations, results, and conclusions of these evaluations in detail.

Upstream Diversions to Treatment along the Elliott Bay Interceptor

Modeling evaluations were completed to determine if upstream diversions to a wet-weather treatment facility along the Elliott Bay Interceptor could reduce or eliminate downstream CSO control facilities. The following evaluations were performed:

- Diversion of flow out of the Elliott Bay Interceptor to a wet-weather treatment facility at the S Michigan St Regulator Station to reduce the size of or eliminate the proposed wet-weather treatment facility at the Brandon St CSO site
- Diversion of flow out of the Elliott Bay Interceptor to a wet-weather treatment facility at the Hanford St Regulator Station to reduce the size of or eliminate the proposed wet-weather treatment facility at the Lander St CSO site
- Diversion of flow out of the Elliott Bay Interceptor to a wet-weather treatment facility at the Hanford St Regulator Station to reduce the size of or eliminate the proposed CSO control facilities at the Lander St, Kingdome, and King St CSO sites
- Diversion of flow out of the Elliott Bay Interceptor to a wet-weather treatment facility at the Lander St Regulator Station to reduce the size of or eliminate the proposed CSO control facilities at the Kingdome and King St CSO sites
- Diversion of flow out of the Elliott Bay Interceptor to a wet-weather treatment facility at the Kingdome Regulator Station to reduce the size of or eliminate the proposed CSO control facility at the King St CSO site.

The evaluations indicated that there was insufficient upstream flow for diversion to eliminate the need for downstream CSO control facilities. The number of CSO control facilities would increase rather than decrease.

See Appendix B.3 for the memorandum that discusses the methodology, limitations, results, and conclusions of these evaluations in detail.

Upstream Diversions to Treatment and Backflowing the Elliott Bay Interceptor from Downstream CSO Sites

The evaluation of upstream diversions along the Elliott Bay Interceptor at regulator stations indicated that it may be possible to install gates in the Elliott Bay Interceptor to cause some flows from the downstream basins to backflow upstream, where they could be diverted to wet-weather treatment facilities. Backflowing the Elliott Bay Interceptor could result in cost savings by avoiding construction of additional conveyance facilities to a consolidated wet-weather treatment facility and might reduce construction impacts in communities along the Elliott Bay Interceptor. An evaluation was performed to determine if this approach could control downstream CSOs. It was assumed that a consolidated wet-weather treatment facility would be located at the CSO sites with the highest CSO Peak Flow Rates:

- Hanford St Regulator Station (to control Hanford #2, Lander St, Kingdome, and King St CSOs)
- S Michigan St Regulator Station (to control S Michigan St CSOs and Brandon St CSOs).

Gates would be installed in the Elliott Bay Interceptor just downstream of the Kingdome Regulator Station and Brandon St Regulator Station to allow flows to be routed upstream or downstream along the Elliott Bay Interceptor. The following evaluations were performed:

- Wet-Weather Treatment Facility at Hanford St Regulator Station:
  - Diversion of flows from the Hanford St Regulator Station to the wet-weather treatment facility
  - Backflowing of flows from the Kingdome and Lander St CSO sites via the Elliott Bay Interceptor upstream to the Hanford St CSO site, where they would be diverted to the wet-weather treatment facility.
- Wet-Weather Treatment Facility at S Michigan St Regulator Station:
  - Diversion of flows from the S Michigan St Regulator Station to the wet-weather treatment facility
  - Backflowing of flows from the Brandon St CSO site via the Elliott Bay Interceptor upstream to the S Michigan St CSO site, where they would be diverted to the wet-weather treatment facility.

The evaluation indicated that it may be possible to consolidate to two wet-weather treatment facilities along the East Duwamish using this approach. It was also determined that peak flows did not arrive at CSO control facilities at the same time. This time lag resulted in facility sizes smaller and less costly than the sum of individual facilities. The findings of these evaluations were incorporated into the alternatives development and evaluation process described later in this technical memorandum; see Section 6.3.2 and Section 6.3.4.

See Appendix B.4 for the memorandum that was prepared that discusses the methodology, limitations, results, and conclusions of these evaluations in detail.

3.3.2 Controlling Hanford #1 and Bayview North CSOs

Modeling performed in June 2010 suggested that the Bayview North Overflow Structure is not controlled; follow-up field inspections confirmed that it is not controlled. Neither modeling nor field inspections indicated that overflows occur at the Bayview South Overflow Structure. The Bayview North Overflow Structure and Hanford@Rainier Overflow Structure overflow to the Diagonal storm drain for eventual discharge to the Duwamish River at the location designated as Hanford #1. Because previous modeling indicated that the Bayview North Overflow Structure was controlled, there has been no separate project identified for this CSO site. It was assumed that more detailed evaluations would be done as part of the Hanford@Rainier CSO control project. With this new information, new alternative development and green stormwater infrastructure evaluations were performed to determine possible approaches to control the Bayview North and Hanford@Rainier CSOs.

The findings of the analyses indicate that capacity of the Bayview Tunnel is not fully utilized during wet-weather events. Thus, it appears possible to convey CSOs from the Bayview North

Overflow Structure to the Bayview Tunnel for treatment at the future treatment facilities selected for Hanford #2 and Lander. Diverting flows from the Bayview North Overflow Structure to the Bayview Tunnel also would reduce the CSO Control Volume for the Hanford@Rainier Overflow Structure, from approximately 1.02 MG to 0.34 MG. The findings of these analyses were incorporated into the alternatives development and evaluation process described later in this technical memorandum (see Section 6.3.3).

See Appendix B.5 for details about the planning work completed to date as well as the future work anticipated to refine this alternative.

3.3.3 Diverting Chelan Ave CSOs to Alki Treatment Facility

To optimize the use of existing facilities, modeling evaluations were performed to determine how Chelan Ave CSOs could be diverted to the Alki Treatment Facility. The alternative that was evaluated included diverting Chelan Ave CSO site flows from the Delridge Trunk and routing them to the Harbor Ave Regulator Station and Harbor CSO Pipeline. From there, Chelan Ave CSOs would be routed to the Alki Treatment Facility for treatment via the West Seattle Tunnel (see Figure 1-1).

The evaluation identified major new facilities, conveyance, and upgrades required to divert these flows to the Alki Treatment Facility. However, confirmation that the diversion location included in the evaluation would fully control Chelan Ave CSOs would be required. The findings of these analyses were incorporated into the alternatives development and evaluation process described later in this technical memorandum (see Section 6.3.6).

See Appendix B.6 for the memorandum that discusses the details about the evaluation and the major new facilities, conveyance, and upgrades required.

4.0. IDENTIFY APPROPRIATE CSO CONTROL APPROACHES

A broad range of CSO control approaches was identified for initial consideration in this Program Review. Each was assessed for its feasibility as a control measure for King County's uncontrolled CSO sites. The approaches selected for consideration in alternatives developed for this Program Review are summarized in Table 4-1 and described in the following sections.

4.1 Sewer Separation

Sewer separation consists of diverting stormwater flows from the existing combined sewer system to a storm drain system, leaving sanitary flows in a separate system. One way to do this is to convert the combined sewer system to a storm drain system and construct a new sewer system for the separated sanitary flows. In highly urbanized areas, sewer separation is disruptive to vehicular and pedestrian traffic because most existing combined sewers are located below urban streets. The construction of a new sewer system parallel to the existing combined sewer system within urban street corridors is further complicated by the number of other utilities generally located beneath these streets.

Sewer separation provides the ability to treat sanitary sewage at a treatment plant while stormwater continues to discharge to surface waters. As such, it provides significant pollutant removal from the CSO discharge. Sewer separation does not, however, eliminate the contamination that is associated with stormwater, such as oil, grease, floatables, heavy metals, and organics, so additional management of the stormwater is required after it is separated out. The following assumptions for sewer separation were made for this Program Review:

- Treatment for stormwater to meet water quality standards for the receiving water body must be provided.
- Separation could be feasible for CSO sites where a majority of the combined sewer flow is from stormwater or where there are few connections.

4.2 Green Stormwater Infrastructure

Green stormwater infrastructure (GSI) refers to a relatively new concept covering a range of small-scale measures to reduce runoff throughout a neighborhood or area. Typical GSI techniques are low-impact measures such as bioretention swales, rain gardens, roof drain disconnects, cisterns, green roof retrofits, and permeable paving implemented to achieve one or more of the following:

- Infiltration of runoff to groundwater
- Distributed small-scale storage of runoff
- Evaporation of runoff after a storm
- Beneficial reuse of detained water rather than discharge to a sewer system.

Local soil and groundwater conditions must be considered when evaluating the use of GSI techniques for reducing stormwater runoff. Many GSI techniques may not be appropriate in areas with impermeable soils and/or high groundwater conditions. GSI techniques by themselves generally are not enough to eliminate CSOs, but by reducing the volume of runoff close to the sources, they can help reduce the size of more expensive control measures downstream.

Pilot and full-scale GSI projects have been successfully implemented in Seattle, and Seattle Public Utilities (SPU) promotes residential GSI practices through its “Residential RainWise Program.” The RainWise program provides educational, technical, and financial assistance to encourage residential customers to take steps to reduce the volume of stormwater running off from their properties. It encourages the private property use of rain gardens, cisterns, permeable pavement, green roofs, tree planting, and roof drain disconnection. King County will partner with SPU in Rainwise for basins upstream of County uncontrolled CSO sites.

For this Program Review, all basins were evaluated for potential GSI application. GSI techniques are considered for CSO basins with medium to high potential for GSI opportunities.

The Program Review evaluates the GSI approach separately from the evaluation of alternatives developed from other CSO control approaches. Where GSI is predicted to reduce the size of the CSO control facility, it will go forward for further evaluation ahead of projects, but the facility sizes are not reduced in this Program Review. Future evaluations, including enhanced monitoring and modeling, will verify the benefit of GSI techniques prior to final facility sizing in preferred alternative development. Additional information on the GSI evaluation is included in *Technical Memorandum 800, Green Stormwater Infrastructure Feasibility Evaluation*, which is included in Appendix C.

4.3 Increased Conveyance

Methods for increasing sewer capacity to reduce CSOs include collection/conveyance system controls that can affect combined sewer flows after runoff has entered the system. Excess system flows can be transferred via a new pipe connecting to the existing downstream conveyance system that has available capacity. The potential impact on downstream system elements must be considered since it could require new or larger facilities downstream.

For this Program Review, increased conveyance is considered for CSO sites where flows can be routed, and capacity within the existing downstream conveyance system is available based on historical monitoring or hydraulic modeling.

4.4 Offline Storage Tanks, Pipes, or Tunnels

Offline storage facilities are tanks, pipes, or tunnels offline from the combined sewer system that provide detention to reduce the peak flows to the conveyance system. The stored volume is then released after flows subside to the point when conveyance or treatment capacity is available. Offline storage facilities fill only when a specific flow elevation is exceeded in the combined sewer system, and empty when sufficient conveyance capacity becomes available in the downstream system. The preferred and most effective storage location is near the downstream end of a basin adjacent to the diversion location (a regulator station in most cases). Where large CSO storage volumes are required, two smaller storage tanks or twin parallel storage pipes can be used to minimize impacts outside of the right-of-way. Alternatives with a single storage facility are referred to as centralized storage; alternatives with more than one facility are referred to as distributed storage. The following assumptions for offline storage facilities are used in this Program Review:

- Only centralized storage was evaluated because it provides fewer facilities to operate and maintain. Distributed storage may be considered instead if there are siting constraints but would need to be further evaluated during preferred alternative development.
- Three types of offline storage facilities were considered:
  - Storage tanks
  - Storage pipes
  - Storage tunnels.
- Storage was considered feasible for CSO sites where a storage facility could drain to the downstream combined sewer system within 12 to 24 hours after the peak flow event (in time for the next major wet-weather event). This is largely dependent on where the facility would be located in the system and if the West Point Wastewater Treatment Plant would have sufficient capacity to allow the facility to drain in time for the next major wet-weather event.

In-line storage (large-diameter replacement or parallel relief sewers) was not considered for the Program Review. In-line storage can be less expensive and can provide effective use of existing facilities. However, hydraulic grade line elevations (to avoid flooding) and minimum flow velocities need to be evaluated for in-line storage. In-line storage could be considered and evaluated during preferred alternative development.

4.5 Wet-Weather Treatment

A goal of wet-weather treatment is to discharge while meeting water quality standards at the edge of applicable mixing zones. A wet-weather treatment facility must at least provide equivalent to primary treatment and disinfection. A combination of treatment processes may be used to achieve required levels of treatment. High-rate mechanical processes can be used to provide treatment at rates much higher than can be achieved with conventional primary treatment. Such facilities generally are sited at the shoreline near the outfall.

This option requires ongoing sampling and analysis to demonstrate adequate pollutant removal for regulatory compliance: removal of settleable solids and floatables and inactivation of microorganisms. The following assumptions for wet-weather treatment facilities are used in this Program Review:

- Considered for CSO sites where storage is not feasible due to the large size needed for the volume to be controlled or capacity constraints in the downstream combined sewer system after a wet-weather event. The latter may be dependent on where the facility would be located in the system, the number and volume of downstream facilities that must drain first, and if the West Point Wastewater Treatment Plant would have sufficient capacity to allow the facility to drain to the downstream combined sewer system in 12 or 24 hours (in time for the next major wet-weather event).
- Assumed not cost-effective in CSO sites where increased conveyance or storage is feasible.

- Assumed that all alternatives providing wet-weather treatment will also include equalization basins to reduce the CSO Peak Flow Rate that the treatment facility must be designed to accommodate and to smooth out the flows.

Table 4-1. Feasibility Assessment for CSO Control Approaches

Description	Advantages	Disadvantages	CSO Sites Feasible
Sewer Separation			
Reroute stormwater running off streets, parking lots, and roofs from the combined sewer system to an existing or newly constructed separated stormwater system.	Reduces the frequency or magnitude of CSO events. Permanently removes stormwater from the combined sewer system. Low operation and maintenance requirements in comparison to other CSO control approaches. Provides steadier flow to treatment plant. Separation and stormwater conveyance can be combined with other road improvements projects.	Does not eliminate contamination associated with separate stormwater discharges (oil, grease, floatables, heavy metals, and organics). Requires treatment for stormwater discharges that impact water quality in a receiving water body. May require new stormwater collection and conveyance facilities in already crowded or restricted utility corridors.	Brandon St
Green Stormwater Infrastructure			
Reduce runoff through infiltration, small-scale detention, evaporation, or beneficial reuse.	Can assist in reducing the size of high-cost downstream control measures. Can be effective in small areas or neighborhoods if the soil and groundwater conditions are suitable. Can provide a neighborhood amenity.	Relatively new concept in CSO control. Not generally effective for CSO control except in combination with other measures. Not effective in areas with impermeable soils and/or high groundwater conditions. May reduce parking in neighborhood.	All except King St, Kingdome, Lander St, Hanford #2
Increased Conveyance			
Transfer excess system flows from a basin with limited capacity to a downstream conveyance system with available capacity via a new line or upsizing an existing line.	Reduces CSOs by transferring flows to a downstream conveyance system or facility with available capacity. May maximize use of existing facilities. May result in fewer facilities requiring operations and maintenance.	Potential impact on downstream system elements must be considered. Can require costly new conveyance pipes in already restricted utility corridors. Moves impacts from one neighborhood to another. May have environmental justice implications.	11th Ave NW, Hanford #1

Table 4-1. Feasibility Assessment for CSO Control Approaches

Description	Advantages	Disadvantages	CSO Sites Feasible
Offline Storage			
Tanks, pipes, or tunnels offline from the combined sewer system that fill when a specific elevation is exceeded in the combined sewer system and empty when down-stream conveyance capacity becomes available.	Provides detention to reduce the peak flow that downstream pipes and pump stations must convey during wet-weather events. Below-ground storage facility reduces visual impact. Allows for capture of settleable solids and floatables.	Land area requirement limits siting options in urban areas. Property acquisition and permitting / cost and time requirements. Larger pipelines to convey large volumes to and from the storage facility require deeper and wider excavation areas. Geotechnical considerations, including avoiding steep slopes, unstable areas, and dewatering during construction. Odor control requirements. Maintenance of mechanical equipment. Limited by the downstream capacity available to receive flows from draining the storage facility after a wet-weather event.	**Tank:** 11th Ave NW, 3rd Ave W, University, Montlake, Chelan Ave, Hanford #1 **Pipe:** W Michigan St, Terminal 115 **Tunnel:** 11th Ave NW, 3rd Ave W, University, Montlake
Wet-Weather Treatment			
Provide treatment for combined sewer flows prior to discharge.	Removes flow from the combined sewer system. Consolidates operation and maintenance at a single site. Can be designed to treat a wide range of flow rates from different size wet-weather events. Capable of treating back-to-back wet-weather events. Continues to provide treatment after a storage tank (sized for 1-year recurrence frequency by volume) would be full, reducing the one untreated discharge per year.	Requires ongoing sampling and analysis to demonstrate adequate pollutant removal for regulatory compliance. Land area requirement limits siting options in urban areas. Challenging staffing to manage intermittent operation. Operations may not be considered appropriate for residential areas. Certified treatment plant operators required. Public impacts (odor, noise, traffic, visual aesthetics). Permitting process, including environmental review. High operation and maintenance costs for water quality monitoring and operating plant. Challenges in maintaining a seasonally-used treatment system.	Kingdome, Lander St, Hanford #2, Brandon St, S Michigan St

5.0. PRELIMINARY ALTERNATIVE DEVELOPMENT AND INITIAL SCREENING

5.1 Identification of Preliminary Alternatives

Preliminary alternatives for this Program Review were developed from two sources:

- The RWSP adopted alternatives for the 14 uncontrolled CSO sites.
- Updated and new alternatives based on information or circumstances that have changed since the RWSP alternatives were adopted; these alternatives use the feasible CSO control approaches identified in Section 4.0. The primary drivers are as follows:
  - Updated hydraulic modeling results—Updated hydraulic modeling provides the most current design criteria for selecting the best type of CSO control approaches as well as for sizing the selected approach. Significant sizing changes may warrant consideration of different control approaches.
  - Consolidation of King County projects—The Program Review considers how CSO control approaches for each uncontrolled CSO site could realize cost or performance benefits by being combined with control approaches for another CSO site or with some other planned King County project.
  - Collaboration with SPU—SPU is also actively involved in a CSO control program, and this Program Review identifies opportunities for collaborative projects that address the CSO control needs of both King County and SPU, are more cost-effective, provide a better environmental outcome, or minimize neighborhood impacts.

Categories of alternatives are described in Section 1.4.1. The following sections provide additional information on consolidated and collaborative alternatives.

5.1.1 Consolidated Alternatives

In consolidated alternatives, some flow is transferred from an uncontrolled CSO basin to another basin by actions such as installing new or larger conveyance pipes, parallel pipes, or flow controls such as gates.

Consolidation can provide more cost-effective control of CSOs, minimize the number of sites necessary for CSO control facilities, and reduce community impacts, operations and maintenance activities, and the risk of isolated, intense events yielding overflows. However, consolidation can require greater conveyance capacity to accommodate peak flow events.

Inter-basin flow transfer was considered only where flows can be routed to an adjacent CSO basin by gravity or by backflowing gravity pipes (reverse flow). Transfers that require a new pump station and interconnecting force main were not considered during the Program Review. Such transfers also would require protective features such as standby generators, backup pumps, and bypass pumping to provide uninterrupted flow transfer under wet-weather emergency conditions. These features typically result in higher capital costs.

5.1.2 Collaborative Alternatives

As discussed in Section 1.5, King County and the City of Seattle (SPU) have established a collaborative process for the development of collaborative alternatives for CSO control. Collaborative alternatives would address CSO control needs for both King County and SPU. Workshops between the two agencies were held at the beginning of the Program Review during the process to identify collaborative alternative concepts that may benefit both agencies. These workshops occurred on June 9, August 6, August 27, and September 9, 2009. Forty collaborative alternative concepts were identified. The development of these concepts into preliminary alternatives was divided between agencies based on which agency was developing similar independent alternatives for facilities that could be modified to receive the other agency's captured flows. The agency sending flows to the collaborative facilities would then develop the necessary conveyance components.

As part of the Program Review, the following procedures for developing collaborative alternatives were established:

- The two agencies agreed to use similar cost estimating methodologies. This included using similar costing tools and allied cost assumptions.
- Generally, the agency with the larger CSO Control Volume led the development of the alternative; the other agency independently developed cost estimates for conveying its flows to the CSO control facility proposed in the alternative.
- Project costs for shared facility components were assigned to each agency based on the percent of CSO Control Volume or CSO Peak Flow Rate contribution from each agency depending on the type of CSO control facility. Costs for facilities to be used only by one agency were not shared.
- Collaborative opportunities found to be cost-effective for both agencies or meeting other social or environmental criteria would be considered for integration into the schedule and rate analysis.
- In cases where King County accepts flow transfers that do not significantly change the size of a facility, but increase operational costs, SPU would reimburse those costs.

5.2 Description of Preliminary Alternatives

From the RWSP adopted alternatives and the consideration of new alternatives for this Program Review, a list of 44 preliminary alternatives was developed. Preliminary alternatives are summarized in the sections below, organized by area and CSO site. Sizes of the proposed CSO control facilities are not included in the preliminary alternative descriptions in this section because the 32-year continuous-simulation model run of King County's combined sewer system for the Program Review was not completed until October 2010, which was after the evaluation of preliminary alternatives. Sizes of proposed CSO control facilities are included in the final alternative descriptions in Section 6.3.

A descriptive table of all alternatives evaluated during the Program Review—preliminary and final—is presented in Appendix A.2. Identifiers for each preliminary alternative were assigned based on the elements indicated in Table 5-1.

Table 5-1. Naming Convention for Preliminary Alternatives

	CSO Site[a]		CSO Control Approach[b]		Sequential Numbering[c]	Agency[d]	Explanation
Example 1	DSN004	-	STOR	-	1	(KC)	1st alternative using storage for control of 11th Ave NW CSO site only; King County participation only
Example 2	DSN014/015	-	STOR	-	3	(KC & SPU)	3rd alternative using storage for control of University and Montlake CSO sites; King County and SPU participation
Example 3	DSN030/032	-	WWT	-	1	(KC)	1st alternative using wet-weather treatment for control of Hanford #2 and Lander St CSO sites; King County participation only

a. CSO site indicated by DSN (see Table 1-1)
b. Control approaches abbreviated as follows: CON = Conveyance; GI = GSI; MOD = Control modifications; SEP = Sewer separation; STOR = Storage; WWT = wet-weather treatment
c. Sequential numbering is assigned for all alternatives with the same CSO site and control approach
d. Agency is either King County alone (KC) or King County and Seattle Public Utilities (KC & SPU)

5.2.1 Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake

Sewer separation was eliminated from consideration for these CSO sites due to the number and complexity of stormwater connections. Wet-weather treatment was eliminated from consideration due to the low volume to be treated.

11th Ave NW Site Alternatives

The following preliminary alternatives were evaluated to control the 11th Ave NW CSO site:

- **Alternative DSN004-STOR-1 (KC)—**This storage alternative is similar to the RWSP adopted alternative (see Section 2.1). It includes a storage facility beneath a segment of NW 45th Street.
- **Alternative DSN004-STOR-2 (KC)—**This storage alternative is similar to the RWSP adopted alternative (see Section 2.1). It includes a storage facility under private Seattle Housing Authority property adjacent to the 11th Ave NW Overflow Structure (this potential private property was not identified in the RWSP).
- **Alternative DSN004-CON-1 (KC)—**This conveyance and storage alternative includes increasing the conveyance capacity from the 11th Ave NW Overflow Structure to the Ballard Regulator Station and constructing a storage facility near the 11th Ave NW Overflow Structure that is smaller than the storage required for Alternatives DSN004-STOR-1 (KC) and DSN004-STOR-2 (KC).

- **Alternative DSN004-CON-2 (KC)—**This conveyance alternative includes increasing the conveyance capacity from the 11th Ave NW Overflow Structure to the Ballard Regulator Station and implementing GSI techniques to eliminate the need for storage.

It may be possible to combine GSI with any of these alternatives to reduce storage and conveyance needs. This could include residential practices under SPU's Residential RainWise Program, roadside rain gardens at 8th Avenue NE and 3rd Avenue NE (north of NE 65th Street), and green alleys.

3rd Ave W Site Alternatives

The following preliminary alternatives were evaluated to control the 3rd Ave W CSO site:

- **Alternative DSN008-STOR-1 (KC)—**This storage alternative is similar to the RWSP adopted alternative (see Section 2.1). It includes a storage facility beneath an extension of W Ewing Street, which is east of 3rd Avenue W and adjacent to the Ship Canal on the south side.
- **Alternative DSN008-STOR-2 (KC & SPU)—**This storage alternative includes a distributed or joint storage facility upstream of the Fremont Siphon (on the north side of the Ship Canal) to control King County's 3rd Ave W CSO site and SPU's CSO Basins 147 and 174. SPU is leading the evaluation for this alternative.
- **Alternative DSN008-STOR-4 (KC & SPU)—**This storage alternative includes construction by SPU of a storage facility upstream of the Fremont Siphon (north of the Ship Canal) to control SPU CSO Basins 147 and 174. The size of the SPU storage facility would be increased to reduce the storage requirements associated with Alternative DSN008-STOR-1 (KC) for King County's 3rd Ave W CSO site.
- **Alternative DSN008-STOR-5 (KC & SPU)—**This storage alternative includes construction of a new siphon to convey SPU flows to the 3rd Ave W Overflow Structure and a joint storage facility on the south side of the Ship Canal near the 3rd Ave W Overflow Structure to control King County's 3rd Ave W CSO site and SPU CSO Basins 147 and 174.

It may be possible to combine GSI with any of these alternatives to reduce storage and conveyance needs. This could include demonstration projects on the Seattle Pacific University campus, residential practices under SPU's Residential RainWise Program, rain gardens, and permeable pavement in parking lots and alleys.

University Site Alternatives

The following preliminary alternatives were evaluated to control the University CSO site:

- **Alternative DSN015-STOR-1 (KC)—**This storage alternative includes a storage facility at one of the potential sites in the University of Washington area identified in the RWSP.
- **Alternative DSN015-STOR-2 (KC)—**This storage alternative includes a storage facility in Ravenna Park near the intersection of King County's Laurelhurst and Green Lake Trunks. The storage facility may offload enough flows to provide capacity in the North Interceptor for additional flows from the Montlake CSO Basin.

- **Alternative DSN015-STOR-3 (KC & SPU)—**This storage alternative includes construction by SPU of a storage facility to control SPU CSO Basin 18. The size of the SPU storage facility would be increased to reduce the storage requirements associated with Alternative DSN015-STOR-1 (KC) for King County's University CSO site.
- **Alternative DSN015-STOR-4 (KC & SPU)—**This storage alternative includes a joint King County/SPU storage facility in the University of Washington area to control King County's University CSO site and SPU's North Union Bay CSO Basin and CSO Basins 140 and 20.
- **Alternative DSN015-STOR-5 (KC)—**This storage alternative includes multiple storage facilities at potential sites in the University of Washington area identified in the RWSP.

It may be possible to combine GSI with any of these alternatives to reduce storage and conveyance needs.

Montlake Site Alternatives

The following preliminary alternatives were evaluated to control the Montlake CSO site:

- **Alternative DSN014-STOR-1 (KC)—**This storage alternative includes a storage facility on the south side of the Ship Canal near the Montlake Regulator Station.
- **Alternative DSN014-STOR-2 (KC & SPU)—**This storage alternative includes a joint King County/SPU storage facility on the south side of Ship Canal near the Montlake Regulator Station to control the King County Montlake CSO site and SPU's Leschi, Madison Park, and Montlake CSOs.

It may be possible to combine GSI with either of these alternatives to reduce storage and conveyance needs. SPU is leading the GSI evaluation for the Montlake CSO Basin.

University and Montlake Consolidated Alternatives

The following preliminary alternatives were evaluated to control the University and Montlake CSO sites:

- **Alternative DSN014/015-STOR-1 (KC)—**This storage alternative is similar to the RWSP adopted alternative and includes a storage facility located in one of the potential sites in the University of Washington area that were identified in the RWSP to control the University and Montlake CSO sites (see Section 2.1).
- **Alternative DSN014/015-STOR-2 (KC & SPU)—**This storage alternative includes construction by SPU of a storage facility to control SPU CSO Basin 18. The size of the SPU storage facility would be increased to reduce the storage requirements associated with Alternative DSN014/015-STOR-1 (KC) for King County's University and Montlake CSO sites.
- **Alternative DSN014/015-STOR-3 (KC & SPU)—**This storage alternative includes a joint King County/SPU storage facility in the University of Washington area to control King County's University and Montlake CSO sites and SPU's North Union Bay CSO Basin and CSO Basin 140.
- **Alternative DSN014/015-STOR-4 (KC)—**This storage alternative is similar to the RWSP adopted alternative and includes multiple storage facilities at potential sites in the

University of Washington area identified in the RWSP to control the University and Montlake CSOs (see Section 2.1).

It may be possible to combine GSI with any of these alternatives to reduce storage and conveyance needs.

11th Ave NW, 3rd Ave W, University, and Montlake Consolidated Alternative

The following preliminary alternative was evaluated to control the 11th Ave NW, 3rd Ave W, University, and Montlake CSO sites:

- **Alternative DSN004/008/014/015-STOR-1 (KC & SPU)—**This storage alternative includes a joint King County/SPU storage and conveyance tunnel from the University Regulator Station to the 3rd Ave W Overflow Structure to control King County's 11th Ave NW, 3rd Ave W, University, and Montlake CSO sites and SPU's Portage Bay/Lake Union, Montlake, North Union Bay, Union Bay/Madison Park, and Fremont/Wallingford CSOs. SPU is leading the evaluation for this alternative.

It may be possible to combine GSI with this alternative to reduce storage and conveyance needs.

5.2.2 Middle EBI—Hanford #2, Lander St, Kingdome, and King St

Sewer separation was eliminated from consideration for these CSO sites due to the number and complexity of stormwater connections. Conveyance improvements alone and storage was eliminated from consideration for Hanford #2, Lander St, and Kingdome due to the excessive sizing required to control the volume.

King St Site Alternatives

The following preliminary alternatives were evaluated to control the King St CSO site:

- **Alternative DSN028-STOR-1 (KC)—**This storage alternative includes a storage facility near the King St Regulator Station.
- **Alternative DSN028-STOR-2 (KC & SPU)—**This storage alternative includes a joint King County/SPU storage facility near the King St Regulator Station to control King County's King St CSO site and SPU CSOs.

Kingdome Site Alternatives

The following preliminary alternative was evaluated to control the Kingdome CSO site:

- **Alternative DSN029-WWT-1 (KC)—**This treatment alternative includes a wet-weather treatment facility near the Kingdome Regulator Station.

Lander St Site Alternatives

The following preliminary alternative was evaluated to control the Lander St CSO site:

- **Alternative DSN030-WWT-1 (KC)—**This treatment alternative includes a wet-weather treatment facility near the Lander St Regulator Station.

Hanford #2 Site Alternatives

The following preliminary alternative was evaluated to control the Hanford #2 CSO site:

- **Alternative DSN032-WWT-1 (KC)—**This treatment alternative is similar to the RWSP adopted alternative (see Section 2.1). It includes a wet-weather treatment facility near the Hanford St Regulator Station.

Kingdome and King St Consolidated Alternatives

The following preliminary alternative was evaluated to control Kingdome and King St CSO sites:

- **Alternative DSN028/029-WWT-1 (KC)—**This treatment alternative is similar to the RWSP adopted alternative (see Section 2.1) and includes a wet-weather treatment facility near the Kingdome Regulator Station.

Hanford #2 and Lander St Consolidated Alternatives

The following preliminary alternative was evaluated to control the Hanford #2 and Lander St CSO sites:

- **Alternative DSN030/032-WWT-1 (KC)—**This treatment alternative includes a wet-weather treatment facility near the Hanford St Regulator Station.

Hanford #2, Lander St, Kingdome, and King St Consolidated Alternatives

The following preliminary alternative was evaluated to control the Hanford #2, Lander St, Kingdome, and King St CSO sites:

- **Alternative DSN028/029/030/032-WWT-1 (KC)—**This treatment alternative includes a wet-weather treatment facility near the Hanford St Regulator Station.

5.2.3 Middle EBI—Hanford #1

Hanford #1 Site Alternatives

The following preliminary alternatives were evaluated to control the Hanford@Rainier and Bayview North CSO sites:

- **Alternative DSN031-STOR-1 (KC)—**This storage alternative includes one storage facility near the Hanford@Rainier Overflow Structure and Bayview North Overflow Structure.
- **Alternative DSN031-STOR-3 (KC & SPU)—**This storage alternative includes a joint King County/SPU storage facility downstream of the Rainier Pump Station to control King County's Hanford@Rainier and Bayview North CSO sites and to allow SPU to drain its CSO storage facilities to the King County conveyance system sooner following a wet-weather event.
- **Alternative DSN031-STOR-4 (KC)—**This storage alternative includes two storage facilities near the Hanford@Rainier Overflow Structure and Bayview North Overflow Structure.
- **Alternative DSN031-STOR-5 (KC &SPU)—**This storage alternative includes two joint storage facilities downstream of the Rainier Pump Station to control King County's Hanford@Rainier and Bayview North CSO sites and allow SPU to drain its CSO storage facilities to the King County conveyance system sooner following a wet-weather event.

It may be possible to combine GSI with any of these alternatives to reduce storage and conveyance needs. This could include residential practices under SPU’s Residential RainWise Program, residential and roadside rain gardens, and green alleys. Seattle University and Yesler Terrace are prime candidates for GSI in these basins.

5.2.4 South EBI

Sewer separation was eliminated from consideration for the S Michigan St CSO site due to the number and complexity of stormwater connections. Conveyance improvements alone and storage was eliminated from consideration for both CSO sites due to the excessive sizing required to control the volume.

S Michigan St Site Alternative

The following preliminary alternatives were evaluated to control the S Michigan St CSO site:

- **Alternative DSN039-WWT-1 (KC)—**This treatment alternative is similar to the RWSP adopted alternative (see Section 2.1). It includes a wet-weather treatment facility near the S Michigan St Regulator Station.
- **Alternative DSN039-WWT-2 (KC & SPU)—**This treatment alternative includes a joint King County/SPU wet-weather treatment facility near the S Michigan St Regulator Station to control King County’s S Michigan St CSO site and SPU’s CSO Basin 111H.

It may be possible to combine GSI with either of these alternatives to reduce treatment and conveyance needs. This could include residential practices under SPU’s Residential RainWise Program, roadside bioswales along Airport Way S, and green alleys. Depth to groundwater could be an issue for infiltration techniques in some areas.

Brandon St Site Alternatives

The following preliminary alternatives were evaluated to control the Brandon St CSO site:

- **Alternative DSN041-WWT-1 (KC)—**This treatment alternative is similar to the RWSP adopted alternative (see Section 2.1). It includes a wet-weather treatment facility near the Brandon St Regulator Station. It may be possible to combine GSI with this alternative. This could include roadside bioswales, green roofs, and permeable pavement. A large portion of the Brandon St CSO Basin is industrial and could be eligible for incentivized GSI construction.
- **Alternative DSN041-SEP-1 (KC)—**This sewer separation alternative includes separation of the sanitary sewer and storm drain systems in the Brandon St CSO Basin.

S Michigan St and Brandon St Consolidated Alternatives

The following preliminary alternatives were evaluated to control the S Michigan St and Brandon St CSO sites:

- **Alternative DSN039/041-WWT-1 (KC)—**This treatment alternative includes a wet-weather treatment facility near the S Michigan St Regulator Station.
- **Alternative DSN039/041-WWT-2 (KC & SPU)—**This treatment alternative includes a joint King County/SPU wet-weather treatment facility near the S Michigan St Regulator

Station to control King County's S Michigan St and Brandon St CSO sites and SPU's CSO Basin 111H.

It may be possible to combine GSI with either of these alternatives to reduce treatment and conveyance needs.

5.2.5 West Duwamish—W Michigan St and Terminal 115

Sewer separation was eliminated from consideration for these CSO sites due to the number and complexity of stormwater connections. Wet-weather treatment was eliminated from consideration due to the low volume to be treated.

W Michigan St Site Alternative

The following preliminary alternative was evaluated to control the W Michigan St CSO site:

- **Alternative DSN042-STOR-1 (KC)—**This storage alternative includes a storage facility near the W Michigan St Regulator Station. It may be possible to combine GSI with this alternative. Depth to groundwater could be an issue for infiltration in some areas.

Terminal 115 Site Alternative

The following preliminary alternative was evaluated to control the Terminal 115 CSO site:

- **Alternative DSN038-STOR-1 (KC)—**This storage alternative is similar to the RWSP adopted alternative (see Section 2.1). It includes a storage facility near the Terminal 115 Overflow Structure.

W Michigan St and Terminal 115 Consolidated Alternatives

The following preliminary alternatives were evaluated to control the W Michigan St and Terminal 115 CSO sites:

- **Alternative DSN038/042-STOR-1 (KC)—**This storage alternative includes a storage facility near the Terminal 115 Overflow Structure.
- **Alternative DSN038/042-CON-1 (KC)—**This conveyance alternative includes conveyance of Terminal 115 and W Michigan St CSOs to a wet-weather treatment facility near the S Michigan St Regulator Station to control W Michigan St, Terminal 115, S Michigan St, and/or Brandon St CSO sites.

It may be possible to combine GSI with either of these alternatives to reduce storage and conveyance needs.

5.2.6 West Duwamish—Chelan Ave

Chelan Ave Site Alternatives

The following preliminary alternatives were evaluated to control the Chelan Ave CSO site:

- **Alternative DSN036-STOR-1 (KC)—**This storage alternative includes a storage facility near the Chelan Ave Regulator Station.
- **Alternative DSN036-CON-1 (KC)—**This conveyance alternative includes transferring flows to the West Seattle Tunnel and Alki Treatment Facility.

It may be possible to combine GSI with either of these alternatives to reduce storage and conveyance needs.

5.3 Screening of Preliminary Alternatives

5.3.1 Screening Criteria

Criteria were developed as part of the Program Review to screen preliminary alternatives. The screening criteria were refined through meetings with King County on June 23, July 28 and August 25, 2010. The 16 screening criteria are organized into six categories.

- Technical considerations
  - Technical complexity
  - Flexibility/adaptive management
  - Constructability
  - Implementation schedule
  - Siting
  - Coordination with other King County projects
- Cost effectiveness
  - Relative life-cycle costs
- Community and public health
  - Construction impacts
  - Potential community impacts
  - Human health
  - Environmental/social justice
- Environmental impacts
  - Overall environmental
  - Sustainability
- Land use and permitting
  - Permitting complexity
- Operations and maintenance
  - Operations and maintenance
  - Employee safety.

Each criterion has associated definitions to be used in rating alternatives as low, medium, or high for that criterion (e.g., "A low rating is applied for alternatives that…"). A full list of screening criteria, including corresponding high, medium, and low rating descriptions, is included in Appendix D. The appendix includes criteria in addition to those listed above (shown in grey text in the appendix) that were not used for the screening during the Program Review but should be considered among other site-specific criteria in future evaluations.

5.3.2 Screening Process

The screening criteria were reviewed for each preliminary alternative, and the rating (high, medium, or low) for each criterion that best fits the alternative was assigned. The ratings were modified as the screening criteria were refined and in response to King County team feedback. The final ratings for each criterion and preliminary alternative are presented in Appendix E.

The criteria ratings did not indicate major flaws in any of the preliminary alternatives; further development of the alternatives, including cost estimates, was required before removing any from consideration based on the criteria alone. However, some preliminary alternatives did not advance to final alternative development; these alternatives were screened based on the following considerations:

- King County determined that alternatives for the Program Review should identify broad potential project areas rather than specific sites. There is uncertainty associated with the availability of sites and future development plans, particularly when some of the CSO control facilities are not anticipated to be constructed for 10 years or more. Because of this decision, preliminary alternatives that differed only in the site identified for the project were consolidated, and the alternative description was modified to exclude identification of a specific site.
- Collaborative alternatives with SPU were removed if SPU determined that conveyance to the collaborative CSO control facility would not be cost-effective or if the SPU flow contributions were considered minimal to warrant a separate alternatives evaluation.
- Updated modeling of the 11th Ave NW CSO site with increased conveyance demonstrated that control of this CSO site could be achieved with conveyance alone, without the need for any storage (see Table 3-1). Therefore, the conveyance-plus-storage alternative for this CSO site was modified to remove the storage component and add potential GSI opportunities, and the conveyance-plus-GSI alternative was eliminated as a separate alternative.
- The Montlake-University consolidated preliminary alternatives were removed because they were determined to be cost-prohibitive due to higher Montlake CSO volumes from the most recent modeling results that would require conveyance to the storage facility across the Montlake Cut via the Montlake Siphon.

5.3.3 Screened Alternatives

Based on the screening process, it was decided that the preliminary alternatives presented in Table 5-2 would not move forward to final alternative development. Preliminary alternatives that advanced to final alternative development are indicated in Appendix A.2.

Table 5-2. Preliminary Alternatives Not Evaluated as Final Alternatives

Description	Explanation for Not Carrying Forward
11th Ave NW CSO Site	
Alternative DSN004-STOR-2 (KC)	
Storage tank on private Seattle Housing Authority property.	Because King County decided not to evaluate specific sites for Program Review alternatives, this alternative is the same as Alternative DSN004-STOR-1 (KC).
Alternative DSN004-CON-2 (KC)	
Increase conveyance to Ballard Siphon. Use GSI to eliminate the need for storage.	Per 10/13/10 meeting, potential GSI opportunities will be included in Alternative DSN004-CON-1 (KC) and will not be evaluated as a separate alternative. Modeling also determined that storage is no longer needed with increased conveyance alternative.
3rd Ave W CSO Site	
Alternative DSN008-STOR-4 (KC & SPU)	
SPU increases storage capacity upstream of the Fremont Siphon to control CSO Basins 147 and 174, reducing storage requirements for King County at 3rd Ave W.	Per 11/10/10 meeting with SPU, SPU will either take all King County flows upstream of the Fremont Siphon or send all of SPU flows to the 3rd Ave W storage facility south of the Ship Canal. SPU will not increase the size of its storage upstream of the Fremont Siphon to reduce storage needs for a King County 3rd Ave W storage facility south of the Ship Canal.
University CSO Site	
Alternative DSN015-STOR-2 (KC)	
Storage tank in Ravenna Park.	Because King County decided not to evaluate specific sites for Program Review alternatives, this alternative is the same as Alternative DSN015-STOR-1 (KC).
Alternative DSN015-STOR-3 (KC & SPU)	
Storage tank to control University CSOs only, but the storage size would be reduced by SPU CSO control projects.	Per 11/29/10 conference call, King County indicated that SPU is sizing its storage upstream of the University Regulator Station to control University CSOs. Thus, there is no longer a reduced size for the King County storage facility.
Alternative DSN015-STOR-5 (KC)	
Multiple storage tanks to control University CSOs only, located in a combination of multiple sites in the University of Washington area.	Because King County decided not to evaluate specific sites for Program Review alternatives, this alternative is the same as Alternative DSN015-STOR-1 (KC).

Table 5-2. Preliminary Alternatives Not Evaluated as Final Alternatives

Description	Explanation for Not Carrying Forward
University and Montlake CSO Sites	
Alternative DSN014/015-STOR-1 (KC)	
Convey Montlake flows to storage tank north of Ship Canal on potential site in University of Washington area to control University and Montlake CSOs.	Due to the flow and volume increase associated with Montlake CSOs in the October modeling run, King County is unable to convey Montlake flows to the University CSO Basin via the existing Montlake Siphon. A new siphon to convey Montlake flows to the University CSO Basin would be cost-prohibitive.
Alternative DSN014/015-STOR-2 (KC & SPU)	
Storage tank to control University and Montlake CSOs, with size reduced by SPU CSO control projects.	Same as for Alternative DSN014/015-STOR-1 (KC)
Alternative DSN014/015-STOR-3 (KC & SPU)	
Joint King County/SPU storage tank to control King County University and Montlake CSOs and SPU CSOs.	Same as for Alternative DSN014/015-STOR-1 (KC)
Alternative DSN014/015-STOR-4 (KC)	
Convey Montlake flows to storage tanks north of Ship Canal on multiple potential sites in the University of Washington area.	Same as for Alternative DSN014/015-STOR-1 (KC)
Hanford #1 CSO Site	
Alternative DSN031-STOR-3 (KC & SPU)	
Joint King County/SPU storage facility downstream of Rainier Pump Station.	King County modeling determined that the SPU contribution to Hanford #1 alternatives is minimal; thus, collaborative alternatives will not be evaluated separately. This is a flow transfer. Site alternatives will indicate that the alternative can be with or without SPU flows.
Alternative DSN031-STOR-5 (KC & SPU)	
Two joint King County/SPU storage facilities downstream of Rainier Pump Station.	Same as for Alternative DSN031-STOR-3 (KC & SPU)
S Michigan St CSO Site	
Alternative DSN039-WWT-2 (KC & SPU)	
Joint wet-weather treatment facility to control S Michigan St CSO site and SPU's CSO Basin 111H	Per 12/16/10 meeting with SPU, SPU indicated that it would cost more to convey to the joint wet-weather treatment facility than to control its CSOs with an independent CSO control facility.
S Michigan St and Brandon St CSO Sites	
Alternative DSN039/041-WWT-2 (KC & SPU)	
Joint wet-weather treatment facility to control S Michigan St and Brandon St CSO sites and SPU's CSO Basin 111H	Same as for Alternative DSN039-WWT-2 (KC & SPU).

Table 5-2. Preliminary Alternatives Not Evaluated as Final Alternatives

Description	Explanation for Not Carrying Forward
W Michigan St and Terminal 115 CSO Sites	
<u>Alternative DSN038/042-CON-1 (KC)</u>	
Conveyance to a wet-weather treatment facility to control W Michigan St, Terminal 115, S Michigan St, and Brandon St CSO sites	Per 10/13/10 meeting, King County indicated that the flows are not large enough at Terminal 115 and W Michigan St to justify conveyance to the wet-weather treatment facility located near the S Michigan St CSO site.

5.4 Alternative Variations

As a result of the site-specific hydraulic modeling, two preliminary alternatives were further developed into two separate alternatives to be carried forward for final evaluation. Both are consolidated wet-weather treatment alternatives along the Elliott Bay Interceptor. The original preliminary alternatives did not specify the means of conveyance to the wet-weather treatment facility. Based on the modeling of backflowing within the existing conveyance to transfer downstream flows to upstream treatment locations (see Section 3.3.1), these alternatives were developed with the option of constructing new conveyance facilities to the treatment facility or modifying the Elliott Bay Interceptor to allow backflowing. The initial two preliminary alternatives were thus developed as the following four alternatives:

- Wet-weather treatment facility for Hanford #2, Lander St, Kingdome, and King St CSO sites
  - DSN028/029/030/032-WWT-1 (KC) (New Conveyance)
  - DSN028/029/030/032-WWT-1 (KC) (EBI Modifications)
- Wet-weather treatment facility for S Michigan St and Brandon St CSO Sites
  - DSN039/041-WWT-1 (KC) (New Conveyance)
  - DSN039/041-WWT-1 (KC) (EBI Modifications)

Three new alternatives also were identified to be carried through for final evaluation based on the screening of preliminary alternatives and the site-specific hydraulic modeling:

- **DSN029/030/032-WWT-1 (KC), Wet-Weather Treatment Facility for Hanford #2, Lander St, and Kingdome CSO Sites—**This alternative is a variation on the consolidated wet-weather treatment alternative for the Hanford #2, Lander St, Kingdome, and King St CSO sites. It omits the King St CSO site to allow for a reduction in required wet-weather treatment facility size and conveyance needs.
- **DSN031-CON-1 (KC), Conveyance for Hanford #1 CSO Site—**This alternative makes use of available conveyance in the Bayview Tunnel, as identified in the site-specific hydraulic modeling for Hanford #1, allowing a reduction in the storage volume identified for other Hanford #1 alternatives, as described in Section 3.3.2.
- **DSN036-STOR-2 (KC), Storage Facility for Chelan Ave CSO Site—**This alternative is a variation on the storage alternative for the Chelan Ave CSO site. It includes conveyance improvements to divert Chelan Ave CSO Basin flows from the Delridge

Trunk to the West Seattle Pump Station, the site of the Chelan Ave storage facility identified in the RWSP. Conveyance improvements were identified in the site-specific hydraulic modeling for Chelan Ave, as described in Section 3.3.3.

This page left blank intentionally.

6.0. FINAL ALTERNATIVE DEVELOPMENT

The preliminary alternatives that were advanced for further consideration through the initial screening process described in Section 5.3, as well as the alternative variations described in Section 5.4, are included in the final alternatives.

Each final alternative was further developed before a final evaluation, using the triple-bottom-line analysis process, was performed to identify recommended preferred alternatives for each uncontrolled CSO site. The additional development during this phase included refining the size, location, and cost information included with each alternative.

This section describes the planning-level design criteria and cost estimating methodology used to develop the final alternatives—followed by a description of all the final alternatives.

6.1 Planning-Level Design Criteria

Planning-level design criteria were developed for three general types of CSO control facilities: CSO storage tanks, CSO storage pipes, and wet-weather treatment facilities. The planning-level design criteria were used to determine the following for each alternative:

- **Sizing—**Planning-level sizing focused on estimating the overall facility footprint (required land area). Representative footprint sizes for each alternative are used to indicate how large a site may need to be acquired and to estimate property costs. The footprint sizing criteria for storage tanks and storage pipes are presented in Appendices F.1 and F.2, respectively. The footprint sizing criteria for wet-weather treatment facilities are presented in Appendices F.3 and F.4 and in Section 6.1.3.
- **Location—**Specific project sites were not identified for this Program Review because of uncertainties associated with the availability of sites and future development plans. Instead, an approximate boundary of potential sites was developed for each alternative, based on construction issues (such as preferred maximum depth of excavation) and hydraulic performance requirements (such as requiring that flow be conveyed to CSO control facilities by gravity rather than by pumping). The approximate boundary is intended for planning purposes only and does not represent all potential site locations. Further study and evaluation will be completed prior to selection of preferred sites as part of preliminary and final design. The methodology for defining approximate boundaries is described in this section.
- **Cost—**Planning-level cost estimates are used as one component of the triple-bottom-line analysis of alternatives. The planning-level cost estimating methodologies used for this evaluation are summarized in Section 6.2 and described in detail in the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities*.

Potential reduction in CSO Control Volume or CSO Peak Flow Rate that could be achieved using GSI techniques is not reflected in costs and sizes of proposed CSO control facilities in the Program Review; more in-basin monitoring and modeling needs to be completed to quantify the benefit of the GSI approach before any sizing reduction is made to the associated CSO control facility.

The planning-level design criteria described in this section are unrelated to the screening criteria used during the preliminary alternative screening process. The planning-level design criteria for final alternatives were used to define the size, location, and cost of proposed CSO control facilities. The screening criteria used during the preliminary alternative screening process will be revisited during the final alternative screening process, described in Chapter 7.

6.1.1 Design Criteria for Storage Tanks

This section summarizes key information about the design criteria for CSO storage tanks. Schematic diagrams and the design criteria that were used as the basis of developing sizing of storage tanks and boundaries of potential sites are provided in Appendix F.1.

Operating Scenarios

Design criteria were established for two operating scenarios:

- **Scenario 1: Maximum water surface level in the CSO storage tank equals the existing overflow elevation (the water level at which combined sewage is diverted to the CSO outfall)—**This is the preferred operating scenario because it provides a passive system in which a CSO would occur before the tank would surcharge. It does not depend on isolation valves to prevent surcharging of the tank and surface flooding.
- **Scenario 2: Maximum water surface level in the CSO storage tank is lower than the existing overflow elevation—**Site-specific conditions may require this scenario (e.g., when the CSO storage tank is downhill from the existing regulator station). In these instances, isolation valves can be used to prevent surcharging of the CSO storage tank and surface flooding.

Considerations and Key Design Criteria

Approximate boundaries for potential CSO storage tank sites are defined by two general considerations:

- **Maximum Ground Surface Elevation—**This elevation is determined based on the criterion that the CSO storage tank excavation depth should not exceed 50 feet. Where this consideration is the limiting factor, the boundary of potential sites is defined by the topographic contour equal to the maximum ground surface elevation.
- **Maximum Conveyance Length—**Where maximum conveyance length is the limiting factor, the boundary of potential sites is a circular path centered on the diversion location with a radius equal to 80 percent of the maximum conveyance length. The following design criteria are used to determine the maximum conveyance length:
  - The invert of the influent gravity sewer at the storage tank should be no more than 25 feet below the ground surface. This criterion is established to reduce constructability risks and allow open-cut construction methods for pipe installation. If the invert of the existing regulator station is greater than 25 feet deep, then the influent gravity sewer invert at the storage tank will have to be more than 25 feet deep, and the influent gravity sewer likely will be installed using trenchless construction methods.
  - The preferred slope of the influent gravity sewer to the CSO storage tank is 0.5 percent. The slope may be increased if needed to reduce the pipe diameter (this

will result in a shorter maximum conveyance length) or decreased if needed to expand the boundary (this will result in a larger required pipe diameter).

- The preferred maximum diameter of the influent gravity sewer is 48 inches. This criterion is established to minimize conveyance costs. Larger pipe diameters may be used for the following circumstances:
    - Collaborative alternatives for which the pipe diameter is increased to accommodate additional flows from SPU (e.g., storage with SPU at 3rd Ave W south of the Ship Canal, at King Street, or at Montlake).
    - Alternatives that require trenchless construction methods.
    - Alternatives where the approximate boundary of potential sites was too limited if slope was increased and diameter reduced to 48 inches.
- The crown of the influent gravity sewer at the diversion location should be below the existing overflow elevation. This allows the capacity of the influent gravity sewer to be fully utilized during wet-weather events. In instances where the crown is above the existing overflow elevation, the slope of the influent gravity sewer can be increased (reducing boundary limits) to decrease the diameter of the influent gravity sewer, lowering the crown of pipe below the existing overflow elevation. A drop structure may also be used, but this would require the slope of the influent gravity sewer to decrease and a possible increase in pipe diameter.

The maximum straight-line radius length from the diversion location that would correspond to the conveyance length established using the design criteria listed above is reduced by 20 percent to account for the likelihood that the influent gravity sewer will not have a straight alignment from the diversion location to the CSO storage tank. Thus, the radius of the circular path equals 80 percent of the estimated maximum conveyance length.

Figure 6-1 shows an example of how maximum ground surface elevation and maximum conveyance length combine to establish the approximate boundary of potential sites for a CSO storage tank alternative.

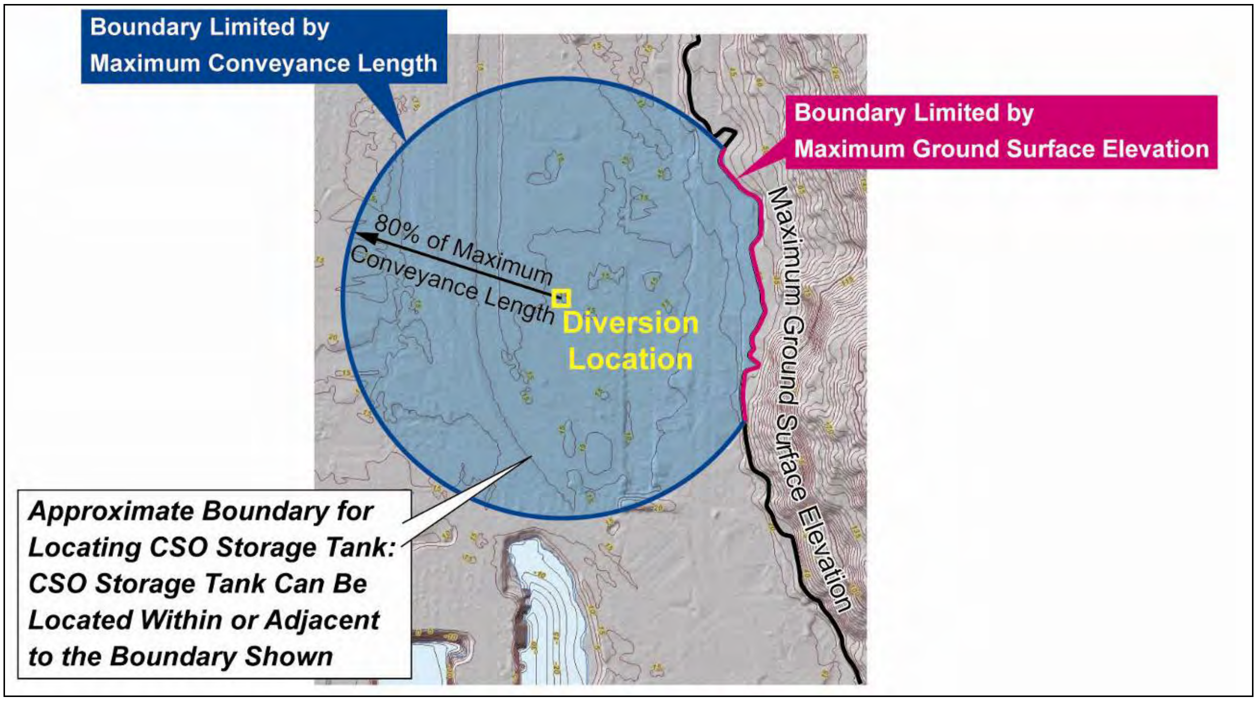

Figure 6-1. Example of Approximate Boundary for Locating CSO Storage Tank Alternative

The following additional design criteria are also used to establish the boundaries of potential sites for CSO storage tanks:

- The maximum water surface level in the CSO storage tank is set depending on the operating scenarios described above:
  - For Scenario 1, the maximum water surface level in the tank equals the existing overflow elevation.
  - For Scenario 2, the maximum water surface level in the tank is 1 foot below the invert elevation of the influent gravity sewer at the CSO storage tank.
- No pumping is required to convey flows from the King County combined sewer system to the CSO storage tank.
- Combined sewer system flows are generally assumed to be diverted to the storage tank from the existing regulator station. Three alternatives were developed with the diversion upstream of the regulator station: University, 3rd Ave W (north side of Ship Canal), and Chelan Ave (West Seattle Pump Station site). It may be possible that flows can be diverted upstream of the existing regulator station for other alternatives; this will be evaluated during preferred alternative development.
- CSO storage tanks will not be located in water bodies.

Process for Establishing Approximate Boundary of Potential Sites

Process Diagram #1 and Process Diagram #2 in Appendix F.1 present the process for establishing the approximate boundary of potential sites using the considerations and design criteria described above. The boundaries established by this process could vary as follows if any of the key design criteria are modified:

- The boundary may be expanded if:
  - Flows can be diverted further upstream of the assumed diversion location.
  - The upstream invert of the influent gravity sewer at the diversion location can be raised higher.
  - Construction of a deeper storage tank is acceptable (excavation depth greater than 50 feet).
  - An influent pump station and force main are used to convey flows to the storage tank.
  - The slope of the influent gravity sewer is decreased (requiring a larger pipe).
  - The alignment of the influent gravity sewer is relatively straight from the diversion location to the storage tank, so that no 20-percent reduction is required.
- The boundary may be reduced if:
  - The slope of the influent gravity sewer is increased, which decreases the diameter of the influent gravity sewer.
  - The influent gravity sewer excavation depth needs to be reduced such that the boundary needs to be located at a lower ground surface elevation closer to the existing regulator station.

Boundaries for Consolidated Storage Alternatives

Consolidated storage alternatives include a single CSO storage tank to control multiple CSO sites. For this Program Review, two boundaries of potential sites were developed for consolidated storage alternatives:

- Approximate Boundary for **Assumed Location** of CSO Storage Tank—This boundary is estimated using the boundary development process described above, with the CSO site with the highest CSO Peak Flow Rate as the diversion location. This boundary is represented by a solid line on alternative figures in Appendix G. The CSO storage tank has been assumed to be located within or adjacent to the solid boundary for conveyance cost estimating purposes.
- Approximate Boundary for **Alternate Location** of CSO Storage Tank—This boundary is established using the boundary development process described above at the alternate CSO site(s) that are included in the consolidated alternative and connecting the boundaries of the CSO sites being consolidated. The boundary is the combination of boundaries estimated for the alternate CSO sites(s) that are included in the consolidated alternative and is represented by a dashed line on alternative figures in Appendix G. The dashed boundary is only intended to indicate that the CSO storage tank could be located anywhere between the CSO sites, but conveyance would need to be reevaluated if the CSO storage tank moves from the assumed location (solid boundary).

The same design criteria, assumptions, and process are used to establish both the solid and dashed boundaries. Differences in the boundaries are due to the different site conditions (diversion location, CSO Peak Flow Rate, ground surface elevations, etc.).

6.1.2 Design Criteria for Storage Pipes

For the Program Review, it is assumed that the CSO storage pipes can be located in rights of way or existing King County easements immediately adjacent to the assumed diversion locations, thereby minimizing conveyance to storage. Further study and evaluation will be completed prior to selection of preferred sites for the diversion locations and CSO storage pipes during preliminary and final design. Details and a storage pipe schematic are provided in Appendix F.2.

6.1.3 Design Criteria for Wet-Weather Treatment Facilities

For the Program Review, it is assumed that all alternatives providing wet-weather treatment will also include equalization basins to reduce the peak flow rate that the treatment facility must be designed to accommodate. Development of treatment alternatives, therefore, requires determination of the most cost-effective combination of treatment and equalization capacities. The following methodology was used to develop the treatment alternatives:

- Establish design criteria for treatment facilities and equalization basins.
- Determine the optimum treatment and equalization capacity combination as follows:
  - Develop flow-volume curves that define the range of combinations of treatment peak flow rate and equalization basin volume that will accommodate expected CSO Peak Flow Rates for each treatment alternative.
  - Develop footprint sizing curves for treatment facilities and equalization basins based on treatment peak flow rate and equalization basin volume, respectively.
  - Estimate property costs for the equalization basins and treatment facilities by multiplying the corresponding footprint sizes by the property and building unit cost ($ per square foot) of the CSO basin where the treatment facility is located.
  - Develop construction cost curves as a function of peak flow rate for treatment facilities and as a function of volume for equalization basins.
  - Identify the treatment peak flow rate and equalization basin volume with the lowest combined cost by plotting the total construction and property costs for each combination of treatment and equalization basin capacities.
- Determine footprint sizing for treatment alternatives (treatment facilities and equalization basins) based on the selected optimum design capacities and the established design criteria.
- Establish boundaries of potential sites for treatment alternatives based on the selected optimum design capacities and the established design criteria.

Description of Treatment Facilities and Design Criteria

As described in *Technical Memorandum 700, Treatment Technology Selection*, two CSO treatment processes have been identified for treatment alternatives in this Program Review:

- **Chemically Enhanced Primary Treatment (CEPT) with Lamella Plates—**This CSO treatment process improves on conventional primary clarification by providing chemical feeds to enhance coagulation, flocculation, and removal of suspended solids. Inclined plates increase the sedimentation basin's effective settling area. A schematic of the process is shown in Figure 6-2.

- **Ballasted Sedimentation**—This process uses CEPT with lamella plates in combination with a ballast material (microsand or recirculated sludge) to optimize settling and provide the best potential treatment within the smallest footprint. A schematic of the process is shown in Figure 6-3.

For either CSO treatment process, the treatment alternatives will include an equalization basin to reduce peak flow rates to the treatment process and improve treatment effectiveness. Flows from the combined sewer system will be pumped to the treatment facility, and flows exceeding the hydraulic capacity of the treatment process will be stored in the equalization basin prior to treatment. The treatment process will operate at maximum capacity until the equalization basin is emptied. This will ensure that all CSOs are treated and that the equalization basin is used only during peak-flow events that exceed the treatment facility's design capacity.

Key design criteria for wet-weather treatment facilities are provided in Appendix F.3. Key design criteria for equalization basins are provided in Appendix F.1 and Appendix F.4.

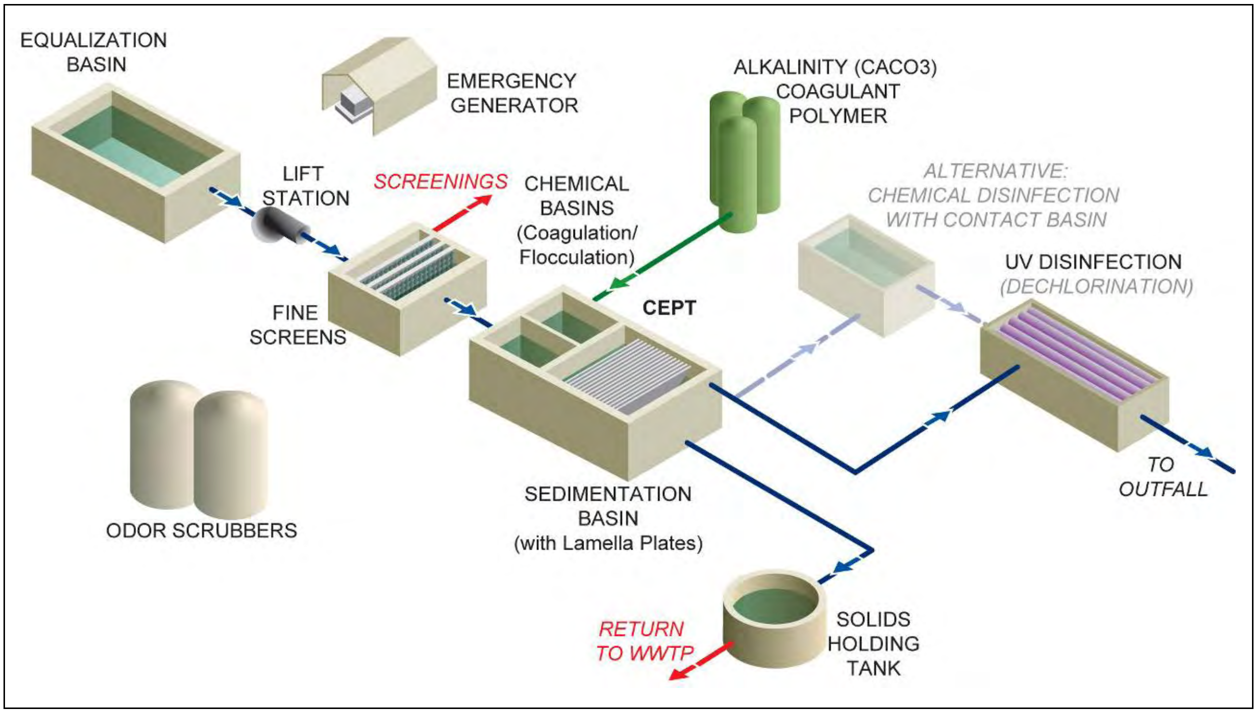

Figure 6-2. Sample Process Flow Schematic for CEPT with Lamella Plates

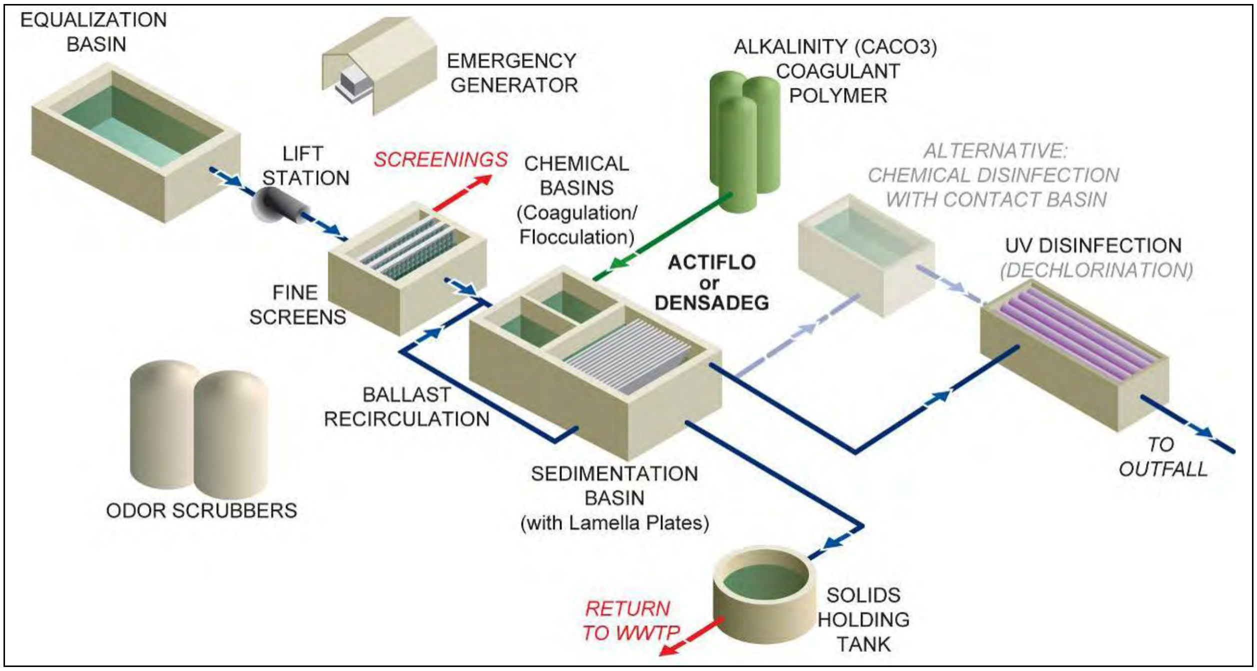

Figure 6-3. Sample Process Flow Schematic for Ballasted Sedimentation

Optimum Capacity Assessment

Flow-Volume Curves

King County created flow-volume curves representing combinations of treatment peak flow rate and equalization basin volume that result in an average of one untreated discharge per year per outfall on average. The curves are based on overflow hydrographs from modeling performed in October 2010 (see Section 3.2). Curves were developed for treatment alternatives for the following CSO sites:

- Kingdome
- Lander St
- Hanford #2
- Brandon St
- S Michigan St
- Consolidated King St and Kingdome
- Consolidated Hanford #2 and Lander St
- Consolidated Hanford #2, Lander St, and Kingdome
- Consolidated Hanford #2, Lander St, Kingdome, and King St
- Consolidated Brandon St and S Michigan St.

Details regarding the methodology of this analysis, as well as the flow-volume curves for each alternative, are presented in Appendix F.4.

Wet-Weather Treatment Facility Footprint Sizing Curves

The following methodology was used to develop footprint sizing curves for wet-weather treatment facilities for both CSO treatment processes; details and the resulting curves and equations are presented in Appendix F.3:

- **Step 1. Define Processes Included in Representative Wet-Weather Treatment Facilities—**Unit processes at the treatment facility include the main treatment process as well as ancillary processes such as pumping facilities and solids handling equipment. The processes included in a representative wet-weather treatment facility for both CSO treatment processes were developed as described in Appendix F.3
- **Step 2. Estimate Footprints (acres) of Existing Wet-Weather Treatment Facilities Using Ballasted Sedimentation—**Using existing record drawings and planning-level documents, the approximate footprints of existing wet-weather treatment facilities using ballasted sedimentation were estimated.
- **Step 3. Adjust Footprints of Existing Facilities to Develop Representative Wet-Weather Treatment Facility Footprints—**Some unit processes identified for the representative wet-weather treatment facility footprint (Step 1) are not included in the existing facilities evaluated. Typical footprints estimated based on existing facilities (Step 2) were adjusted to include all unit processes identified as part of a representative CSO treatment process.
- **Step 4. Develop Footprint Sizing Curve for Wet-Weather Treatment Facilities Using Ballasted Sedimentation—**A footprint sizing curve was developed using the adjusted footprint data (Step 3). The footprint size (in acres) versus wet-weather treatment facility peak flow rate (in MGD) was plotted, and a best-fit curve and equation were developed. The curve is shown in Appendix F.3; the equation is as follows:

  Footprint (acres) = 0.0073 Q + 1.2425
  Q = peak flow rate in MGD

- **Step 5. Develop Footprint Sizing Curve for Wet-Weather Treatment Facilities Using CEPT with Lamella Plates—**A footprint sizing curve was developed for CEPT with lamella plates by adjusting the footprint data from Step 4. Footprints associated with larger chemical mixing tanks and settling basins were added, and footprints associated with unit processes not typically included in a CEPT facility were removed (grit removal facility and solids handling facility). The resulting curve is shown in Appendix F.3; the best-fit equation is as follows:

  Footprint (acres) = 0.0071 Q + 1.587
  Q = peak flow rate in MGD

Equalization Basin Footprint Sizing Curves

A curve was developed that depicts footprint sizing versus equalization basin volume. The footprint sizing curve, based on the storage tank design criteria listed in Appendix F.1 and assuming a 3:1 length-to-width ratio and a side water depth of 20 feet, is presented in Appendix F.4. The best-fit equation representing the curve is as follows:

Footprint (acres) = 0.226 V + 0.1772
V = equalization basin volume in MG

Property Costs

Property costs were developed for each combination of treatment peak flow rate and equalization basin volume. The footprint sizes that were determined for the treatment facilities and equalization basins were multiplied by the "land and building" unit cost ($ per square foot) of the CSO basin where the treatment facility is located to estimate property costs. "Land and building" unit costs of the uncontrolled CSO sites are presented in Appendix C of the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities*.

Construction Cost Curves

Three construction cost curves were developed for the optimum capacity assessment: a construction cost curve for equalization basins and two construction cost curves for treatment facilities (one for each CSO treatment process). The curves show construction cost as a function of storage volume for equalization basins and as a function of peak flow rate for treatment facilities. Appendix F.4 shows the construction cost curves used in the optimum capacity assessment.

Total Cost Curves

Combined treatment and equalization cost curves for each alternative were developed as a function of treatment peak flow rate. For a given treatment peak flow rate, the combined cost for each treatment alternative was estimated as follows:

- **Treatment facility construction cost** was determined based on peak flow rate, using the treatment facility construction cost curves.
- Treatment facility footprint sizing was determined based on peak flow rate, using the treatment facility footprint sizing curves.
- **Treatment facility property cost** was estimated by multiplying the footprint size by the "land and building" unit cost ($ per square foot) of the CSO basin where the treatment facility is located.
- Equalization basin volume was determined based on treatment facility peak flow rate, using the flow-volume curves for the treatment alternative.
- **Equalization basin construction cost** was determined based on volume, using the equalization basin construction cost curves.
- Equalization basin footprint sizing was determined based on volume, using the equalization basin footprint sizing curves.
- **Equalization basin property cost** was estimated by multiplying the footprint size by the "land and building" unit cost ($ per square foot) of the CSO basin where the treatment facility is located.
- **Total cost** was calculated as the sum of construction cost and property cost for the treatment facility and the equalization basin.

Figure 6-4 is a typical total cost curve that shows total combined costs of the above project elements (total cost) as a function of the treatment facility capacity (design flow rate). In this case, the curve illustrates that the optimal balance of equalization basin capacity and treatment capacity is when the treatment capacity is approximately 23 MGD. For this example, the corresponding equalization volume was approximately 0.79 MG. The full set of cost curves for each treatment alternative is provided in Appendix F.4.

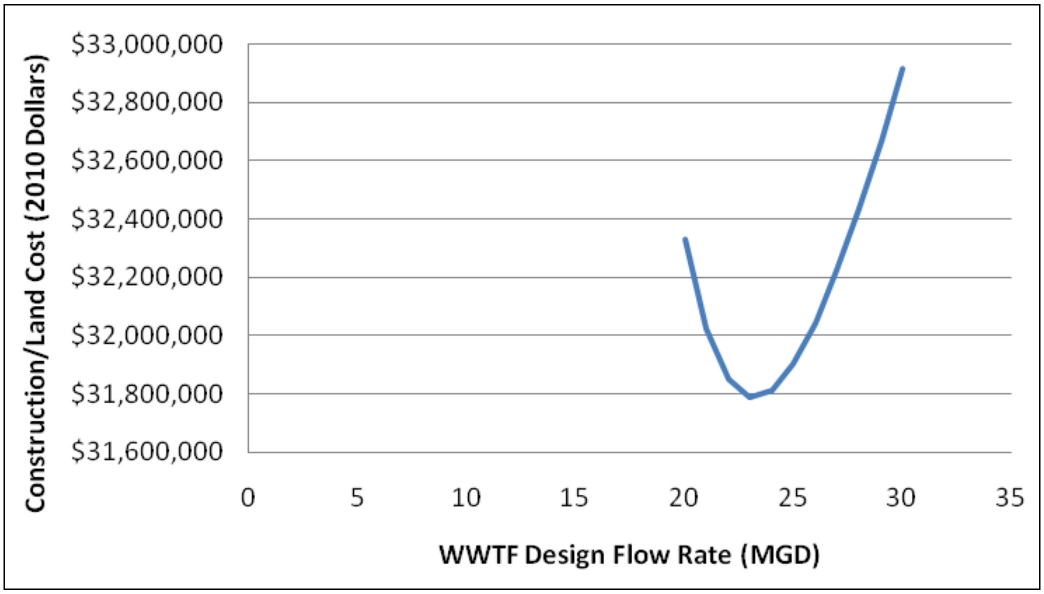

Figure 6-4. Example of a Total Cost Curve for a Ballasted Sedimentation Treatment/Equalization Alternative (Lander St)

Optimum Capacity Results

Each total cost curve includes a low point for cost (see Figure 6-4), and that point was selected as the optimal-capacity value. The treatment peak flow rate was set at the flow corresponding to the low cost, and the corresponding equalization basin volume was then determined from the flow-volume curve. Table 6-1 shows the results for both CSO treatment processes for all treatment alternatives.

Table 6-1. Treatment and Equalization Design Capacities for Wet-Weather Treatment Facility Alternatives

Alternative	CSO Treatment Process	Treatment Peak Flow Rate (MGD)	Equalization Basin Volume (MG)
Kingdome	Ballasted Sedimentation	48	0.87
	CEPT with Lamella Plates	49	0.79
Lander St	Ballasted Sedimentation	23	0.79
	CEPT with Lamella Plates	24	0.71
Hanford #2	Ballasted Sedimentation	68	0.94
	CEPT with Lamella Plates	70	0.77
Brandon St	Ballasted Sedimentation	24	0.41
	CEPT with Lamella Plates	25	0.33
S Michigan St	Ballasted Sedimentation	40	0.86
	CEPT with Lamella Plates	41	0.77

Table 6-1. Treatment and Equalization Design Capacities for Wet-Weather Treatment Facility Alternatives

Alternative	CSO Treatment Process	Treatment Peak Flow Rate (MGD)	Equalization Basin Volume (MG)
Consolidated King St and Kingdome	Ballasted Sedimentation	56	1.45
	CEPT with Lamella Plates	58	1.28
Consolidated Hanford #2 and Lander St	Ballasted Sedimentation	94	0.97
	CEPT with Lamella Plates	96	0.82
Consolidated Hanford #2, Lander St, and Kingdome	Ballasted Sedimentation	139	1.57
	CEPT with Lamella Plates	142	1.36
Consolidated Hanford #2, Lander St, Kingdome, and King St	Ballasted Sedimentation	151	1.71
	CEPT with Lamella Plates	155	1.43
Consolidated S Michigan St and Brandon St	Ballasted Sedimentation	66	0.89
	CEPT with Lamella Plates	68	0.72

Footprint Sizing

Footprint sizing for treatment facilities and equalization basins was developed for the selected optimum facility capacities using the design criteria provided in Appendices F.3 and F.1, respectively.

In some cases, a modification was required for the sizing of treatment facilities using CEPT with lamella plates. The footprint sizing curves for this CSO treatment process assumed that the CEPT settling basin would store 5 to 7 feet of solids during peak wet-weather events, so the curves do not include footprint associated with a separate solids handling facility. A separate evaluation was completed for each wet-weather treatment facility alternative to determine if the storage volume in the CEPT settling basin was sufficient for solids storage. If additional solids handling was required, the solids handling volume and surface area were calculated, and the overall facility footprint was increased accordingly. The solids handling evaluation is discussed in the *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities* and *Technical Memorandum 700, Treatment Technology Selection.*

Boundary for Potential Sites

The boundary for potential sites was established for each wet-weather treatment facility alternative as summarized below. Appendix F.3 provides design criteria and process diagrams.

Considerations and Key Design Criteria

The approximate boundaries of potential sites for wet-weather treatment facilities are generally based on maximum conveyance lengths for the treatment facility influent and effluent gravity sewers, both of which are assumed to be gravity lines with no pumping required. Ground surface elevation is not a consideration for these alternatives because treatment facilities are all located in relatively flat areas. Key design criteria for the maximum conveyance lengths of the two sewers are as follows:

- Effluent Gravity Sewer:

  - The crown of the effluent gravity sewer at the wet-weather treatment facility (the upstream end of the sewer) is assumed to be at the ground surface.
  - The water surface elevation at the treatment facility is assumed to be 4 feet above ground surface.
  - The downstream water surface elevation is assumed to be the historical King County tide elevation (over the last 10 years) plus 0.5 feet to account for potential sea level rise (= 108.71 feet at King County vertical datum). The downstream water surface elevation is assumed to be the same for all the wet-weather treatment facility alternatives and is independent of proposed CSO outfall location.
  - No pumping will be required; however, a driving head may be available due to the differential between the upstream and downstream water surface elevations.
  - The preferred slope of the effluent gravity sewer is 0.5 percent. The slope may be increased if needed to reduce the pipe diameter (this will result in a shorter maximum conveyance length) or decreased if needed to expand the boundary (this will result in a larger required pipe diameter).
  - The crown of the effluent gravity sewer at the diversion location should be below the existing overflow elevation. In instances where the crown is above the existing overflow elevation, the slope of the effluent gravity sewer can be increased (reducing boundary limits) to decrease the diameter of the effluent gravity sewer, lowering the crown of pipe below the existing overflow elevation.
- Influent Gravity Sewer
  - The invert of the influent gravity sewer at the treatment facility should be no more than 25 feet below the ground surface. This criterion is established to reduce constructability risks and allow open-cut construction methods for pipe installation.
  - The preferred slope of the influent gravity sewer is 0.5 percent. The slope of the influent sewer is adjusted only if the maximum depth of 25 feet is exceeded.
  - The length of the influent gravity sewer to the wet-weather treatment facility is initially assumed to be equal to the length of the effluent gravity sewer.
  - The crown of the influent gravity sewer at the diversion location should be below the existing overflow elevation. In instances where the crown is above the existing overflow elevation, the diameter of the influent gravity sewer should be reduced, so that the crown is below the overflow elevation. A new slope should be determined based on the reduced diameter, and the maximum conveyance length should be reduced to maintain the downstream invert elevation with the new slope. This leads to a reduced maximum conveyance length for the influent gravity sewer, which becomes the controlling length for the boundary rather than the effluent gravity sewer maximum conveyance length.

The following additional design criteria are used to establish the boundary of potential sites:

- An influent pump station at the proposed wet-weather treatment facility is required to lift flows to the facility.

- Combined sewer system flows are generally assumed to be diverted to the wet-weather treatment facility from the existing regulator station. It may be possible that flows can be diverted upstream of the existing regulator station for some alternatives; this will be evaluated during preferred alternative development.
- Wet-weather treatment facilities will not be located in water bodies.

Process for Establishing Approximate Boundary of Potential Sites

Process Diagram #3 in Appendix F.3 presents the process for establishing the approximate boundary of potential sites using the considerations and design criteria described above. The boundaries established by this process could vary as follows if any of the key design criteria are modified:

- The boundary may be expanded if:
  - Flows can be diverted further upstream of the assumed diversion location.
  - The effluent gravity sewer discharges to a new deeper structure rather than being limited to the invert of the existing regulator station.
  - The slope of the effluent gravity sewer is decreased (requiring a larger pipe).
- The boundary may be reduced if:
  - The slope of the effluent gravity sewer is increased, which decreases the diameter of the pipe.

Consolidated Wet-Weather Treatment Facility Alternatives

Consolidated wet-weather treatment alternatives include a single wet-weather treatment facility to control multiple CSO sites. For this Program Review, two boundaries of potential sites were developed for consolidated treatment alternatives:

- Approximate Boundary for **Assumed Location** of Wet-Weather Treatment Facility — This boundary is estimated using the boundary development process described above, with the CSO site with the highest CSO Peak Flow Rate as the diversion location. This boundary is represented by a solid line on alternative figures in Appendix G. The wet-weather treatment facility has been assumed to be located within or adjacent to the solid boundary for conveyance cost estimating purposes.
- Approximate Boundary for **Alternate Location** of Wet-Weather Treatment Facility— This boundary is established using the boundary development process described above at the alternate CSO site(s) that are included in the consolidated alternative and connecting the boundaries of the CSO sites being consolidated. The boundary is a combination of boundaries estimated for the alternate CSO site(s) that are included in the consolidated alternative and is represented by a dashed line on alternative figures in Appendix G. The dashed boundary is only intended to indicate that the wet-weather treatment facility could be located anywhere between the CSO sites, but conveyance would need to be reevaluated if the wet-weather treatment facility moves from the assumed location (solid boundary).

The same design criteria, assumptions, and process are used to establish both the solid and dashed boundaries. Differences in the boundaries are due to the different site conditions (diversion location, CSO Peak Flow Rate, ground surface elevations, etc.)

6.2 Estimating Planning-Level Costs

6.2.1 Cost Estimating Methodology and Accuracy

King County has developed models for planning-level conveyance facility cost estimating (the Tabula Rasa model) and for estimating allied project costs. These were used to develop cost estimates for the final alternatives in the Program Review. The *Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities* presents the project cost estimating methodologies used to estimate project and life-cycle costs.

The accuracy of an estimate varies depending on the methods used, the amount of project information available, and the time available to prepare the estimate. Using these criteria, the Association for the Advancement of Cost Engineering (AACE) classifies estimates into five types, as shown in Table 6-2. The design status of the final alternatives in the Program Review is such that the cost estimates are Class 5 estimates. The accuracy range for Class 5 estimates is –50 percent to +100 percent.

Table 6-2. Design Status for Determining Cost Estimate Class

	Class 5	Class 4	Class 3	Class 2	Class 1
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production/Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined

6.2.2 Comparison of King County and SPU Methodologies

King County and SPU each led evaluations of different collaborative alternatives. It was important that they use the same cost estimating methodologies, so that each agency could use collaborative-alternative cost estimates developed by the other agency for reasonable comparisons with their independent alternatives (alternatives that control King County CSOs or SPU CSOs only). The two agencies worked together to develop similar cost estimating methodologies for evaluating collaborative alternatives. They agreed that construction costs would be used for initial screenings of these alternatives and that each agency would develop its own life-cycle costs. Construction costs of storage and conveyance facilities were estimated using the Tabula Rasa Costing Tool (Version 3.1.2) and the January 2010 Engineering News Record Construction Cost Index (ENR CCI) for the City of Seattle (8645.35).

Still, some differences in the two agencies' methodologies were identified, as summarized in Table 6-3. Many of the differences were based on the fact that SPU identified representative sites for new facilities rather than defining approximate boundaries of potential sites, as King County did. This difference affects conveyance cost (length) and property costs.

Table 6-3. Summary of Differences in King County and SPU Cost Estimating Methodologies and Potential Impacts on Costs

	Potential Impacts on Costs	
Cost Component	**King County Cost Estimating Methodology**	**SPU Cost Estimating Methodology**
Conveyance (Diameter and Length)	Higher	Lower
Draining of Storage Facility	Lower	Higher
Regulator Station	Higher	Lower
Property Costs	Higher	Lower
Allied Costs	Similar	Similar
Allocation of Costs	Varies	Varies

Because the final number of proposed collaborative alternatives was small, King County determined that it was more time efficient to use its own cost estimating methodology to develop refined cost estimates for collaborative alternatives whose evaluation was led by SPU. These cost estimates were then used in the screening of King County final alternatives. Estimating approaches for preferred alternatives will be negotiated for predesign.

The following sections discuss the differences between the King County and SPU estimates for each cost component as well as King County's approach to developing refined estimates for collaborative alternatives developed by SPU.

Conveyance Sizing

King County and SPU used different methodologies to determine the diameter and length of conveyance pipes from the assumed diversion locations to the CSO control facilities. The differences and potential impacts to costs are described in the following sections.

Diameter

King County sized conveyance to CSO storage facilities based on the Maximum Peak Overflow Rate, as shown in Table 3-1. The Maximum Peak Overflow Rate is generally greater than the CSO Peak Flow Rate, which is what SPU used to size conveyance. Sizing conveyance for the Maximum Peak Overflow Rate provides adequate capacity to convey flows during wet-weather events that have CSO volumes smaller than the CSO Control Volume but peak flow rates higher than the 1-year event (event with 1-year recurrence frequency by volume).

For collaborative alternatives, King County used the Maximum Peak Overflow Rate for King County flows and the CSO Peak Flow Rate for SPU flows (SPU did not estimate Maximum Peak Overflow Rates for its alternatives). SPU sized conveyance based on the CSO Peak Flow Rate for both King County and SPU flows. Thus, King County generally sized conveyance to CSO storage facilities with larger diameters than SPU, resulting in higher conveyance costs.

When King County refined cost estimates of SPU-developed collaborative alternatives, the conveyance diameters estimated by SPU were used in the refined cost estimates because Maximum Peak Overflow Rates from SPU were not available.

Length

King County identified general areas but not specific sites for alternatives, so the conveyance length to CSO control facilities was conservatively estimated as the maximum conveyance length to the outer edge of the approximate boundary of potential sites. This resulted in longer conveyance lengths than required if a site closer to the diversion location is selected. SPU identified representative sites for each alternative, and based its estimated conveyance lengths on the assumed diversion location and location of the representative site. Therefore, King County generally assumed longer conveyance lengths to CSO control facilities than SPU, resulting in higher estimated conveyance costs.

Because King County did not identify specific sites for their collaborative alternatives, SPU conveyed its flows to the assumed diversion location. This could result in much longer conveyance lengths for SPU because the location of the CSO control facility could be somewhere between the SPU diversion location and the King County diversion location.

When King County refined cost estimates of SPU-developed collaborative alternatives, the conveyance lengths estimated by SPU were used in the refined cost estimates because approximate boundaries of potential sites had not yet been established by King County.

Draining of Storage Facility

King County accounts for draining pump costs using Tabula Rasa by assuming submersible pumps within the structure of the storage facility. SPU accounts for draining pump costs using Tabula Rasa by assuming a separate pump station. King County's methodology resulted in lower construction costs for storage facilities and the draining of storage facilities.

When King County refined cost estimates of SPU-developed collaborative alternatives, King County estimated the costs of submersible pumps within the structure of the storage facility using Tabula Rasa and did not estimate costs of a separate pump station.

Regulator Station

King County assumed $490,000 for each regulator station per Tabula Rasa, assuming an above-grade structure. SPU generally assumed $100,000 for diversion structures.

When King County refined cost estimates of SPU-developed collaborative alternatives, it estimated the costs of regulator stations assuming $490,000 per regulator station.

Property Costs

King County used a market-based approach to estimate property values near its uncontrolled CSO sites to develop planning-level cost estimates. This approach used sales data of properties that have sold over a specific time period to estimate values for similar properties. King County property value estimates for the Program Review were based on properties with improvements because there is a higher probability that King County would need to acquire property with improvements for these projects, given the scarcity of vacant property and size of the sites needed. Unit property costs were developed for each uncontrolled CSO basin. SPU used Tabula Rasa to estimate property costs for its alternatives, which generally resulted in lower property costs. When King County refined cost estimates of SPU-developed collaborative alternatives, it used the square footage requirement as estimated by SPU and the corresponding King County-developed property value for the specific CSO basin.

Allied Costs

King County used a cost model by PRISM (2011) to estimate allied costs for final alternatives. The cost model is based on the type of construction (treatment, conveyance, or pump station) and the construction cost. SPU used a multiplier of 2 on the construction costs to estimate total project costs. SPU also included property costs with its construction costs, whereas King County included property costs as a separate cost item. Though the methodologies differed, King County and SPU's different cost estimating methodologies resulted in similar project costs.

When King County refined cost estimates of SPU-developed collaborative alternatives, it used its own allied cost model and separated property costs from construction costs.

Allocation of Costs

For facilities that would handle both King County and SPU flows, King County allocated costs based on the King County and SPU CSO Control Volumes. For conveyance pipes that convey only King County flows, King County allocated the entire cost to King County. For conveyance pipes that convey only SPU flows, King County allocated the entire cost to SPU.

SPU allocated the entire construction and project costs, including conveyance, based on the King County and SPU CSO Control Volumes, regardless of whether the facilities are shared.

The cost impact of these differing methodologies varies depending on the alternative. If all of the facilities are shared, then King County's and SPU's methodologies result in the same allocation of costs. However, if there are different conveyance needs for each agency, then the allocation of costs would differ based on the methodology used.

When King County refined cost estimates of SPU-developed collaborative alternatives, it used its own methodology for allocation of costs, allocating based on CSO Control Volume for shared facilities and allocating to the agency that benefitted for facilities that are not shared.

6.3 Description of Final Alternatives

Final alternative descriptions are presented in the sections below, organized by area. Final alternative documentation—including detailed descriptions, cost estimates, and siting figures—is presented in Appendix G. A table of all alternatives evaluated during the Program Review—preliminary and final—is presented in Appendix A.2.

After the final alternatives had been developed with refined cost, location, and sizing information, each was assigned a new identifier to streamline the identification for reviewers, using the convention shown in Table 6-4. The original identifiers used for the preliminary alternatives described in Section 5.2 and the alternative variations described in Section 5.4 are also used in the documentation provided in Appendices A through H. The new identifiers are used for the descriptions of alternatives throughout the remainder of this technical memorandum and in Appendix H. Table 6-5 serves as a key to be used in correlating the two alternative naming conventions.

Table 6-4. Naming Convention for Final Alternatives

	CSO Area[a]		CSO Site[b]		Agency[c]		Control Approach [d]	Explanation
Example 1	SC	-	11th Ave NW	-	KC	-	CONV	Conveyance alternative for 11th Ave NW CSO site, King County participation only
Example 2	MEBI	-	King	-	Collab		STOR	Storage alternative for King St CSO site, King County and SPU participation
Example 3	SEBI	-	Cons Brandon-SMichigan	-	KC	-	WWTF (EBI Modifications)	Wet-weather treatment alternative for Brandon St and S Michigan St CSO sites using modifications to the EBI, King County participation only
Example 4	WDUW	-	Chelan	-	KC	-	STOR 2	Second storage alternative for Chelan Ave CSO site, King County participation only

a. CSO areas abbreviated as follows: SC = Ship Canal; MEBI = Middle Elliott Bay Interceptor; SEBI = South Elliott Bay Interceptor; WDUW = West Duwamish.
b. "Cons" before site name indicates a consolidated alternative.
c. Agency indicated as "KC" for King County alone or "Collab" for King County and SPU.
d. Control approaches abbreviated as follows: CONV (or Conv) = Conveyance; SEP = Sewer separation; STOR = Storage; Tunnel = Storage tunnel; WWTF = Wet-weather treatment facility. Multiple alternatives of the same type for a given CSO site are indicated by numbering or descriptor in parentheses.

Table 6-5. Correlation of Final and Preliminary Alternative Identifiers

Final Alternative Identifier	Preliminary Alternative Identifier
11th Ave NW Site Alternatives	
SC-11th Ave NW-KC-STOR	DSN004-STOR-1 (KC)
SC-11th Ave NW-KC-Conv	DSN004-CON-1 (KC)
3rd Ave W Site Alternatives	
SC-3rd Ave W-KC-STOR	DSN008-STOR-1 (KC)
SC-3rd Ave W-Collab-STOR 1	DSN008-STOR-5 (KC & SPU)
SC-3rd Ave W-Collab-STOR 2	DSN008-STOR-2 (KC & SPU)
University Site Alternatives	
SC-University-KC-STOR	DSN015-STOR-1 (KC)
SC-University-Collab-STOR	DSN015-STOR-4 (KC & SPU)
Montlake Site Alternatives	
SC-Montlake-KC-STOR	DSN014-STOR-1 (KC)
SC-Montlake-Collab-STOR	DSN014-STOR-2 (KC & SPU)
11th Ave NW, 3rd Ave W, University, and Montlake Consolidated Alternative	
SC-Cons Tunnel-Collab-STOR	DSN004/008/014/015-STOR-1 (KC & SPU)
King St Site Alternatives	
MEBI-King-KC-STOR	DSN028-STOR-1 (KC)
MEBI-King-Collab-STOR	DSN028-STOR-2 (KC & SPU)
Kingdome Site Alternative	
MEBI-Kingdome-KC-WWTF	DSN029-WWT-1 (KC)

Table 6-5. Correlation of Final and Preliminary Alternative Identifiers

Final Alternative Identifier	Preliminary Alternative Identifier
Lander St Site Alternative	
MEBI-Lander-KC-WWTF	DSN030-WWT-1 (KC)
Hanford #2 Site Alternative	
MEBI-Hanford-KC-WWTF	DSN032-WWT-1 (KC)
King St and Kingdome Consolidated Alternative	
MEBI-Cons Kingdome-King-KC-WWTF	DSN028/029-WWT-1 (KC)
Hanford #2 and Lander St Consolidated Alternative	
MEBI-Cons Hanford-Lander-KC-WWTF	DSN030/032-WWT-1 (KC)
Hanford #2, Lander St, and Kingdome Consolidated Alternative	
MEBI-Cons Hanford-Lander-Kingdome-KC-WWTF	DSN029/030/032-WWT-1 (KC)
Hanford #2, Lander St, Kingdome, and King St Consolidated Alternatives	
MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (New Conveyance)	DSN028/029/030/032-WWT-1 (KC) (New Conveyance)
MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications)	DSN028/029/030/032-WWT-1 (KC) (EBI Modifications)
Hanford #1 Site Alternatives	
MEBI-Han-Rain-BV-KC-STOR 1	DSN031-STOR-1 (KC)
MEBI-Han-Rain-BV-KC-STOR 2	DSN031-STOR-4 (KC)
MEBI-Han-Rain-BV-KC-CONV/STOR	DSN031-CON-1 (KC)
S Michigan St Site Alternative	
SEBI-SMichigan-KC-WWTF	DSN039-WWT-1 (KC)
Brandon St Site Alternatives	
SEBI-Brandon-KC-WWTF	DSN041-WWT-1 (KC)
SEBI-Brandon-KC-SEP	DSN041-SEP-1 (KC)
S Michigan St and Brandon St Consolidated Alternatives	
SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance)	DSN039/041-WWT-1 (KC) (New Conveyance)
SEBI-Cons Brandon-SMichigan-KC-WWTF (EBI Modifications)	DSN039/041-WWT-1 (KC) (EBI Modifications)
W Michigan St Site Alternative	
WDUW-WMichigan-KC-STOR	DSN042-STOR-1 (KC)
Terminal 115 Site Alternative	
WDUW-Term 115-KC-STOR	DSN038-STOR-1 (KC)
W Michigan St and Terminal 115 Consolidated Alternative	
WDUW-Cons W Michigan-Term 115-KC-STOR	DSN038/042-STOR-1 (KC)
Chelan Ave Site Alternative	
WDUW-Chelan-KC-STOR 1	DSN036-STOR-1 (KC)
WDUW-Chelan-KC-STOR 2	DSN036-STOR-2 (KC)
WDUW-Chelan-KC-CONV	DSN036-CON-1 (KC)

6.3.1 Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake

11th Ave NW Site Alternatives

The following two final alternatives were evaluated to control the 11th Ave NW CSO site (see Appendix G.1.1 for descriptions, figures, and cost estimates):

- **Alternative SC-11th Ave NW-KC-STOR** controls the 11th Ave NW CSO site by constructing a 1.85-MG offline storage tank, ancillary facilities, influent gravity sewer, and force main, and modifying the existing 11th Ave NW Overflow Structure.
- **Alternative SC-11th Ave NW-KC-Conv** controls the 11th Ave NW CSO site by constructing approximately 3,200 feet of new 84-inch-diameter conveyance pipe from the 11th Ave NW Overflow Structure to the Ballard Regulator Station and modifying the existing 11th Ave NW Overflow Structure and Ballard Regulator Station.

Potential for GSI is being evaluated in this basin (high priority in GSI evaluations). It may be possible to combine GSI with either of these alternatives to control CSOs and, for the conveyance alternative, reduce the size of the new pipe. GSI being considered includes: RainWise with assumed participation rate of 40 percent, green streets at 8th Avenue NE and 3rd Avenue NE north of NE 65th Street, and green alleys. See Appendix C for more details about the GSI opportunities in the 11th Ave NW CSO Basin.

3rd Ave W Site Alternatives

The following three final alternatives were evaluated to control the 3rd Ave W CSO site (see Appendix G.1.2 for descriptions, figures, and cost estimates):

- **Alternative SC-3rd Ave W-KC-STOR** controls the 3rd Ave W CSO site by constructing a 4.18-MG offline storage tank on the south side of the Ship Canal, ancillary facilities, influent gravity sewer, and force main, and modifying the existing 3rd Ave W Overflow Structure.
- **Alternative SC-3rd Ave W-Collab-STOR 1** controls the 3rd Ave W CSO site and SPU CSO Basins 60, 147, and 174 by constructing a 7.23-MG offline storage tank on the south side of the Ship Canal, ancillary facilities, influent gravity sewer, and force main, and modifying the existing 3rd Ave W Overflow Structure. This collaborative alternative was removed from consideration before the triple-bottom-line analysis (described in Chapter 7) because conveying SPU flows to the storage facility would require upsizing the Fremont Siphon or installing a new siphon, which would not be cost-effective.
- **Alternative SC-3rd Ave W-Collab-STOR 2** controls the 3rd Ave W CSO site and SPU CSO Basins 60, 147, and 174 by constructing a 7.23-MG offline storage facility on the north side of the Ship Canal, ancillary facilities, diversion structure, influent gravity sewer, and force main. This representative alternative was developed by SPU.

Potential for GSI is being evaluated in this basin (low priority in GSI evaluations due to predominantly steep slopes). The small amount of GSI feasible is not expected to significantly reduce the CSO Control Volume needed. GSI being considered includes: 1) demonstration projects on the Seattle Pacific University campus, 2) residential practices under SPU's

Residential RainWise Program, and 3) rain gardens and permeable pavements in parking lots and alleyways. It may be possible to combine GSI with any of these alternatives to control CSOs. See Appendix C for more details about the GSI opportunities in the 3rd Ave W CSO Basin.

University Site Alternatives

The following two final alternatives were evaluated to control the University CSO site (see Appendix G.1.3 for descriptions, figures, and cost estimates):

- **Alternative SC-University-KC-STOR** controls the University CSO site by constructing a 2.94-MG offline storage tank, ancillary facilities, regulator station (diversion structure), influent gravity sewer, and force main.
- **Alternative SC-University-Collab-STOR** controls the University CSO site and SPU North Union Bay CSOs by constructing a 5.23-MG offline storage tank adjacent to the North Interceptor, ancillary facilities, regulator station (diversion structure), influent gravity sewer, and force main.

Potential for GSI is high in basin. It may be possible to combine GSI with either of these alternatives to control CSOs. GSI being considered includes: Residential RainWise with assumed participation rate of 40 percent, green schools, green streets, and green alleys. See Appendix C for more details about the GSI opportunities in the University CSO Basin.

Montlake Site Alternatives

The following two final alternatives were evaluated to control the Montlake CSO site (see Appendix G.1.4 for descriptions, figures, and cost estimates):

- **Alternative SC-Montlake-KC-STOR** controls the Montlake CSO site by constructing a 6.6-MG offline storage tank, ancillary facilities, influent gravity sewer, and force main, and modifying the existing Montlake Regulator Station.
- **Alternative SC-Montlake-Collab-STOR** controls the Montlake CSO site and SPU Leschi, Madison Park, and Montlake CSOs by constructing a 7.87-MG offline storage tank, ancillary facilities, influent gravity sewer, and force main, and modifying the existing Montlake Regulator Station. SPU may only be sending CSOs from the Madison Park and Montlake CSO Basins to the joint storage facility, which may reduce the size of this storage facility.

Potential for GSI is high in the basin. It may be possible to combine GSI with either of these alternatives to control CSOs. GSI being considered includes: Residential RainWise with assumed participation rate of 40 percent, green schools, green streets, and green alleys. See Appendix C for more details about the GSI opportunities in the Montlake CSO Basin.

11th Ave NW, 3rd Ave W, University, and Montlake Consolidated Alternative

The following final alternative was evaluated to control the 11th Ave NW, 3rd Ave W, University, and Montlake CSO sites (see Appendix G.1.5 for description, figure, and cost estimate):

- **Alternative SC-Cons Tunnel-Collab-STOR** controls the 11th Ave NW, 3rd Ave W, University, and Montlake CSO sites and SPU’s Portage Bay/Lake Union, Montlake, North Union Bay, Union Bay/Madison Park, and Fremont/Wallingford CSO Basins by constructing a 21.4-MG storage tunnel along the Ship Canal. This representative alternative was developed by SPU.

Potential for GSI is high in the basins. It may be possible to combine GSI with this alternative to control CSOs. GSI being considered includes: Residential RainWise with assumed participation rate of 40 percent, green schools, green streets, and green alleys. See Appendix C for more details about the GSI opportunities in the 11th Ave NW, 3rd Ave W, University, and Montlake CSO Basins. Comparison of the conveyance alternative for 11th Ave NW may lead to the removal of its flows from the tunnel design.

6.3.2 Middle EBI—Hanford #2, Lander St, Kingdome, and King St

King St Site Alternatives

The following two final alternatives were evaluated to control the King St CSO site (see Appendix G.3.4 for descriptions, figures, and cost estimates):

- **Alternative MEBI-King-KC-STOR** controls the King St CSO site by constructing a 2.63-MG offline storage tank, ancillary facilities, influent gravity sewer, and force main, and modifying the King St Regulator Station.
- **Alternative MEBI-King-Collab-STOR** controls the King St CSO site and SPU CSOs (Vine St, Madison St, University St, and Washington St CSOs) by constructing a 3.28-MG offline storage tank, ancillary facilities, influent gravity sewer, and force main, and modifying the King St Regulator Station. SPU may only be sending CSOs from the Madison St, University St, and Washington St CSO Basins to the joint storage facility, which may reduce the size of this storage facility. This collaborative alternative was not included in the triple-bottom-line analysis (described in Chapter 7) for simplicity in evaluating area alternatives. It is assumed that either of the King St storage alternatives could be chosen for future development, but the King-County-only storage site alternative was used in the triple-bottom-line analysis instead of this collaborative alternative.

Kingdome Site Alternative

The following final alternative was evaluated to control the Kingdome CSO site (see Appendix G.3.3 for description, figure, and cost estimate):

- **Alternative MEBI-Kingdome-KC-WWTF** controls the Kingdome CSO site by constructing a wet-weather treatment facility (design capacity of 48.0 MGD using ballasted sedimentation or 49.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, influent pump station, influent gravity sewer, effluent gravity sewer and an extension to the CSO outfall, and modifying the Kingdome Regulator Station.

Lander St Site Alternative

The following final alternative was evaluated to control the Lander St CSO site (see Appendix G.3.2 for description, figure, and cost estimate):

- **Alternative MEBI-Lander-KC-WWTF** controls the Lander St CSO site by constructing a wet-weather treatment facility (design capacity of 23.0 MGD using ballasted sedimentation or 24.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, influent pump station, influent gravity sewer, effluent gravity sewer, and an extension to the existing CSO outfall, and modifying the Lander St Regulator Station.

Hanford #2 Site Alternative

The following final alternative was evaluated to control the Hanford #2 CSO site (see Appendix G.3.1 for description, figure, and cost estimate):

- **Alternative MEBI-Hanford-KC-WWTF** controls the Hanford #2 CSO site by constructing a wet-weather treatment facility (design capacity of 68.0 MGD using ballasted sedimentation or 70.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, influent pump station, influent gravity sewer, effluent gravity sewer, and an extension to the existing CSO outfall, and modifying the Hanford St Regulator Station.

King St and Kingdome Consolidated Alternative

The following final alternative was evaluated to control the King St and Kingdome CSO sites (see Appendix G.3.5 for description, figure, and cost estimate):

- **Alternative MEBI-Cons Kingdome-King-KC-WWTF** controls the King St and Kingdome CSO sites by constructing a wet-weather treatment facility (design capacity of 56.0 MGD using ballasted sedimentation or 58.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, influent pump station, influent gravity sewers, effluent gravity sewer, and a new CSO outfall, and modifying the King St and Kingdome Regulator Stations.

Hanford #2 and Lander St Consolidated Alternative

The following final alternative was evaluated to control the Hanford #2 and Lander St CSO sites (see Appendix G.3.6 for description, figure, and cost estimate):

- **Alternative MEBI-Cons Hanford-Lander-KC-WWTF** controls the Hanford #2 and Lander St CSO sites by constructing a wet-weather treatment facility (design capacity of 94.0 MGD using ballasted sedimentation or 96.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, influent gravity sewers, effluent gravity sewer, and a new CSO outfall, and modifying the Hanford St and Lander St Regulator Stations.

Hanford #2, Lander St, and Kingdome Consolidated Alternative

The following final alternative was evaluated to control the Hanford #2, Lander St, and Kingdome CSO sites (see Appendix G.3.7 for description, figure. and cost estimate):

- **Alternative MEBI-Cons Hanford-Lander-Kingdome-KC-WWTF** controls the Hanford #2, Lander St, and Kingdome CSO sites by constructing a wet-weather treatment facility (design capacity of 139.0 MGD using ballasted sedimentation or 142.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, conveyance from Kingdome and Lander St Regulator Stations to the wet-weather treatment facility, influent gravity sewer, effluent gravity sewer, and a new CSO outfall, and modifying the Hanford St, Lander St, and Kingdome Regulator Stations.

Hanford #2, Lander St, Kingdome, King St Consolidated Alternatives

The following two final alternatives were evaluated to control the Hanford #2, Lander St, Kingdome, and King St CSO sites (see Appendix G.3.8 for descriptions, figures, and cost estimates):

- **Alternative MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (New Conveyance)** controls the Hanford #2, Lander St, Kingdome, and King St CSO sites by constructing a wet-weather treatment facility (design capacity of 151.0 MGD using ballasted sedimentation or 155.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, conveyance from King St, Kingdome, and Lander St Regulator Stations to the wet-weather treatment facility, influent gravity sewer, effluent gravity sewer, and a new CSO outfall, and modifying the King St, Kingdome, Lander St, and Hanford St Regulator Stations.
- **Alternative MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications)** controls the Hanford #2, Lander St, Kingdome, and King St CSO sites by constructing a wet-weather treatment facility (design capacity of 151.0 MGD using ballasted sedimentation or 155.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, EBI Diversion Structure, EBI Gate and Bypass Structure, influent gravity sewer, effluent gravity sewer, and a new CSO outfall, and modifying the Kingdome, Lander St, and Hanford St Regulator Stations.

These alternatives will be evaluated to incorporate SPU flow transfers from the south waterfront area, CSO Outfall 107, and the Genesee projects.

6.3.3 Middle EBI—Hanford #1

Hanford #1 Site Alternatives

The following three final alternatives were evaluated to control the Hanford #1 CSO site (see Appendix G.4 for descriptions, figures, and cost estimates):

- **Alternative MEBI-Han-Rain-BV-KC-STOR 1** controls Hanford #1 and Bayview North CSOs by constructing a 1.79-MG offline storage tank near the Bayview North Overflow Structure, ancillary facilities, conveyance from the Hanford@Rainier Overflow Structure to the storage tank, an influent gravity sewer, and a force main, and modifying the Hanford@Rainier Overflow Structure and Bayview North Overflow Structure.
- **Alternative MEBI-Han-Rain-BV-KC-STOR 2** controls Hanford #1 and Bayview North CSOs by constructing two offline storage tanks (1.02 MG and 0.77 MG) near the Hanford@Rainier Overflow Structure and Bayview North Overflow Structure, respectively, ancillary facilities, influent gravity sewers, and force mains, and modifying the Hanford@Rainier Overflow Structure and Bayview North Overflow Structure.
- **Alternative MEBI-Han-Rain-BV-KC-CONV/STOR** controls Hanford #1 CSOs by constructing a 0.34-MG offline storage tank near the Hanford@Rainier Overflow Structure, ancillary facilities, influent gravity sewer and force main, and modifying the Hanford@Rainier Overflow Structure. This alternative controls Bayview North CSOs by constructing conveyance from the Bayview North Overflow Structure to the Bayview

Tunnel and a new regulator station on the Bayview Tunnel, and modifying the Bayview North Overflow Structure.

Potential for GSI is high in this basin. Seattle University and Yesler Terrace are good candidates for GSI. Much of this basin consists of residential parcels with a few small parks. GSI being considered includes: Residential RainWise, green streets, green schools, and green alleys. RainWise may be restricted to cisterns on many of the residential properties in Sub-basins 223 and 225. It may be possible to combine GSI with any of these alternatives to control CSOs. See Appendix C for more details about the GSI opportunities in the Hanford #1 CSO Basin.

6.3.4 South EBI

S Michigan St Site Alternative

The following final alternative was evaluated to control the S Michigan St CSO site (see Appendix G.5.1 for description, figure, and cost estimate):

- **Alternative SEBI-SMichigan-KC-WWTF** controls the S Michigan St CSO site by constructing a wet-weather treatment facility (design capacity of 40.0 MGD using ballasted sedimentation or 41.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, influent gravity sewer, effluent gravity sewer, and an extension to the existing CSO outfall, and modifying the existing S Michigan St Regulator Station.

Potential for GSI is high in the basin. It may be possible to combine GSI with this alternative to control CSOs. The community is very interested in Commercial and Residential RainWise and GSI for this basin. GSI being considered includes green alleys and bioswales. Depth to groundwater could be an issue for infiltration techniques in some areas. Potential partnerships with the Environmental Coalition of South Seattle and the Lower Duwamish Working Group may be possible. See Appendix C for more details about the GSI opportunities in the S Michigan St CSO Basin.

Brandon St Site Alternatives

The following two final alternatives were evaluated to control the Brandon St CSO site (see Appendix G.5.2 for descriptions, figures, and cost estimates):

- **Alternative SEBI-Brandon-KC-WWTF** controls the Brandon St CSO site by constructing a wet-weather treatment facility (design capacity of 24.0 MGD using ballasted sedimentation or 25.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, influent gravity sewer, effluent gravity sewer, and an extension to the existing CSO outfall, and modifying the existing Brandon St Regulator Station.
- **Alternative SEBI-Brandon-KC-SEP** controls the Brandon St CSO site by constructing a new separated sanitary sewer system and reusing the existing combined sewer system as a new storm drain system. This alternative includes on-site water quality projects for new stormwater.

Potential for GSI is high in the basin in this area. It may be possible to combine GSI with any of these alternatives to control CSOs. The community is very interested in Commercial and Residential RainWise and GSI for this basin. GSI being considered includes green alleys and bioswales. Depth to groundwater could be an issue for infiltration techniques in some areas.

Potential partnerships with the Environmental Coalition of South Seattle and the Lower Duwamish Working Group may be possible. See Appendix C for more details about the GSI opportunities in the Brandon St CSO Basin.

S Michigan St and Brandon St Consolidated Alternatives

The following two final alternatives were evaluated to control the S Michigan St and Brandon St CSO sites (see Appendix G.5.3 for descriptions, figures, and cost estimates):

- **Alternative SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance)** controls the S Michigan St and Brandon St CSO sites by constructing a wet-weather treatment facility (66.0 MGD using ballasted sedimentation or 68.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, conveyance from Brandon St Regulator Station to the wet-weather treatment facility, influent gravity sewer, effluent gravity sewer, and a new CSO outfall, and modifying the Brandon St and S Michigan St Regulator Stations.
- **Alternative SEBI-Cons Brandon-SMichigan-KC-WWTF (EBI Modifications)** controls the S Michigan St and Brandon St CSO sites by constructing a wet-weather treatment facility (66.0 MGD using ballasted sedimentation or 68.0 MGD using CEPT with lamella plates), equalization basin, ancillary facilities, EBI Diversion Structure, EBI Gate and Bypass Structure, influent gravity sewers, effluent gravity sewer, and a new CSO outfall, and modifying the Brandon St Regulator Station and S Michigan St Regulator Station.

Potential for GSI is high in the two basins in this area. It may be possible to combine GSI with any of these alternatives to control CSOs. The community is very interested in Commercial and Residential RainWise and GSI for these basins. GSI being considered includes green alleys and bioswales. Depth to groundwater could be an issue for infiltration techniques in some areas. Potential partnerships with the Environmental Coalition of South Seattle and the Lower Duwamish Working Group may be possible. See Appendix C for more details about the GSI opportunities in the S Michigan St and Brandon St CSO Basins.

6.3.5 West Duwamish—W Michigan St and Terminal 115

W Michigan St Site Alternative

The following final alternative was evaluated to control the W Michigan St CSO site (see Appendix G.6.1 for description, figure, and cost estimate):

- **Alternative WDUW-WMichigan-KC-STOR** controls the W Michigan St CSO site by constructing a 0.27-MG offline storage pipe, ancillary facilities, a regulator station (diversion structure), influent gravity sewer, and force main.

Potential for GSI is low in this basin. It may be possible to combine GSI with this alternative to reduce CSOs. Commercial and Residential RainWise with 40 percent participation may be feasible. See Appendix C for more details about the GSI opportunities in the W Michigan St CSO Basin.

Terminal 115 Site Alternative

The following final alternative was evaluated to control the Terminal 115 CSO site (see Appendix G.6.2 for description, figure, and cost estimate):

- **Alternative WDUW-Term 115-KC-STOR** controls the Terminal 115 CSO site by constructing a 0.05-MG offline storage pipe, ancillary facilities, a regulator station (diversion structure), influent gravity sewer, and a force main.

W Michigan St and Terminal 115 Consolidated Alternative

The following final alternative was evaluated to control the W Michigan St and Terminal 115 CSO sites (see Appendix G.6.3 for description, figure, and cost estimate):

- **Alternative WDUW-Cons W Michigan-Term 115-KC-STOR** controls the W Michigan St and Terminal 115 CSO sites by constructing a 0.32-MG offline storage pipe, ancillary facilities, regulator stations (diversion structures), influent gravity sewers, and a force main.

Potential for GSI is low in this basin. It may be possible to combine GSI with this alternative to reduce CSOs. Commercial and Residential RainWise with 40 percent participation may be feasible. See Appendix C for more details about the GSI opportunities in the W Michigan St and Terminal 115 CSO Basins.

6.3.6 West Duwamish—Chelan Ave

Chelan Ave Site Alternatives

The following three final alternatives were evaluated to control the Chelan Ave CSO site (see Appendix G.7 for descriptions, figures, and cost estimates):

- **Alternative WDUW-Chelan-KC-STOR 1** controls the Chelan Ave and Harbor Ave CSO sites by constructing a 3.85-MG offline storage tank near the Chelan Ave Regulator Station, ancillary facilities, influent gravity sewer, and force main, and modifying the existing Chelan Ave Regulator Station and Alki Trunk.
- **Alternative WDUW-Chelan-KC-STOR 2** controls the Chelan Ave and Harbor Ave CSO sites by constructing two caissons for storage (3.85 MG of total storage) adjacent to the West Seattle Pump Station, ancillary facilities, diversion and pressure pipes (from Delridge Trunk to the Harbor CSO Pipeline), regulator stations (diversion structures), a drain structure, an influent gravity sewer, and a force main, and modifying the existing Harbor Ave Regulator Station and Alki Trunk.
- **Alternative WDUW-Chelan-KC-CONV** controls the Chelan Ave and Harbor Ave CSO sites by constructing a 46.0-MGD upgrade to the 63rd Ave Pump Station and Alki Treatment Facility, diversion and pressure pipes (from Delridge Trunk to the Harbor CSO Pipeline), regulator stations (diversion structures), a drain structure, a force main, and a new CSO outfall, and modifying the existing Harbor Ave Regulator Station.

Potential for GSI is low in this basin. It may be possible to combine GSI with any of these alternatives to reduce CSOs. Commercial and Residential RainWise may be feasible. See Appendix C for more details about the GSI opportunities in the Chelan Ave CSO Basin.

7.0. IDENTIFYING RECOMMENDED PREFERRED ALTERNATIVES

The final alternatives were evaluated using the triple-bottom-line analysis process. This section describes the triple-bottom-line analysis performed to evaluate and compare final alternatives to select recommended preferred alternatives for each area, based on the development and application of environmental, social, and financial metrics.

7.1 Triple-Bottom-Line Analysis Process

A triple-bottom-line analysis evaluates the financial, social and environmental benefits and risks of alternatives under consideration. It identifies the optimal balance between life-cycle costs and social and environmental aspects. The analysis promotes decision-making based on relevant information from a variety of perspectives. It also provides the following benefits:

- Involves a collaborative, transparent consensus-building process.
- Considers costs and benefits based on multiple criteria.
- Addresses multiple, conflicting objectives.
- Provides clear, defensible, well-documented results.
- Identifies key risks.
- Incorporates uncertainty in costs and benefits.

For the financial aspect of triple-bottom-line analysis, the cost of each alternative is estimated based on conceptual design information. Typically, the costs include the present value of capital (i.e., construction), operations, maintenance, and equipment replacement costs. For the social and environmental aspects of the analysis, benefits are analyzed using a technique called "value modeling." Each alternative is evaluated for the extent to which it meets project criteria, and the criteria are weighted according to their relative importance. Triple-bottom-line analysis includes the following steps:

- Develop criteria.
- Establish criteria weighting.
- Develop alternatives.
- Produce cost estimates.
- Evaluate alternatives.
- Perform value modeling.
- Identify risks.
- Perform risk analysis.
- Review results and identify preferred alternatives.

Details on the analysis process are presented in the *Approach to Triple-Bottom-Line Analysis Technical Memorandum* (included in Appendix H.1). The following sections (Section 7.1.1 to Section 7.1.9) describe how each of the triple-bottom-analysis steps listed above was applied for the Program Review.

7.1.1 Develop Criteria

The following criteria were used for the triple-bottom-line analysis:

- Technical considerations
  - Technical complexity
  - Flexibility/adaptive management
  - Constructability
  - Implementation schedule
  - Siting
  - Coordination with other King County projects
- Community and public health
  - Construction impacts
  - Potential community impacts
  - Human health
  - Environmental/social justice
- Environmental impacts
  - Overall environmental
  - Sustainability
- Land use and permitting
  - Permitting complexity
- Operations and maintenance
  - Operations and maintenance
  - Employee safety.

These are the same as the criteria established for the screening of preliminary alternatives (see Section 5.3.1 and Appendix D), with one exception: relative life-cycle cost was not included because life-cycle costs were used separately for final alternative triple-bottom-line analysis. Removing this criterion prevents double accounting for cost-effectiveness in the triple-bottom-line analysis.

7.1.2 Establish Criteria Weighting

Weighting was established for each criteria category, and all criteria within each category received the same weighting factor. Table 7-1 presents the criteria weighting.

Table 7-1. Criteria Weighting for Triple-Bottom-Line Analysis

Criteria Category	Weighting Factor
Technical Considerations	20
Community and Public Health	20
Environmental Impacts	10
Land Use and Permitting	10
Operations & Maintenance	35
Total of Weighting Factors	**100**

The weighting emphasizes criteria categories that help differentiate alternatives from each other. Categories for which alternatives receive a wide range of value scores are given greater weight. Categories for which all alternatives are given similar value scores are less useful in differentiating the alternatives. For these reasons, Environmental Impacts and Land Use and Permitting were assigned lower weighting factors than other categories; alternatives generally received the same value scores in these categories.

7.1.3 Develop Alternatives

Sections 5.0 and 6.0 describe the development of alternatives from preliminary to final. Combinations of the final alternatives were used to create area alternatives, as described in Section 7.1.9.

7.1.4 Produce Cost Estimates

Life-cycle cost estimates of final alternatives were used in the triple-bottom-line analysis. Cost estimates were produced for final alternatives as described in Section 6.2.

7.1.5 Evaluate Alternatives

The preliminary alternatives advanced for further consideration through the initial screening process (Section 5.3) and the alternative variations described in Section 5.4 are included among the final alternatives. These final alternatives are evaluated in the triple-bottom-line analysis.

7.1.6 Perform Value Modeling

The screening of preliminary alternatives assigned ratings of high, medium, or low to each alternative for each criterion (see Appendix E). For the triple-bottom-line analysis, the ratings were converted to value scores by assigning High = 3, Medium = 2, and Low = 1. The ratings were reviewed and refined as appropriate to account for changes in the alternatives between the preliminary and final alternatives screening processes. Ratings and their associated value scores also were assigned for the alternative variations that were developed after the screening of preliminary alternatives.

Once the final alternatives were assigned value scores for all criteria, the weighting factors developed for the criteria categories (Table 7-1) were applied to the value scores, and the weighted value scores were totaled. See Appendix H.2.1 for the value scores and weighting of final alternatives for the triple-bottom-line analysis.

Value scores were calculated for each area alternative by summing and weighting the value scores for each site or consolidated final alternative that it includes, based on the CSO Control Volume for storage alternatives or the CSO Peak Flow Rate for treatment alternatives. For example, the value score would be calculated as follows for an area alternative consisting of two storage site alternatives:

$$\text{Area Alternative Value Score} = \frac{(\text{Site 1 Value Score} * \text{Site 1 CSO Control Volume}) + (\text{Site 2 Value Score} * \text{Site 2 CSO Control Volume})}{\text{Site 1 CSO Control Volume} + \text{Site 2 CSO Control Volume}}$$

7.1.7 Identify Risks

Qualitative risks, rather than quantitative risks, were used for the risk analysis because of the amount of information available and level of development at this planning stage. The following risks were identified and included in the risk analysis (see Appendix H.2.2):

- Constructability
- Equipment failure
- Complex controls
- Permitting of new outfall
- Property availability
- Staff availability
- Coordination with other projects
- Regulatory agency approval
- Construction cost and bid overruns
- Stakeholder pressure
- Changes in volume or flow parameters
- Downstream system impacts.

All qualitative risks were considered to be of equal weight, though some may result in greater impacts on cost and schedule than others.

7.1.8 Risk Analysis

Once the qualitative risks were identified, each qualitative risk was scored for each alternative based on its likelihood and consequence, using the risk assessment framework presented in Figure 7-1. The results of the risk analysis for the final alternatives are presented in Appendix H.2.2.

The results of the risk analysis were converted to a risk score for each final alternative. The risk score for each final alternative was calculated as the number of critical risks multiplied by three plus the number of high risks. For area alternatives, risk scores were summed and weighted based on the CSO Control Volume for storage alternatives or CSO Peak Flow Rate for treatment alternatives for each contributing CSO site, as described for value scores in Section 7.1.5. Based on the risk scoring, each alternative was assigned one of the three colors indicated in Table 7-2. The three colors in Table 7-2 (Blue, Orange, and Red) are unrelated to the four colors associated with Low, Medium, High, and Critical Risks in Figure 7-1.

	Impact				
Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost certain	M	M	H	C	C
Likely	M	M	H	C	C
Possible	L	M	M	H	H
Unlikely	L	L	M	H	H
Rare	L	L	M	M	M

L	Low
M	Medium
H	High
C	Critical

Figure 7-1. Risk Assessment Framework

Table 7-2. Graphical Representation of Risk Scores

Color Representation in Triple-Bottom-Line Analysis Results	Risk Score Range	Description
Blue	0 to 2	Relatively Low Risk
Orange	3 to 7	Relatively Medium Risk
Red	8 to 11	Relatively High Risk

7.1.9 Review Results and Identify Preferred Alternatives

Alternative "screening brackets" were created for each area evaluated in the Program Review. Figure 7-2 shows an example of the alternative screening bracket for the W Michigan St and Terminal 115 area. These brackets graphically depict how site and consolidated alternatives were screened and combined to form area alternatives that were compared to select a recommended preferred alternative for each area. They include site and consolidated alternatives considered for the area, with corresponding value scores and life-cycle costs.

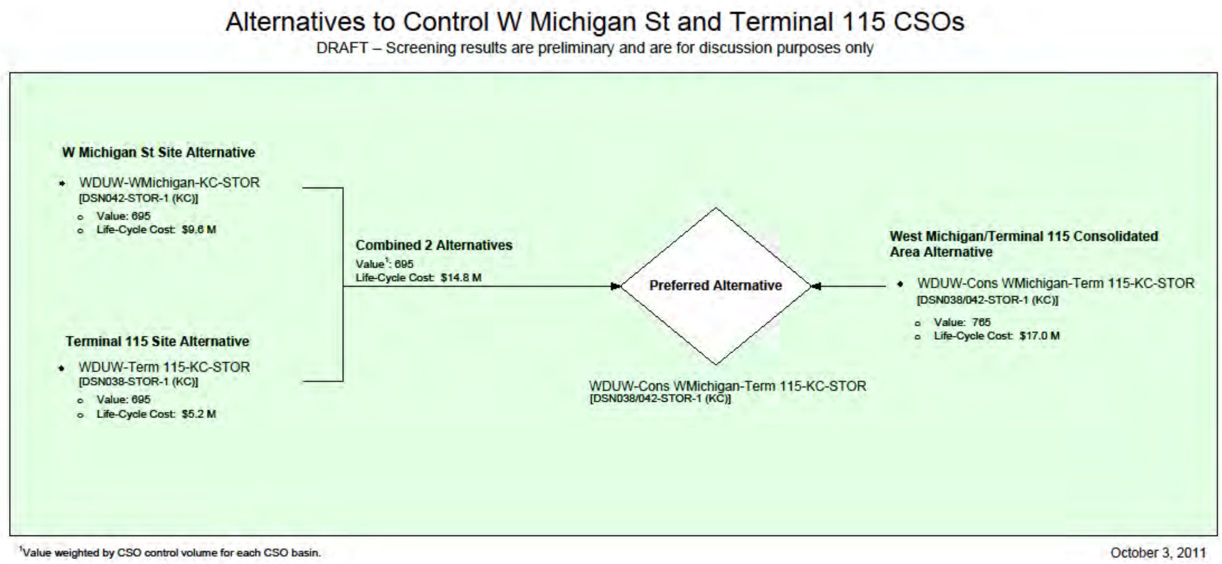

Figure 7-2. Example of Alternative Screening Bracket (W Michigan St and Terminal 115)

Results of the triple-bottom-line analysis were presented at multiple King County meetings for review, input, and recommendations. The review of the results and selection of recommended preferred alternatives, organized by area, are presented in Section 7.2 and Appendix H.3.

Identifying Preferred Site Alternatives

For each uncontrolled CSO site, each site alternative was evaluated by the triple-bottom-line analysis to establish its estimated life-cycle cost, value score, and color-coded risk category. A preferred site alternative was then identified as follows for each uncontrolled CSO site:

- For uncontrolled CSO sites with only one site alternative, that alternative is the preferred site alternative.
- For uncontrolled CSO sites with multiple site alternatives, the estimated life-cycle cost and value score were plotted on scatter graphs, and the points for each alternative were color-coded to indicate its risk category. If any alternative had the lowest cost, highest value score, and lowest risk, it was chosen as the preferred site alternative. Otherwise, the results were qualitatively assessed to identify a preferred site alternative. In the sample scatter graph shown on Figure 7-3, for example, one alternative has a higher value score and lower life-cycle cost, but a higher risk category. Selection of a preferred alternative would qualitatively balance the undesirable higher risk against the desirable low cost and high value score.

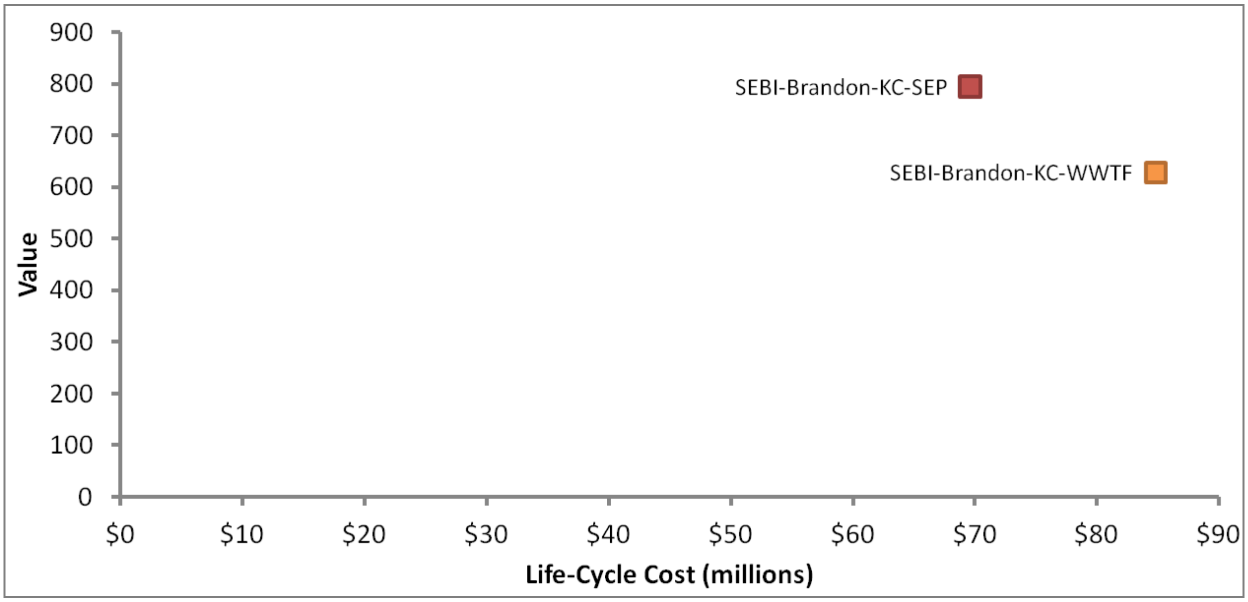

Figure 7-3. Sample Scatter Graph for Identifying Preferred Site Alternative

Identifying Recommended Preferred Alternatives from Area Alternatives

After preferred site alternatives were identified for each uncontrolled CSO site, area alternatives were developed as follows:

- For areas that include one uncontrolled CSO site, each site alternative represents an area alternative. For example, this occurs in the Middle EBI – Hanford #1 area (Section 7.2.3).
- For areas that include more than one uncontrolled CSO site:
  - The combination of preferred site alternatives for every uncontrolled CSO site in the area represents an area alternative. For example, this occurs in the Ship Canal – 11th Ave NW, 3rd Ave W, University, and Montlake area where the four preferred site alternatives are combined as an area alternative to compare to the tunnel alternative (alternative that controls all four uncontrolled sites); see Section 7.2.1.
  - Any consolidated alternative that would control all uncontrolled CSO sites in the area represents an area alternative. For example, this occurs in the Ship Canal – 11th Ave NW, 3rd Ave W, University, and Montlake area where the tunnel alternative controls all uncontrolled sites in the area; see Section 7.2.1.
  - A consolidated alternative that would control some of the uncontrolled CSO sites in the area, combined with another consolidated alternative or site alternatives for the remaining uncontrolled CSO sites in the area, represents an area alternative. For example, this occurs in the Middle EBI – Hanford #2, Lander St, Kingdome, and King St area where multiple area alternatives are formed by combining consolidated alternatives and site alternatives to control all uncontrolled CSO sites in the area; see Section 7.2.2

The triple-bottom-line analysis process was used to determine life-cycle cost, value score, and color-coded risk category for each area alternative. These were then plotted for each area on scatter graphs to identify the recommended preferred alternative for the area in the same way as described above for the preferred site alternatives.

7.2 Comparing Final Alternatives and Selecting Recommended Preferred Alternatives

Appendix H.3 presents the detailed triple-bottom-line analysis conducted for the Program Review, including all scatter graphs developed and alternative screening brackets. The process and results for each area are summarized in the following sections.

7.2.1 Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake

Evaluation of Site Alternatives

Table 7-3 summarizes the triple-bottom-line analysis of site alternatives for each uncontrolled CSO site in this area, and indicates the preferred site alternative for each. Details are provided in Appendix H.3.1. Site alternatives are conceptually shown in Figure 7-4.

The following considerations led to the selection of preferred site alternatives for the uncontrolled CSO sites in this area:

- **11th Ave NW CSO Site—**The two alternatives have similar value and risk scores, but the conveyance alternative (**SC-11th Ave NW-KC-Conv**) is approximately $14 million (39 percent) lower in life-cycle costs than the storage alternative and is therefore preferred.
- **3rd Ave W CSO Site**—The two alternatives have similar life-cycle costs and risk scores (medium risk), but the overall value score is higher for the collaborative alternative. Also, there appears to be limited siting opportunities in the vicinity of the 3rd Ave Overflow Structure on the south side of the Ship Canal, and collaboration with SPU is preferred because it reduces the number of King County and SPU facilities and potential community impacts. Therefore, the collaborative alternative located north of the Ship Canal (**SC-3rd Ave W-Collab-STOR 2**) is preferred.
- **University CSO Site—**The two alternatives have similar risk scores and life-cycle costs, but the overall value score is slightly higher for the independent alternative. Collaboration with SPU has high value because it reduces the number of King County and SPU facilities and potential community impacts; however, this benefit is not captured in the triple-bottom-line analysis results (reduction in number of King County and SPU facilities was not captured in value scores, only reduction in number of King County facilities). Considering the limited siting opportunities in the vicinity of the University Regulator Station, the collaborative alternative (**SC-University-Collab-STOR**) is preferred.
- **Montlake CSO Site—**The two alternatives have similar risk scores and life-cycle costs, but the overall value score is slightly higher for the independent alternative. Collaboration with SPU has high value because it reduces the number of King County and SPU facilities and potential community impacts; however, this benefit is not captured

in the triple-bottom-line analysis results (reduction in number of King County and SPU facilities was not captured in value scores, only reduction in number of King County facilities). Considering the limited siting opportunities in the vicinity of the Montlake Regulator Station, the collaborative alternative (**SC-Montlake-Collab-STOR**) is preferred.

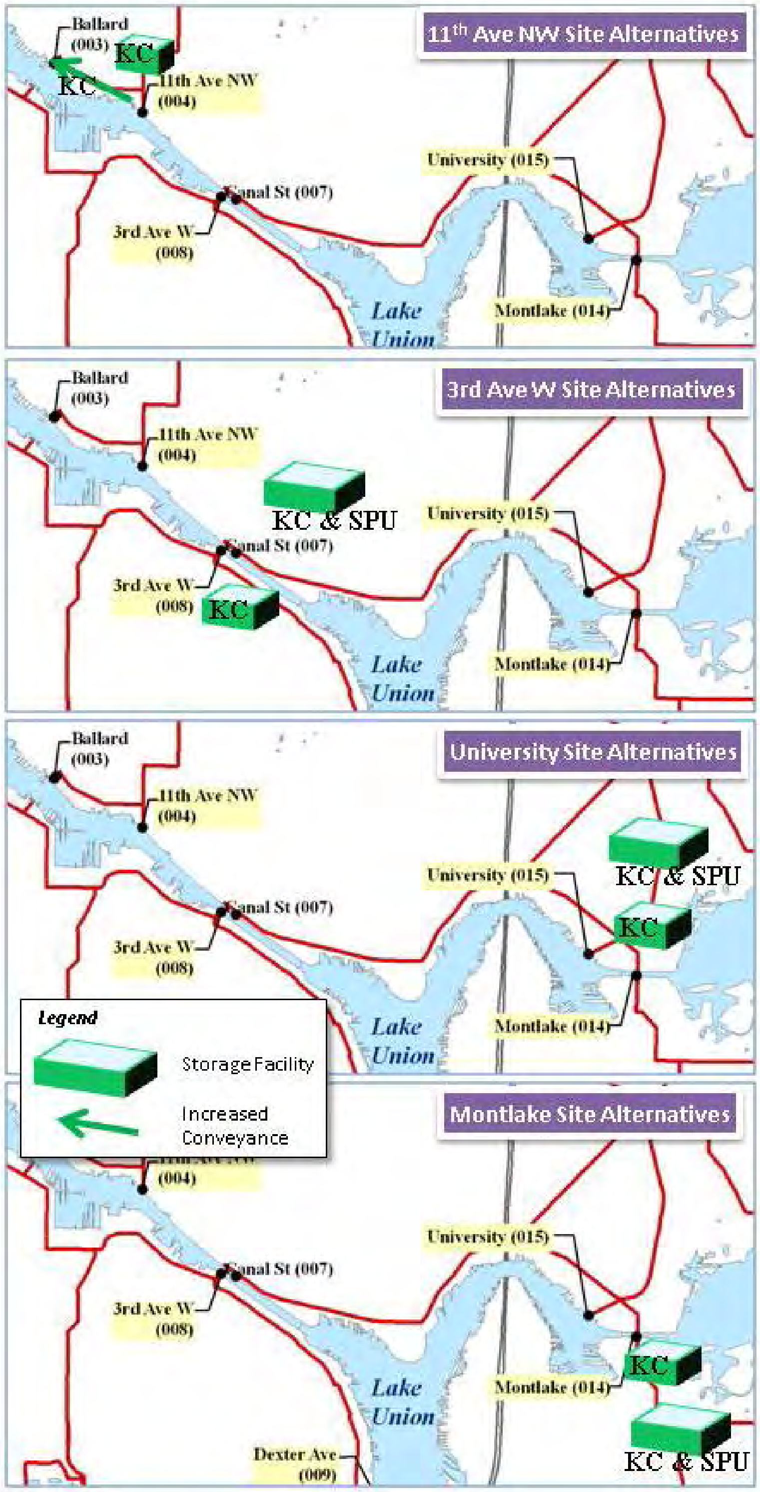

Figure 7-4. Site Alternatives for Ship Canal—11th Ave NW, 3rd Ave W, University, Montlake

Table 7-3. Triple-Bottom-Line Analysis of Site Alternatives for Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Preferred Site Alternative
11th Ave NW Site Alternatives					
SC-11th Ave NW-KC-STOR	1.85-MG storage tank	$36.1	675	Blue (low)	
SC-11th Ave NW-KC-Conv	3,200 feet of 84-inch-diameter conveyance pipe	$22.1	670	Blue (low)	X
3rd Ave W Site Alternatives					
SC-3rd Ave W-KC-STOR	4.18-MG storage tank south of Ship Canal; King County only	$66.9	620	Orange (medium)	
SC-3rd Ave W-Collab-STOR 2	7.23-MG storage tank north of Ship Canal; with SPU	$51.5	650	Orange (medium)	X
University Site Alternatives					
SC-University-KC-STOR	2.94-MG storage tank; King County only	$60.2	615	Orange (medium)	
SC-University-Collab-STOR	5.23-MG storage tank; with SPU	$53.8	595	Orange (medium)	X
Montlake Site Alternatives					
SC-Montlake-KC-STOR	6.60-MG storage tank; King County only	$115.9	630	Orange (medium)	
SC-Montlake-Collab-STOR	7.87-MG storage tank; with SPU	$105.5	610	Orange (medium)	X

a. Life-cycle cost allocated to King County.

Identification of Area Alternatives

The area alternatives for the Ship Canal-11th Ave NW, 3rd Ave W, University, and Montlake area are as follows (area alternatives are shown conceptually in Figure 7-5):

- Combined Preferred Site Alternatives:
  - SC-11th Ave NW-KC-Conv (11th Ave NW Conveyance)
  - SC-3rd Ave W-Collab-STOR 2 (3rd Ave W Storage with SPU, North of Ship Canal)
  - SC-University-Collab-STOR (University Storage with SPU)
  - SC-Montlake-Collab-STOR (Montlake Storage with SPU).
- Consolidated Alternative—SC-Cons Tunnel-Collab-STOR (Storage Tunnel with SPU)

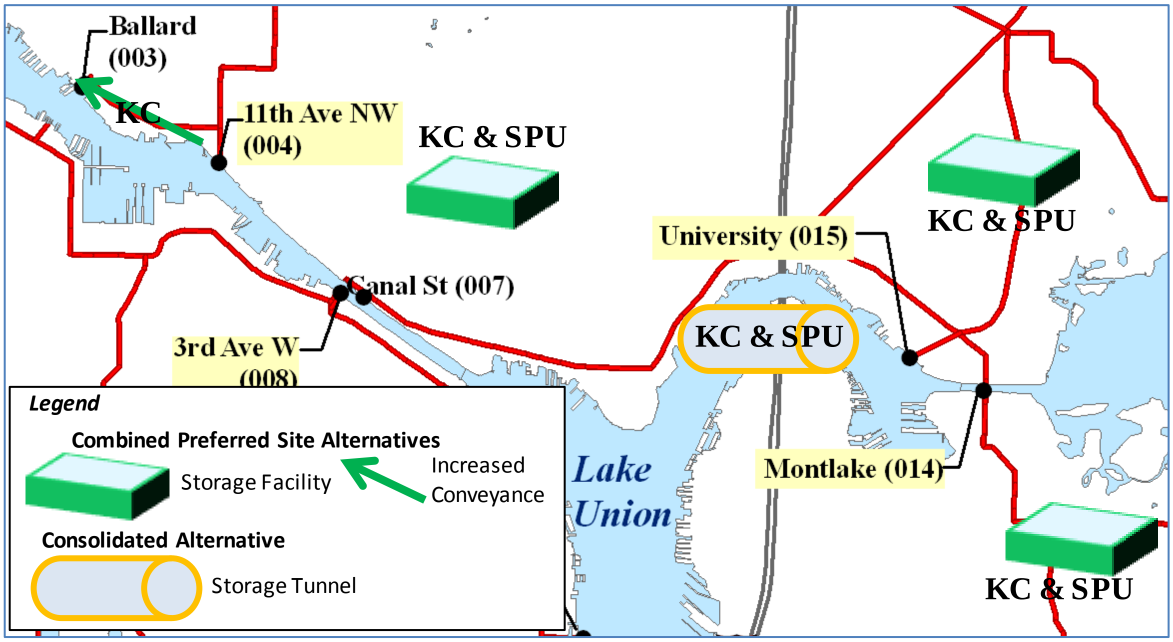

Figure 7-5. Area Alternatives for Ship Canal—11th Ave NW, 3rd Ave W, University, Montlake

Evaluation of Area Alternatives

Table 7-4 summarizes the triple-bottom-line analysis of the area alternatives for the Ship Canal area and indicates the recommended preferred alternative for this area. Details are provided in Appendix H.3.1. The combined preferred site alternatives have a slightly lower value score, but they also have lower risk and significantly lower estimated life-cycle cost. Therefore, the **combined preferred site alternatives** are the recommended preferred alternative for the Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake area.

Table 7-4. Triple-Bottom-Line Analysis of Area Alternatives for Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Recom-mended Preferred Alternative
Combined Preferred Site Alternatives					
SC-11th Ave NW-KC-Conv	3,200 feet of 84-inch-diameter conveyance pipe	$233	625	Orange (medium)	X
SC-3rd Ave W-Collab-STOR 2	7.23-MG storage tank north of Ship Canal; with SPU				
SC-University-Collab-STOR	5.23-MG storage tank; with SPU				
SC-Montlake-Collab-STOR	7.87-MG storage tank; with SPU				
Consolidated Alternative					
SC-Cons Tunnel-Collab-STOR	21.4-MG storage tunnel along the Ship Canal; with SPU	$284	635	Red (high)	

a. Life-cycle cost allocated to King County.

7.2.2 Middle EBI—Hanford #2, Lander St, Kingdome, and King St

Evaluation of Site Alternatives

All four of the uncontrolled CSO sites in this area have only one site alternative (King St has a storage alternative and Kingdome, Lander St, and Hanford #2 each have a wet-weather treatment alternative), so the site alternatives are the preferred site alternatives. Ballasted sedimentation is the CSO treatment process assumed for the triple-bottom-line analysis.

Identification of Area Alternatives

The area alternatives for the Middle EBI-Hanford #2, Lander St, Kingdome, and King St area are as follows (area alternatives are shown conceptually in Figure 7-6):

- Alternative A—Three Independent Wet-Weather Treatment Facilities + Storage:
  - Alternative MEBI-Kingdome-KC-WWTF, which includes a 48-MGD wet-weather treatment facility to control Kingdome CSOs.
  - Alternative MEBI-Lander-KC-WWTF, which includes a 23-MGD wet-weather treatment facility to control Lander St CSOs.
  - Alternative MEBI-Hanford-KC-WWTF, which includes a 68-MGD wet-weather treatment facility to control Hanford #2 CSOs.
  - Alternative MEBI-King-KC-STOR, which includes a 2.63-MG storage tank to control King St CSOs.
- Alternative B—Two Independent Wet-Weather Treatment Facilities:
  - Alternative MEBI-Cons Kingdome-King-KC-WWTF, which includes a 56-MGD wet-weather treatment facility to control King St and Kingdome CSOs.
  - Alternative MEBI-Cons Hanford-Lander-KC-WWTF, which includes a 94-MGD wet-weather treatment facility to control Hanford #2 and Lander St CSOs.
- Alternative C—Two Independent Wet-Weather Treatment Facilities + Storage:
  - Alternative MEBI-Kingdome-KC-WWTF, which includes a 48-MGD wet-weather treatment facility to control Kingdome CSOs.
  - Alternative MEBI-Cons Hanford-Lander-KC-WWTF, which includes a 94-MGD wet-weather treatment facility to control Hanford #2 and Lander St CSOs.
  - Alternative MEBI-King-KC-STOR, which includes a 2.63-MG storage tank to control King St CSOs.
- Alternative D1—One Independent Wet-Weather Treatment Facility, with New Conveyance to Wet-Weather Treatment Facility:
  - Alternative MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (New Conveyance), which includes a 151-MGD wet-weather treatment facility, with new conveyance from the four regulator stations to the treatment facility, to control Hanford #2, Lander St, Kingdome, and King St CSOs.

- Alternative D2—One Independent Wet-Weather Treatment Facility, with EBI Modifications as Conveyance to Wet-Weather Treatment Facility:
  - Alternative MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications), which includes a 151-MGD wet-weather treatment facility, with modifications to the EBI to divert flows to the treatment facility, to control Hanford #2, Lander St, Kingdome, and King St CSOs.
- Alternative E—One Independent Wet-Weather Treatment Facility + Storage:
  - Alternative MEBI-Cons Hanford-Lander-Kingdome-KC-WWTF, which includes a 139-MGD wet-weather treatment facility to control Hanford #2, Lander St, and Kingdome CSOs.
  - Alternative MEBI-King-KC-STOR, which includes a 2.63-MG storage tank to control King St CSOs.

Evaluation of Area Alternatives

Table 7-5 summarizes the triple-bottom-line analysis of the area alternatives. Details are provided in Appendix H.3.2. All of the area alternatives have high risk scores. Alternatives D2, D1, E, and B have comparable life-cycle costs and comparable values. These four alternatives reduce the number of CSO control facilities from four to one or two. Alternative D2 **(MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications))** has the highest value and lowest life-cycle cost and is the recommended preferred alternative for the Middle EBI—Hanford #2, Lander St, Kingdome, and King St area.

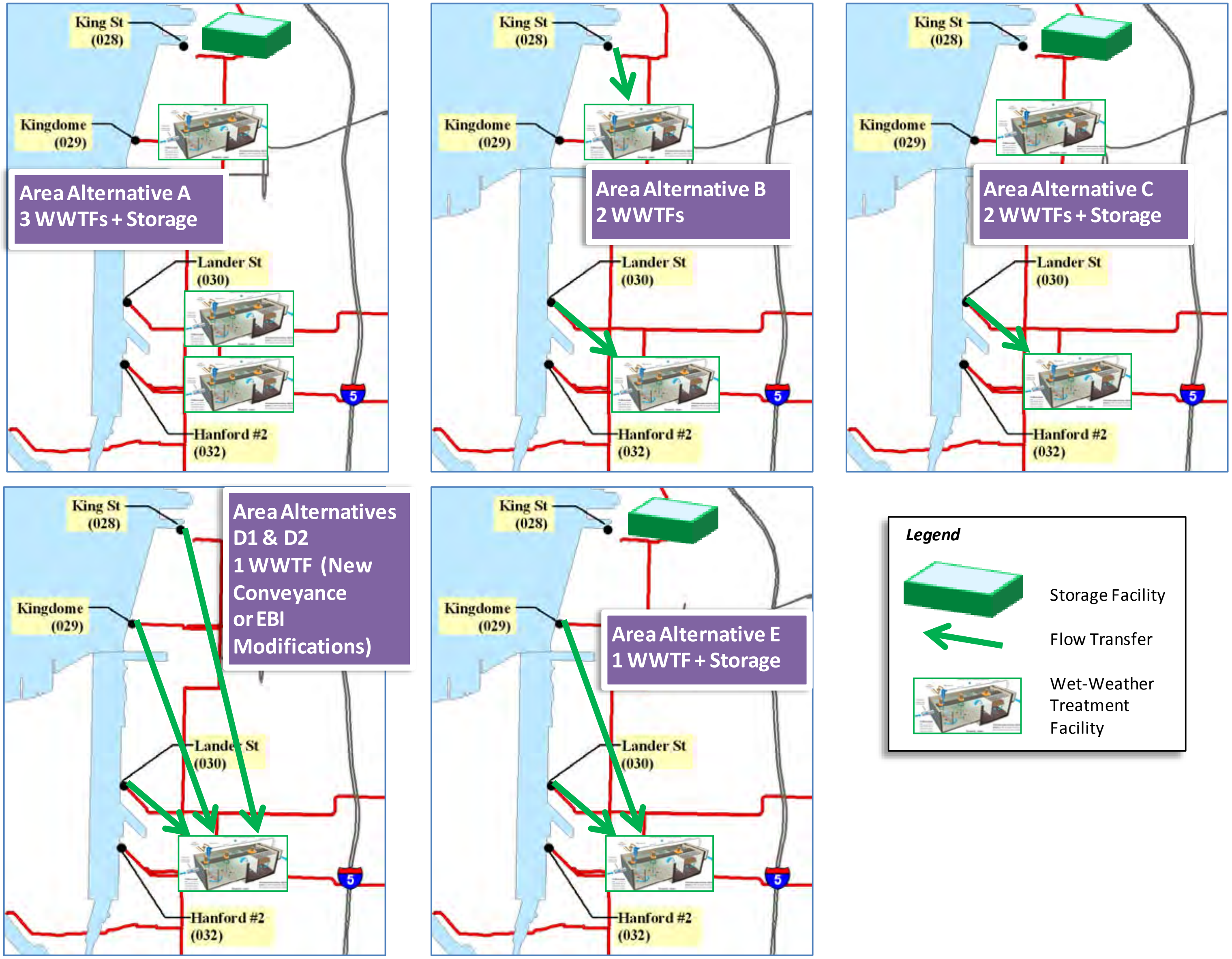

Figure 7-6. Area Alternatives for Middle EBI—Hanford #2, Lander St, Kingdome, King St

This page is left blank intentionally.

Table 7-5. Triple-Bottom-Line Analysis of Area Alternatives for Middle EBI—Hanford #2, Lander St, Kingdome, and King St

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Recom-mended Preferred Alternative
Alternative A—Three Independent Wet-Weather Treatment Facilities + Storage					
MEBI-Kingdome-KC-WWTF	48-MGD wet-weather treatment facility	$412	593	Red (high)	
MEBI-Lander-KC-WWTF	23-MGD wet-weather treatment facility				
MEBI-Hanford-KC-WWTF	68-MGD wet-weather treatment facility				
MEBI-King-KC-STOR	2.63-MG storage tank				
Alternative B—Two Independent Wet-Weather Treatment Facilities					
MEBI-Cons Kingdome-King-KC-WWTF	56-MGD wet-weather treatment facility	$369	620	Red (high)	
MEBI-Cons Hanford-Lander-KC-WWTF	94-MGD wet-weather treatment facility				
Alternative C—Two Independent Wet-Weather Treatment Facilities + Storage					
MEBI-Kingdome-KC-WWTF	48-MGD wet-weather treatment facility	$380	606	Red (high)	
MEBI-Cons Hanford-Lander-KC-WWTF	94-MGD wet-weather treatment facility				
MEBI-King-KC-STOR	2.63-MG storage tank				
Alternative D1—One Independent Wet-Weather Treatment Facility, with New Conveyance to Wet-Weather Treatment Facility					
MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (New Conveyance)	151-MGD wet-weather treatment, with new conveyance	$338	640	Red (high)	
Alternative D2—One Independent Wet-Weather Treatment Facility, with EBI Modifications as Conveyance to Wet-Weather Treatment Facility					
MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications)	151-MGD wet-weather treatment facility, with modifications to the EBI	$331	660	Red (high)	**X**
Alternative E—One Independent Wet-Weather Treatment Facility + Storage					
MEBI-Cons Hanford-Lander-Kingdome-KC-WWTF	139-MGD wet-weather treatment facility	$368	641	Red (high)	
MEBI-King-KC-STOR	2.63-MG storage tank				

a. Life-cycle cost allocated to King County.

7.2.3 Middle EBI—Hanford #1

Because this area has only one uncontrolled CSO site, each site alternative is also an area alternative. Table 7-6 summarizes the triple-bottom-line analysis of site/area alternatives for this area and indicates the recommended preferred alternative. Details are provided in Appendix H.3.3. The site/area alternatives are shown conceptually in Figure 7-7. All three alternatives have relatively low risks. The conveyance and storage alternative has the highest value and lowest life-cycle cost, by approximately 55 percent. Therefore, the storage and conveyance alternative (**MEBI-Han-Rain-BV-KC-CONV/STOR)** is the recommended preferred alternative for the Middle EBI—Hanford #1 area.

Table 7-6. Triple-Bottom-Line Analysis of Site/Area Alternatives for Middle EBI—Hanford #1

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Recom-mended Preferred Alternative
MEBI-Han-Rain-BV-KC-STOR 1	1.79-MG storage tank	$51.6	725	Blue (low)	
MEBI-Han-Rain-BV-KC-STOR 2	1.02-MG and 0.77-MG storage tanks	$41.9	595	Blue (low)	
MEBI-Han-Rain-BV-KC-CONV/STOR	0.34-MG storage tank and conveyance improvements to use Bayview Tunnel	$19.0	755	Blue (low)	X

a. Life-cycle cost allocated to King County.

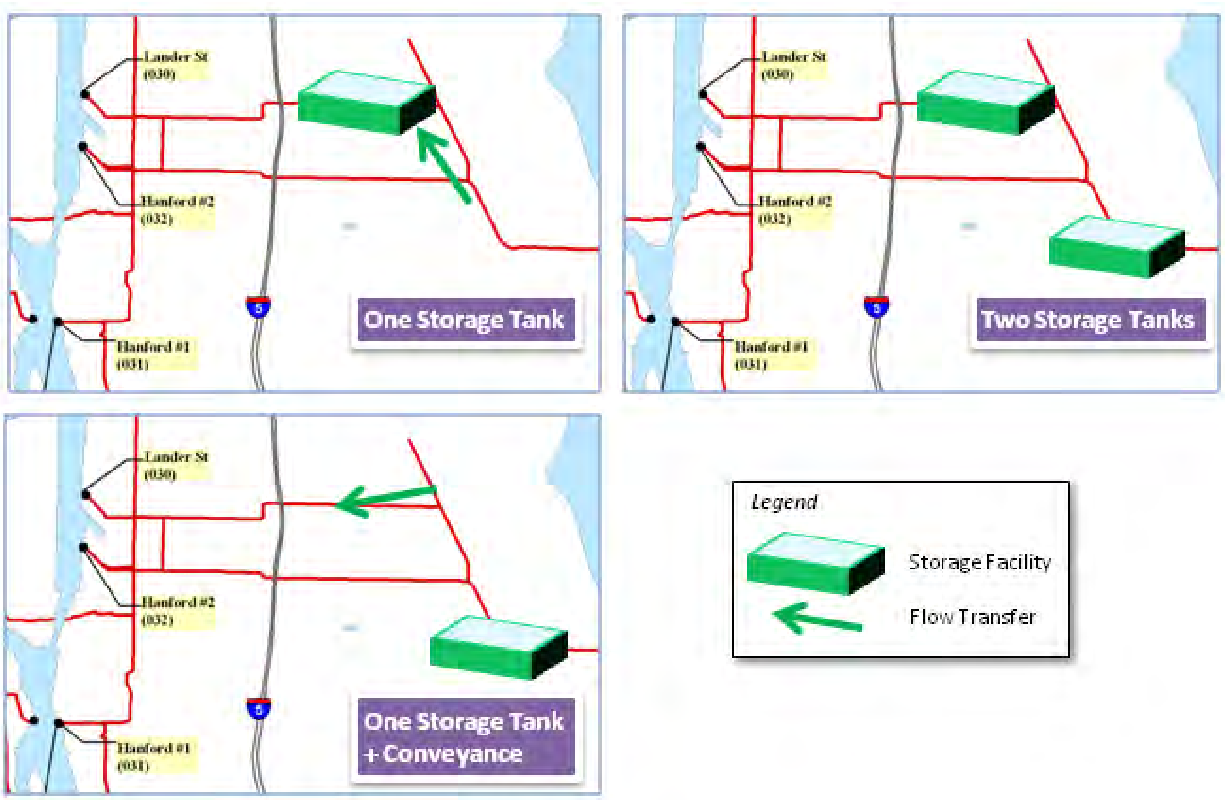

Figure 7-7. Site/Area Alternatives for Middle EBI—Hanford #1

7.2.4 South EBI

Evaluation of Site Alternatives

Table 7-7 summarizes the triple-bottom-line analysis of site alternatives for the two uncontrolled CSO sites in this area and indicates the preferred site alternative for each. Details are provided in Appendix H.3.4. Only one site alternative was developed for the S Michigan St CSO site, and that is the preferred site alternative. The triple-bottom-line analysis was used to select a preferred site alternative from the two Brandon St CSO site alternatives (see Figure 7-8). For the wet-weather treatment alternatives at both CSO sites, it was assumed that ballasted sedimentation would be used.

Table 7-7. Triple-Bottom-Line Analysis of Site Alternatives for South EBI

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Preferred Site Alternative
S Michigan St Site Alternative					
SEBI-SMichigan-KC-WWTF	40-MGD wet-weather treatment facility	$123.8	630	Orange (medium)	**X**
Brandon St Site Alternatives					
SEBI-Brandon-KC-WWTF	24-MGD wet-weather treatment facility	$84.8	630	Orange (medium)	
SEBI-Brandon-KC-SEP	New separated sanitary sewer system; convert the combined sewer system to a storm drain system	$69.6	795	Red (high)	**X**

a. Life-cycle cost allocated to King County.

The sewer separation site alternative for the Brandon St CSO site has a higher value score than the treatment alternative and 18-percent lower life-cycle cost. Even though the sewer separation alternative has a higher risk score, it was decided that its higher value and lower life-cycle costs make it the best alternative for this CSO site. Therefore, the sewer separation alternative (**SEBI-Brandon-KC-SEP)** is the preferred site alternative for the Brandon St CSO site.

Identification of Area Alternatives

The area alternatives for the South EBI area are as follows (area alternatives are shown conceptually in Figure 7-8):

- Combined Preferred Site Alternatives:
  - SEBI-SMichigan-KC-WWTF (S Michigan St Wet-Weather Treatment)
  - SEBI-Brandon-KC-SEP (Brandon St Sewer Separation).
- Treatment with New Conveyance—SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance)

- Treatment with Modifications to the EBI—SEBI-Cons Brandon-SMichigan-KC-WWTF (EBI Modifications)

All wet-weather treatment facilities are assumed to use ballasted sedimentation.

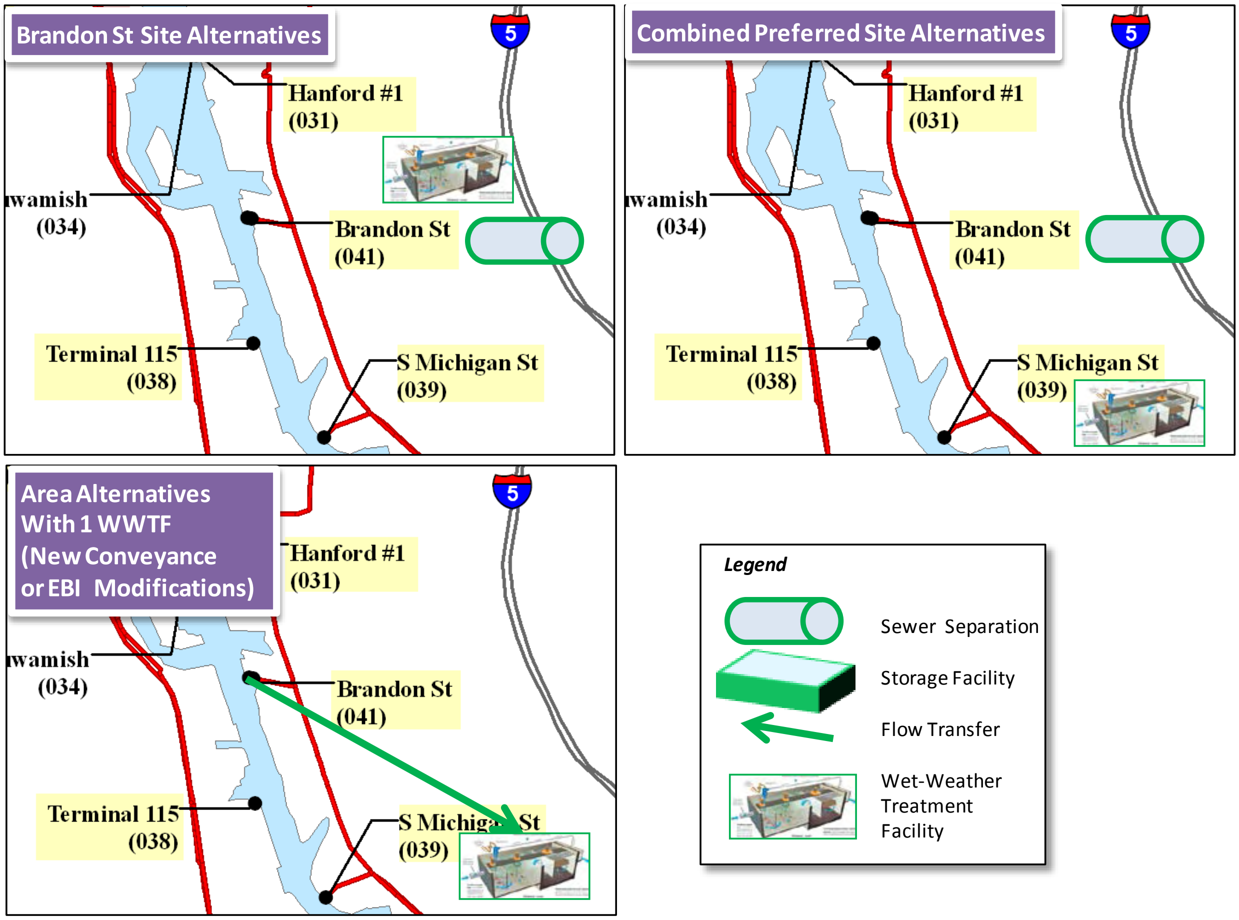

Figure 7-8. Brandon St Site Alternatives and South EBI Area Alternatives

Evaluation of Area Alternatives

Table 7-4 summarizes the triple-bottom-line analysis of the area alternatives for this area and indicates the preferred area alternative. Details are provided in Appendix H.3.4.

Although the combined preferred site alternatives have the highest value score, it also has the highest life-cycle cost, by approximately 8 percent. The consolidated treatment alternative with new conveyance is lower in risk and life-cycle cost (approximately 7 percent lower) and only slightly lower in value than the treatment alternative with EBI modifications. Therefore, the treatment with new conveyance alternative (**SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance)**) is the recommended preferred alternative for the South EBI area.

Table 7-8. Triple-Bottom-Line Analysis of Area Alternatives for South EBI

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Recom-mended Preferred Alternative
Combined Preferred Site Alternatives					
SEBI-SMichigan-KC-WWTF	40-MGD wet-weather treatment facility	$193.4	687	Orange (medium)	
SEBI-Brandon-KC-SEP	New separated sanitary sewer system; convert the combined sewer system to a storm drain system				
Treatment with New Conveyance					
SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance)	66-MGD wet-weather treatment facility and new conveyance	$167.5	620	Orange (medium)	**X**
Treatment with Modifications to the EBI					
SEBI-Cons Brandon-SMichigan-KC-WWTF (EBI Modifications)	66-MGD wet-weather treatment facility and modifications to the EBI to divert flows	$179.4	640	Red (high)	

a. Life-cycle cost allocated to King County.

7.2.5 West Duwamish—W Michigan St and Terminal 115

Evaluation of Site Alternatives

For both uncontrolled CSO sites in this area, only one site alternative, a storage alternative, was developed, so the storage alternatives are the preferred site alternatives.

Identification of Area Alternatives

The area alternatives for the West Duwamish—W Michigan St and Terminal 115 area are as follows (area alternatives are shown conceptually in Figure 7-9):

- Combined Preferred Site Alternatives:
  - WDUW-WMichigan-KC-STOR (W Michigan St Storage)
  - WDUW-Term 115-KC-STOR (Terminal 115 Storage)
- Consolidated Storage—WDUW-Cons W Michigan-Term 115-KC-STOR.

Evaluation of Area Alternatives

Table 7-9 summarizes the triple-bottom-line analysis of the area alternatives for this area and indicates the preferred area alternative. Details are provided in Appendix H.3.5.

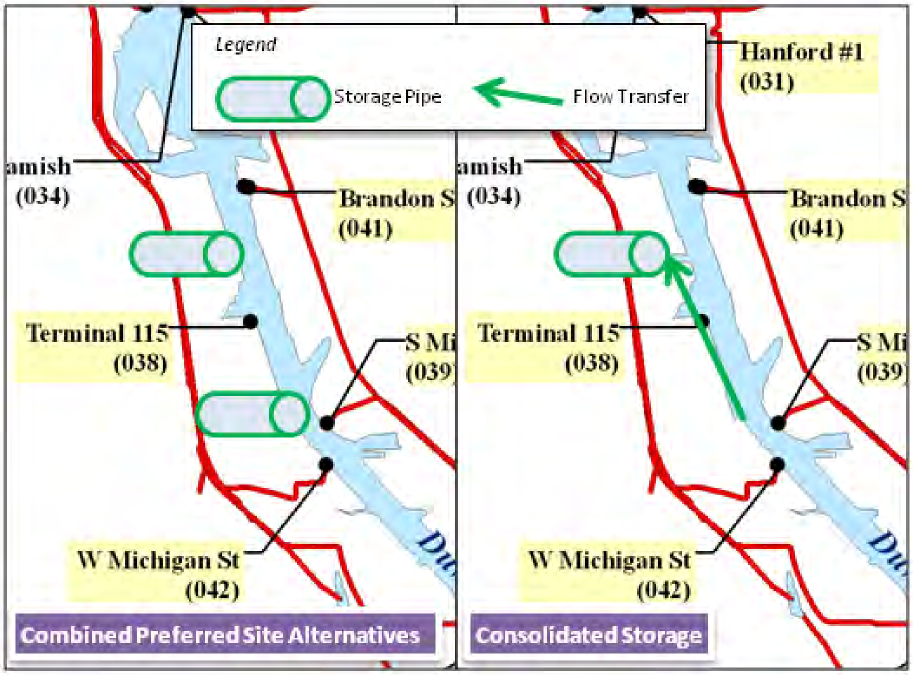

Figure 7-9. Area Alternatives for West Duwamish—W Michigan St and Terminal 115

Table 7-9. Triple-Bottom-Line Analysis of Area Alternatives for West Duwamish—W Michigan St and Terminal 115

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Recom-mended Preferred Alternative
Combined Preferred Site Alternatives					
WDUW-WMichigan-KC-STOR	0.27-MG storage pipe	$14.8	695	Blue (low)	
WDUW-Term 115-KC-STOR	0.05-MG storage pipe				
Consolidated Storage					
WDUW-Cons W Michigan-Term 115-KC-STOR	0.32-MG storage pipe	$17.0	765	Blue (low)	X

a. Life-cycle cost allocated to King County.

The two area alternatives have the same relative risk (low risk). The consolidated storage alternative has the higher value but also higher life-cycle cost, by approximately 15 percent. The consolidated alternative reduces the number of CSO control facilities from two storage pipes to one. King County determined that the additional cost was warranted by the benefit of consolidating two storage pipes into a single storage pipe. Therefore, the consolidated storage alternative (**WDUW-Cons W Michigan-Term 115-KC-STOR**) is the recommended preferred alternative for the West Duwamish—W Michigan St and Terminal 115 area.

7.2.6 West Duwamish—Chelan Ave

Because this area has only one uncontrolled CSO site, each site alternative is also an area alternative. The alternatives are conceptually shown in Figure 7-10. Table 7-10 summarizes the triple-bottom-line analysis of site/area alternatives for this area and indicates the recommended preferred alternative. Details are provided in Appendix H.3.6. The storage alternative near the Chelan Ave Regulator Station has the lowest risk, lowest life-cycle costs (15 percent less than the next lowest cost alternative), and highest value. This alternative also is less complex than the other two alternatives because upstream diversions are not required. Therefore, the storage near the Chelan Ave Regulator Station alternative (**WDUW-Chelan-KC-STOR 1)** is the recommended preferred alternative for the West Duwamish—Chelan Ave area.

Table 7-10. Triple-Bottom-Line Analysis of Site/Area Alternatives for West Duwamish—Chelan Ave

Alternative	Description	Life-Cycle Cost[a] (2010 $; millions)	Value Score	Risk Color (Category)	Recom-mended Preferred Alternative
WDUW-Chelan-KC-STOR 1	3.85-MG storage tank	$60.0	745	Blue (low)	**X**
WDUW-Chelan-KC-STOR 2	Two 90-foot-diameter caissons, conveyance improvements	$70.4	705	Orange (medium)	
WDUW-Chelan-KC-CONV	46-MGD upgrade to 63rd Ave Pump Station and Alki Treatment Facility, conveyance improvements	$111.7	640	Red (high)	

a. Life-cycle cost allocated to King County.

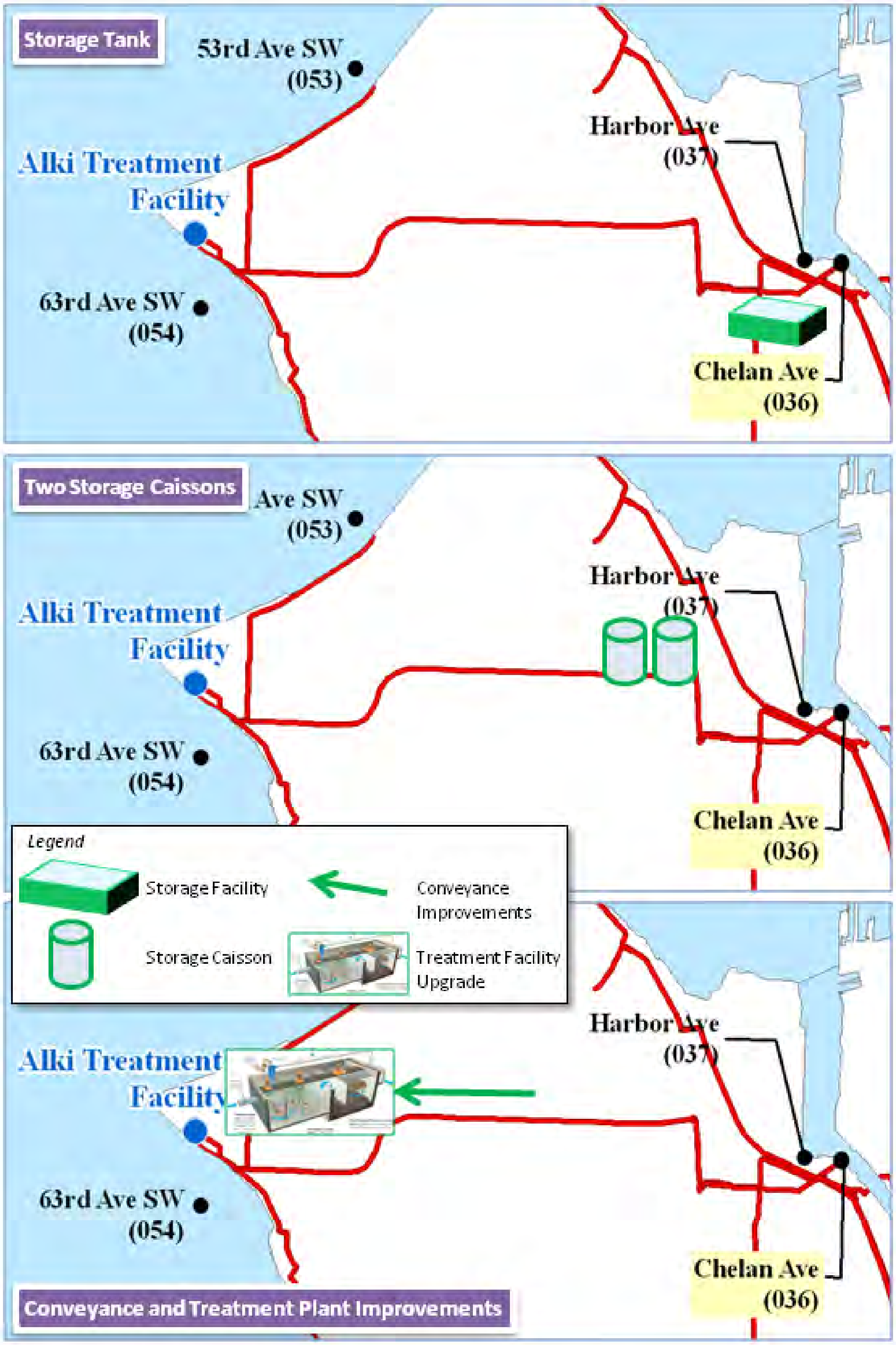

Figure 7-10. Site/Area Alternatives for West Duwamish—Chelan Ave

7.3 Agency Approval

On April 5, 2011, the King County WTD Division Director and SPU Drainage & Wastewater Division Director met to discuss the following collaborative alternatives:

- SC-3rd Ave W-Collab-STOR 2: 7.23-MG storage tank north of Ship Canal; with SPU; recommended preferred alternative
- SC-University-Collab-STOR: 5.23-MG storage tank; with SPU; recommended preferred alternative
- SC-Montlake-Collab-STOR: 7.87-MG storage tank; with SPU; recommended preferred alternative
- SC-Cons Tunnel-Collab-STOR: 21.4-MG storage tunnel along the Ship Canal; with SPU.

Both directors agreed to advance the recommended preferred alternatives (SC-3rd Ave W-Collab-STOR 2, SC-University-Collab-STOR, and SC-Montlake-Collab-STOR) into the rate and schedule analysis. Both directors also agreed that King County and SPU should further develop and define the tunnel alternative.

SPU will be unable to give preliminary confirmation of the collaborative alternatives until it issues the Draft Environmental Impact Statement and Draft Long-Term Control Plan as part of the State Environmental Policy Act process during the first quarter of 2014. The City of Seattle mayor and council will adopt the Long-Term Control Plan during the fourth quarter of 2014. After mayor and council adoption, a memorandum of agreement for the collaborative alternatives can be drafted and executed between King County and SPU.

This page left blank intentionally.

8.0. RECOMMENDED PREFERRED ALTERNATIVES

This section summarizes the recommended preferred alternatives selected through the triple-bottom-line analysis. It presents potential risks, issues, and additional items to consider in future evaluations when developing the recommended preferred alternatives.

Table 8-1 presents a summary of the recommended preferred alternatives, organized by area, with construction and property acquisition costs and life-cycle costs. Appendix A.3 presents a summary comparison of the RWSP adopted alternatives and the recommended preferred alternatives from this Program Review, including a discussion of cost differences between the RWSP and the Program Review.

Table 8-1. Summary of Costs for Recommended Preferred Alternatives

	Costs Allocated to King County (2010 $ millions)		
Alternative	**Construction and Property Acquisition Costs**	**Project Costs**	**Life-Cycle Costs**
Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake			
SC-11th Ave NW-KC-Conv	$11.7	$23.7	$22.1
SC-3rd Ave W-Collab-STOR 2	$27.4	$50.3	$51.5
SC-University-Collab-STOR	$24.4	$45.2	$53.8
SC-Montlake-Collab-STOR	$52.1	$95.4	$105.5
Total	$116	$215	$233
Middle EBI—Hanford #2, Lander St, Kingdome, and King St			
MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications)	$138	$271	$331
Middle EBI—Hanford #1			
MEBI-Han-Rain-BV-KC-CONV/STOR	$9.5	$19.2	$19.0
South EBI			
SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance)	$72.3	$140	$168
West Duwamish—W Michigan St and Terminal 115			
WDUW-Cons W Michigan-Term 115-KC-STOR	$7.1	$14.8	$17.0
West Duwamish—Chelan Ave			
WDUW-Chelan-KC-STOR 1	$27.2	$51.7	$60.0
Total	**$370**	**$711**	**$830**

8.1 Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake

8.1.1 Recommended Preferred Alternative

The recommended preferred alternative for the Ship Canal—11th Ave NW, 3rd Ave W, University, and Montlake area consists of the preferred site alternatives for this area:

- 11th Ave NW Conveyance—Alternative SC-11th Ave NW-KC-Conv, which includes approximately 3,200 feet of 84-inch-diameter conveyance pipe to increase the conveyance capacity from the 11th Ave NW Overflow Structure to the Ballard Regulator Station to control King County CSOs.
- 3rd Ave W Storage with SPU North of Ship Canal—Alternative SC-3rd Ave W-Collab-STOR 2, which includes a 7.23-MG storage tank on the north side of the Ship Canal to control King County and SPU CSOs.
- University Storage with SPU—Alternative SC-University-Collab-STOR, which includes a 5.23-MG storage tank near the University Regulator Station to control King County and SPU CSOs.
- Montlake Storage with SPU—Alternative SC-Montlake-Collab-STOR, which includes a 7.87-MG storage tank near the Montlake Regulator Station to control King County and SPU CSOs.

See Appendix G.1 for details regarding these site alternatives.

8.1.2 Potential Risks, Issues, and Additional Considerations

Potential Risks

Potential critical and high risks identified during the Program Review for the recommended preferred alternatives were based on planning-level information. Many of the risks are associated with potential changes to the project as more detailed information and site-specific conditions become known. Identification of these potential risks will be helpful to the next phase of work on these projects. Potential risks include the following, organized by CSO site:

- 11th Ave NW
  - Construction complexity associated with installing a new 84-inch-diameter conveyance pipe along Shilshole Avenue NW and NW 45th Street could result in major design/construction changes.
- 3rd Ave W
  - Complex controls could result in the CSO site not being controlled or the proposed facility operating more frequently than planned. King County flows are diverted to the storage tank from a diversion point upstream of the 3rd Ave W Overflow Structure, so predictive controls are required to determine when diversion is needed to prevent CSOs.

- Siting difficulties associated with acquiring property large enough for a storage tank could cause schedule delays or significant project changes.
- Potential increase in storage volume could result in a change in design and increase in cost. King County flows are diverted from the North Interceptor upstream of the 3rd Ave W Overflow Structure; modeling has not been completed to determine if the size of the storage will increase based on the upstream diversion location.

- University and Montlake
  - Construction complexity associated with possibility of microtunneling being required to install influent gravity sewer could result in major design/construction changes when more site-specific geotechnical information is known.
  - Siting difficulties associated with acquiring property large enough for a storage tank could cause schedule delays or significant project changes.
  - Community stakeholders could press for a specific project site, resulting in schedule delays or change in alternative.

Potential Issues

Potential issues identified for the 3rd Ave W storage tank include uncertainties with the SPU-defined project, such as siting, storage volume, and cost estimates. SPU is leading the development of this alternative and has not yet selected a preferred alternative; King County has only included a representative alternative recommended by SPU to include in the analyses.

For the collaborative storage tanks (3rd Ave W, University, and Montlake), operation and maintenance implications need to be understood since they will have design implications.

Additional Considerations

For the Montlake storage tank, there may be additional collaborative opportunities with the Washington State Department of Transportation and its State Route 520 improvements project. It is also likely that SPU will send less flow to this collaborative storage tank than was assumed in the evaluation (SPU will likely only send flows from the Madison Park CSO Basin and Montlake CSO Basin). King County is also considering evaluating other types of storage facilities for this CSO site due to the potential siting difficulties.

For the storage tank site alternatives, the volumes of the CSO storage tanks were not reduced based on potential storage capacity in the influent gravity sewers. Depending on the hydraulics of the proposed system, additional storage capacity may be available in the influent gravity sewers.

There does not appear to be enough information to screen out the storage tunnel alternative (Alternative SC-Cons Tunnel-Collab-STOR) from consideration or select it as the preferred alternative at this time. The storage tunnel could reduce siting risks associated with the four King County preferred site alternatives and SPU independent alternatives, as well as reducing the number of facilities to be operated and maintained, but the tunnel alternative would need to site portals and shafts. King County and SPU will continue to evaluate and refine the storage tunnel alternative. King County will evaluate the operation and maintenance requirements and potential issues, including safety, and contact other agencies around the nation that currently operate and maintain large-diameter CSO storage tunnels. SPU will strengthen the project definition and refine the costs for this alternative.

The storage tunnel alternative is being developed by SPU, and it appears that the current planning-level design is conservative with excavation depth assumptions (current assumption is that the tunnel would be constructed 40 feet below the Fremont Siphon). However, other costs may be inadequately accounted for, including odor control and air management associated with tunnel operation. If costs and risks are reduced with refinement of the design, this alternative may be reconsidered.

Potential critical and high risks identified during the Program Review for the storage tunnel alternative were based on planning-level information. Many of the risks identified below are associated with potential changes to the project as more detailed information and site-specific conditions become known. Identification of these potential risks will be helpful to the next phase of work on these projects. Potential risks include the following:

- Construction complexity associated with deep excavation of tunnel portals and tunnel construction could result in major design/construction changes.
- Complex controls could result in the CSO sites not being controlled or the proposed facility operating more frequently than planned. Four King County and four or five SPU CSO sites would be controlled by this storage tunnel, so complex controls would be needed to ensure that each CSO site is controlled to its regulatory requirement.
- Siting difficulties associated with acquiring easements and property for the west and east tunnel portals could cause schedule delays or significant project changes.
- Limited trained staff is available to operate and maintain the storage tunnel. Operation and maintenance issues need to be further defined and resolved to ensure a proper design and adequately-trained staff.
- Coordination with SPU could impact the schedule and project definition. Coordination with SPU needs to be further defined in later stages of development to ensure cost and schedule compliance.
- Community stakeholders could press for a specific site alignment and portal locations of the tunnel or press for another alternative, resulting in schedule delays or change in alternative.

Another alternative that should be considered in future evaluations is possibly sending only the 3rd Ave W, University, and Montlake CSOs to the collaborative storage tunnel and controlling 11th Ave NW CSOs with the increased conveyance site alternative. Based on the costs developed as part of the Program Review, the construction cost to convey 11th Ave NW CSOs to the tunnel is similar to the construction cost of the increased conveyance site alternative ($10.58 million versus $11.66 million, respectively). Controlling 11th Ave NW CSOs separately from the tunnel may allow the tunnel to move east of the Fremont Siphon, so it would avoid crossing it, possibly allowing the tunnel to be constructed shallower.

8.2 Middle EBI—Hanford #2, Lander St, Kingdome, and King St

8.2.1 Recommended Preferred Alternative

The recommended preferred alternative for the Middle EBI—Hanford #2, Lander St, Kingdome, and King St area is Alternative D2, which consists of Alternative MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (EBI Modifications) to control Hanford #2, Lander St, Kingdome, and King St CSOs. This alternative includes a 151-MGD wet-weather treatment facility (assuming the use of a ballasted sedimentation treatment process) near the Hanford St Regulator Station and modifications to the EBI to divert flows to the new wet-weather treatment facility. See Appendix G.3.8 for details regarding this alternative.

8.2.2 Potential Risks, Issues, and Additional Considerations

Potential critical and high risks identified during the Program Review for the recommended preferred alternative were based on planning-level information. Many of the risks are associated with potential changes to the project as more detailed information and site-specific conditions become known. Identification of these potential risks will be helpful to the next phase of work on these projects. Potential risks include the following:

- Construction complexity associated with a large gate and bypass structure and diversion structure along the 96-inch-diameter Elliott Bay Interceptor, as well as a new CSO outfall, could result in major design/construction changes.
- Complex controls could result in the CSO sites not being controlled or the proposed facility operating more frequently than planned. Complex controls are required to determine when the Elliott Bay Interceptor gate closes to cause backflow to the wet-weather treatment facility at Hanford #2 and control four CSO sites. Proper controls are critical to ensure that the CSOs are controlled.
- A new CSO outfall that conveys large treated discharges to the Duwamish River may face regulatory challenges and delay or complicate the alternative.
- Siting difficulties associated with acquiring property for a wet-weather treatment facility of this size could cause schedule delays or significant project changes.

Complexities and risks associated with backflowing the Elliott Bay Interceptor will be further explored in a workshop with experts, which is scheduled for later this year. King County will also be completing additional modeling of this alternative. Depending upon the outcome of the workshop, identification of fatal flaws, possible reduction in risks, and refined modeling evaluations, Alternative D1, MEBI-Cons Hanford-Lander-King-Kingdome-KC-WWTF (New Conveyance), is a potential alternate choice.

The recommended preferred alternative may include minimal flow transfers from SPU to the proposed wet-weather treatment facility.

8.3 Middle EBI—Hanford #1

8.3.1 Recommended Preferred Alternative

The recommended preferred alternative for the Middle EBI—Hanford #1 area is Alternative MEBI-Han-Rain-BV-KC-CONV/STOR, which includes a 0.34-MG storage tank near the Bayview North Overflow Structure and conveyance improvements to use available capacity in the Bayview Tunnel. See Appendix G.4 for details regarding this alternative.

8.3.2 Potential Risks, Issues, and Additional Considerations

No critical or high risks were identified during the Program Review for this recommended preferred alternative.

This alternative would include a complex storm drain crossing with a drop structure, and the new conveyance pipe would need to be installed by microtunneling due to deep excavation.

The conveyance upgrade would increase flows to the Hanford and Lander Street Regulator Stations. Additional modeling will be required to determine the impact of the increased flows on the downstream regulator stations and proposed CSO control facilities. For this planning stage, it is assumed that the increased flows from the Bayview North Overflow Structure would minimally impact the size of the proposed CSO control facilities for the Hanford and Lander St Regulator Stations.

The recommended preferred alternative may include minimal flow transfers from SPU to the proposed storage facility.

8.4 South EBI

8.4.1 Recommended Preferred Alternative

The recommended preferred alternative for the South EBI area is Alternative SEBI-Cons Brandon-SMichigan-KC-WWTF (New Conveyance) to control S Michigan St and Brandon St CSOs. This alternative includes a 66-MGD wet-weather treatment facility (assuming the use of a ballasted sedimentation treatment process) near the S Michigan St Regulator Station and new conveyance from the Brandon St Regulator Station to the new wet-weather treatment facility. See Appendix G.5.3 for details regarding this consolidated alternative.

8.4.2 Potential Risks, Issues, and Additional Considerations

Recommended Preferred Alternative

Potential critical and high risks identified during the Program Review for the recommended preferred alternative were based on planning-level information. Many of the risks are associated with potential changes to the project as more detailed information and site-specific conditions become known. Identification of these potential risks will be helpful to the next phase of work on these projects. Potential risks include the following:

- Equipment failure associated with the influent pump station during peak event could lead to increased overflows.

- The new CSO outfall that conveys large treated discharges to the Duwamish River at S Michigan St may face regulatory challenges that could delay or complicate the alternative.
- Siting difficulties associated with acquiring property for a wet-weather treatment facility of this size could cause schedule delays or significant project changes.
- Community stakeholders could press for a specific location for the wet-weather treatment facility, resulting in schedule delays or change in alternative.

Combined Site Alternatives

Though the consolidated treatment alternative was the recommended preferred alternative, King County decided to evaluate the sewer separation alternative for the Brandon St CSO Basin further (Alternative SEBI-Brandon-KC-SEP). This alternative includes a new separated sanitary sewer system and reuse of the existing combined sewer system as a storm drain system in the Brandon St CSO Basin. It would be combined with the treatment alternative at S Michigan St (Alternative SEBI-SMichigan-KC-WWTF) to control S Michigan St and Brandon St CSOs. Further review of stormwater regulations, operations and maintenance implications, and evaluation of life-cycle costs may indicate that the combined site alternatives (Brandon St sewer separation and S Michigan St treatment) should be reconsidered.

The life-cycle cost estimates for the Brandon St sewer separation alternative do not include the cost and benefit associated with permanent removal of stormwater flows from the King County combined sewer system. Permanent removal of stormwater from the Brandon St CSO Basin could reduce the size of other proposed CSO control facilities. King County will evaluate the potential cost and benefit associated with this alternative further.

The stormwater treatment costs are allocated fully to King County for this evaluation; however, businesses may be required to provide stormwater treatment by SPU, which would reduce life-cycle costs.

The Brandon St sewer separation alternative also requires field verification to confirm the number of connections to the proposed separated sewer system as well as a verification of conformance with stormwater treatment regulations.

Potential critical and high risks identified during the Program Review for the combined site alternatives were based on planning-level information. Many of the risks are associated with potential changes to the project as more detailed information and site-specific conditions become known. Identification of these potential risks will be helpful to the next phase of work on these projects. Potential risks include the following:

- S Michigan St
  - Equipment failure associated with the influent pump station during peak event could lead to increased overflows.
  - Siting difficulties associated with acquiring property for a wet-weather treatment facility of this size could cause schedule delays or significant project changes.
  - This site alternative would require two separate facilities to be operated and maintained, compared to the consolidated alternatives for this area, putting a greater demand on operation and maintenance staff resources.

- Community stakeholders could press for a specific location for the wet-weather treatment facility, resulting in schedule delays or change in alternative.

- Brandon St
  - Equipment failure could lead to increased overflows if a vacuum sewer system or grinder pump system was included in the alternative.
  - Difficulty in negotiating with property owners to acquire temporary construction easements to connect side sewers to separated sewer system could cause schedule delays and significant project changes.
  - Limited trained staff is available to operate and maintain the new separated sewer system if King County is required to maintain it.
  - Coordination with SPU regarding the operation of the storm and sanitary sewers systems could impact schedule and project definition.

8.5 West Duwamish—W Michigan St and Terminal 115

8.5.1 Recommended Preferred Alternative

The recommended preferred alternative for the West Duwamish—W Michigan St and Terminal 115 area is Alternative WDUW-Cons W Michigan-Term 115-KC-STOR, which controls W Michigan St and Terminal 115 CSOs with a 0.32-MG storage pipe near the Terminal 115 Overflow Structure. See Appendix G.6.3 for details regarding this consolidated alternative.

8.5.2 Potential Risks, Issues, and Additional Considerations

No critical or high risks were identified during the Program Review for this alternative; however, conflicts with the South Treatment Plant effluent transfer system should be avoided in design.

Due to the small storage volume associated with this storage pipe, it may be possible to construct a single storage pipe between the W Michigan St Regulator Station and Terminal 115 Overflow Structure instead of installing a new conveyance pipe to convey W Michigan St CSOs from the W Michigan St Regulator Station to the Terminal 115 Overflow Structure.

Overall, the combined preferred site alternatives have costs, values, and risks similar to those of the consolidated area alternative. Future evaluations should consider evaluating both alternatives.

8.6 West Duwamish—Chelan Ave

8.6.1 Recommended Preferred Alternative

The recommended preferred alternative for the West Duwamish—Chelan Ave area is Alternative WDUW-Chelan-KC-STOR 1, which includes a 3.85-MG storage tank near the Chelan Ave Regulator Station and modifications to the Alki Trunk. See Appendix G.7 for details regarding this alternative.

8.6.2 Potential Risks, Issues, and Additional Considerations

The only potential high risk identified during the Program Review for this alternative is potential siting difficulty associated with acquiring property for storage of this size. Property in the vicinity of the Chelan Ave Regulator Station is primarily owned by the Port of Seattle with some scattered private property owners. Early discussions with the Port of Seattle and coordinating activities would be required to explore siting possibilities.

If property is difficult to acquire near the Chelan Ave Regulator Station, the storage alternative at the West Seattle Pump Station (Alternative WDUW-Chelan-KC-STOR 2) could be reconsidered as an alternate choice. The proposed facilities are located on property that is owned by King County, adjacent to the West Seattle Pump Station. Potential critical and high risks identified during the Program Review for Alternative WDUW-Chelan-KC-STOR 2 include the following:

- Construction complexity associated with construction of two 90-foot-diameter caissons (approximately 70 feet deep) adjacent to West Seattle Pump Station could result in major design/construction changes.
- Complete controls could result in the CSO sites not being controlled or the proposed facility operating more frequently than planned. King County flows would be diverted to the storage facility upstream of the Chelan Ave Regulator Station, so predictive controls would be required to determine when diversion is needed to prevent CSOs.
- Potential increase in storage volume could result in a change in design and increase in cost. King County flows would be diverted upstream of the Chelan Ave Regulator Station along the Delridge Trunk; modeling has not been completed to determine if the size of the storage would increase based on the upstream diversion location.
- Potential operations and maintenance issues associated with cleaning of deep, round storage structures.

This page left blank intentionally.

9.0. OPTIMIZATION OF EXISTING FACILITIES FOR INCREASED CONTROL

The King County CSO Control Program plans CSO control projects and transfers them to the King County Project Management unit to initiate the predesign phase of the project. The CSO Control Program and Operations and Maintenance (O&M) staff participate in the predesign, design, and construction phases of the projects to ensure the project goals and policies are maintained, to monitor facility startup and assist in achieving CSO control, and then to re-institute planning for any needed capital modifications needed if control cannot be achieved through O&M adjustments and small projects. During startup responsibilities, there is overlap between the O&M, project management, planning, and NPDES administration groups. Once a CSO control facility has achieved final control, the facilities are under the management of the O&M group in compliance with the NPDES permit.

The seasonal and intermittent operation of these complex CSO control facilities prolongs the commissioning period. Problems and issues may not be identified or confirmed until one or two wet seasons have occurred, and then modifications can be developed. Many modifications to these facilities can only be safely implemented during dry weather. However, these modifications can only be tested in wet weather with rainfall sufficient to operate the facilities several times under a range of conditions. (If the problems only become apparent under high flows conditions, then the solutions cannot be fully tested until such flows return.) If the modifications do not resolve the problems or issues, then another round of planning, implementation, and testing must occur. King County has found that the startup and tuning of these intermittently operated facilities is an iterative process.

At this time, several County CSO control projects have been completed but are still being adjusted to achieve full control. Several of these CSO control projects were developed to control several inter-related CSO sites. In these cases, the controls are viewed as a system, and control is not fully achieved until the system meets CSO control standards. King County has deferred designating the project system and components as ”controlled” while final adjustments to the components of the system are made.

This section describes what has been completed and what is planned to bring these CSO control facilities into full control.

9.1 Alki Treatment Facility

The Alki facilities include the West Seattle Tunnel and Pump Station, the 63rd Ave Pump Station CSO, and the Alki Treatment Facility. These were built or upgraded to transfer base flows to the West Point Wastewater Treatment Plant for secondary treatment. Under an agreed-upon standard with Ecology, up to 2.25 times average wet-weather flows (18.9 MGD) required secondary treatment while the remaining volumes would be treated as CSOs. The old primary treatment plant would be modified to provide wet-weather treatment and disinfection. Dechlorination facilities were required later. The wet-weather treatment facility was designed to operate approximately 60 times per year but discharge only approximately 29 times per year.

Total projected annual discharge volume was approximately 108 MG. Stored flows and settled solids would be drained back to the West Seattle Tunnel and conveyed to the West Point Wastewater Treatment Plant.

The transfer to the West Point Wastewater Treatment Plant was completed in 1998, and the treatment plant modifications were completed in 2001. The 63rd Ave Pump Station CSO met the control standard immediately. However, the Alki Treatment Facility has repeatedly failed to meet the 50 percent total suspended solids (TSS) removal permit limit. In 2005, as a response to new permit requirements, King County implemented a number of changes to the facility to dechlorinate effluent and consistently meet new fecal coliform and chlorine limits in discharges to Puget Sound. King County has viewed the resolution of impediments to the achievement of the 50-percent TSS removal and consistent chlorination/dechlorination of effluent as being a function of O&M and has not instituted planning for facility modifications under the major capital improvements program.

Since startup of the Alki facilities, an inaccessible flow meter and hydraulic unit controlling the regulator gate at the entrance to the tunnel failed, preventing modulation of the flows to the Alki Treatment Facility. Thus, more flow was conveyed to the West Seattle Tunnel and onto secondary treatment than planned, and less flow was conveyed to the Alki Treatment Facility. King County has identified no adverse downstream impacts (no increase in CSOs along the Elliott Bay Interceptor) and has identified environmental benefits (more flow and pollution captured and sent to secondary treatment). However, then the highest and most dilute storm flows would be conveyed to the Alki Treatment Facility for treatment. There is little TSS to remove in such flows, so meeting the 50-percent TSS removal permit limit has been difficult. The option of spending large capital dollars to restore facility operation to the original design intent would release more pollution to Puget Sound than is currently being achieved. King County believes this is an artifact of application of a performance standard intended for continuously operated treatment plants to an intermittently operated facility that does not achieve the desired environmental benefit. King County would like to discuss alternative permitting options for this situation.

Table 9-1 presents the Alki Treatment Facility issues, corresponding causes, and actions completed or planned to correct the issues and the schedule. These issues are being addressed to bring the facility into permit compliance.

9.1.1 Alki Treatment Facility Improvements Schedule

Monitor effectiveness of surge controls through approximately four storms with flows to Alki Treatment Facility greater than 50 MGD.

Table 9-1. Alki Treatment Facility Issues, Causes, Corrective Actions, and Schedule

Issue	Cause	Corrective Actions	Schedule
Failure to meet 50-percent TSS removal permit limit	Broken, inaccessible bubbler preventing gate modulation. Less, but highly dilute, flow to the Alki Treatment Facility than design intended. Repair would result in greater discharge to the Alki Treatment Facility.	Recommend discussion of alternate permitting approach to maintain current pollution capture.	Pending discussion with Ecology
Flow surge through Alki Treatment Facility	West Seattle Tunnel inlet gate lack of operation.	PWR 653 submitted to correct gate. • Inspection completed – September 2010 • Engineering Analysis – October 2010 • Alternative Selection – November 2010	September 2011
		Evaluating the operational benefits to Alki performance by modulating the 63rd inlet gates	Ongoing
Fecal coliform and chlorine permit limit exceedances	Pump ramp up caused surge and short-circuiting of disinfection/dechlorination process	Revised the pumping strategy at 63rd Ave Pump Station to better utilize the station's single variable frequency drives (VFD) to reduce surging and to smooth pumping to Alki Treatment Facility.	Completed April 2010; evaluation of effectiveness underway as storms allow.
		Sodium bisulfite (SBS) dechlorination system – modifying an existing storage facility to house 2000 gallons of SBS. The project is currently at 50 percent design. Received input from Seattle Fire Department, which will require a major redesign to a new location (i.e., the old digester equipment room).	March 2012
Missed samples	New Ovation control system was installed, and the system worked locally but did not alarm remotely.	Procedures have been changed, so that the elevations and settings for control and alarms are checked and tested both locally and remotely after any monitoring and control system-related work.	Completed October 2010
		Training program has been updated, so the annual refresher training is provided prior to each wet season for Offsite and DCB staff includes how to recognize a fill event at Alki and a review of the permit sampling requirements.	Annual training plan updated September 2010
		Procedures have been changed, so that the elevations and settings for control and alarms are checked and tested both locally and remotely after any monitoring and control system-related work; to formalize and better document the lock out / tag out training.	Training completed December 2010 – ongoing

Issue	Cause	Corrective Actions	Schedule
Missed chlorine residual samples	Sample pump clogged	Install an external pump base plate with a debris screen and new flush water lines to keep debris from the impellor suction.	September 2010

9.2 Carkeek CSO Treatment Plant

The Carkeek CSO Treatment Plant came on line in 1994 as part of another system to transfer base flows to the West Point Wastewater Treatment Plant for secondary treatment. The plant originally was permitted to discharge 8 times per year for a total of 10 MG. This was based on the average reported in the Facilities Plan. More flow than expected was entering the plant. A study concluded that some flows had been underestimated by the modeling methods in place during design. Ecology accepted the study and modified the frequency and volume permit limits to reflect the actual situation to allow 14 discharges per year, for an annual volume of 46 MG. Since then, modifications were completed to respond to new requirements. The Carkeek CSO Treatment Plant was retrofitted in 2005 with dechlorination facilities and other modifications to address the new permit limits for chlorine and lower fecal coliform concentrations. These are viewed by King County as ongoing routine O&M activities under the NPDES permit. This facility is considered completed and controlled.

Table 9-2 presents the Carkeek CSO Treatment Plant issues, corresponding causes, actions completed to correct the issues, and the schedule. These issues were addressed to bring the plant into permit compliance.

9.2.1 Carkeek Improvements Schedule

There is a project to replace flow meters, include additional metering capacity, and initiate automatic pumpdown at the facility.

Table 9-2. Carkeek CSO Treatment Plant Issues, Causes, Corrective Actions, and Schedule

Issue	Cause	Corrective Actions	Schedule
Plant received more flow than permitted	Service area flows were missed during the modeling completed for design in the late 1980s.	Study completed to determine cause. Ecology agreed changing the permit limits was appropriate.	Resolved
Chlorine residual exceedance; non-representative sample		High Cl2 residual alarm during a discharge event	Completed December 2009
		Alarm Logic added December 31, 2009 (If effluent is >.MGD and the effluent residual is >.49, the following alarm will be displayed: "CARK-Effluent CL2 Residual – High"	
		Replaced & protected corroded relay	Completed August 2010
		Implement new strategy using solenoid valve on City water line; add "no flow" switch to effluent sample line.	Completed January 2011
Missed samples		Training program has been updated to formalize and better document the annual refresher training.	Completed August 2010
		Training to be provided prior to each wet season and as needed, during the wet season.	
Improving reliability and including additional alarm capability		Replacing existing influent and effluent auto samples prior to any problems.	End of September 2011

9.3 Denny Way Regulator/Dexter Ave Regulator/Elliott West CSO Treatment Facility

The Denny Way/Lake Union CSO Control project was built to control the county's Denny Way Regulator and Dexter Ave Regulator CSOs. It was a joint project with the City of Seattle to also control the city's East Lake Union CSOs. Construction was completed in May 2005. The project is referred to as the Mercer/Elliott West CSO Control System.

The project consisted of four major elements:

- The city's control projects along East Lake Union that convey captured CSOs to the county's new facilities (not discussed further in this technical memorandum)
- The East Portal, which captures flow from a number of sewer lines in the South Lake Union area, including the city's East Lake Union projects

- The Central Trunk Diversion Structure to send excess flow to the 14-foot-diameter Mercer Tunnel to eliminate overflows at the Dexter Ave Regulator along southwest Lake Union
- The Elliott West CSO Treatment Facility located on Elliott Bay.

Two new CSO outfalls were built in Elliott Bay—one outfall to replace the outfall structure at the Denny Way Regulator and another outfall, including monitoring and dechlorination facilities, for the Elliott West CSO Treatment Facility. The Mercer Tunnel provides storage for up to 7.2 MG and primary clarification for flows entering the tunnel. The Elliott West CSO Treatment Facility was designed to provide final treatment—screening, disinfection, and dechlorination—to flows that exceed the capacity of the Mercer Tunnel. Such treatment was expected to occur about 14 to 20 times per year.

While significant overflow volume reduction has been achieved at both the Denny Way Regulator and Dexter Ave Regulator, the one untreated discharge per year standard has not yet been achieved at the CSO sites. Control of the two CSO sites depends on the Mercer/Elliott West CSO Control System performance. The very complex Mercer/Elliott West CSO Control System has also had difficulty meeting its permit requirements. Attention has been first focused on refining its operations and performance. As its performance has improved, attention has been able to focus on the other components – the two regulators. King County does not consider this system controlled, but that the system is still in the startup period. At this time the adjustments are within the practice of King County's operations, maintenance, and asset management staff and do not require planning for additional capital improvement projects.

9.3.1 Mercer/Elliott West CSO Control System Improvements Schedule

Table 9-3 presents the Mercer/Elliott West CSO Control System issues, corresponding causes, actions completed or planned to correct the issues, and the schedule. These issues are being addressed to bring the system into permit compliance.

Mercer/Elliott West CSO Control System Improvements Schedule:

Planned actions for the Mercer/Elliott West CSO Control System are described in the 2008 CSO Control Plan Update. Subsequent actions and their status are listed below:

- Monitor effectiveness of sampling improvements project – ongoing
- Monitor chlorination-dechlorination improvements project – ongoing
- Modify sodium hypochlorite dosing pump control system to resolve auto start failure – end of 2011
- Install a chlorine analyzer to measure immediate chlorine demand and modify dosing program – end of 2011.

Table 9-3. Mercer/Elliott West CSO Control System Issues, Causes, Corrective Actions, and Schedule

Issue	Cause	Corrective Actions	Schedule
Unanticipated dry-weather flows, debris and hydrogen sulfide reducing the tunnel's storage capacity by 1 to 2 MG, causing pump damage and complicating treatment compliance.	Dry-weather flows entering the Mercer Tunnel from Seattle's East Lake Union system.	The volume of dry-weather flows to the tunnel was reduced but not resolved after the City of Seattle completed three extensive pipeline cleanings in 2006 and 2007; however, dry-weather flows into the tunnel resumed with the December 3, 2007 storm. Weir modifications (stop log installation, see **Error! Reference source not found.**) were made by King County and funded by Seattle to resolve the flow into the Mercer Tunnel.	Resolved July 2008. Flows will be monitored to verify that the modifications continue to work. The City of Seattle will continue to investigate the East Lake Union system for possible sources of sediments. If the sedimentation can be corrected, the weir will be returned to its original configuration.
Hydraulics			
Overflow from the dechlorination and transition structures during large storm in December 2006.	Duck bill valve on outfall was restricting flow.	Duck bill valve removed and flow temporarily limited to 240 MGD.	March 2007
Overflow from the dechlorination and transition structures occurred again in December 2007.	The hydraulic grade line in the effluent pipeline was higher than the tops of the dechlorination and transition structures, forcing flow to escape the structures.	Add an aboveground structure over the dechlorination structure to overcome hydraulic grade line limitations, allow for dampening of hydraulic surges and air release to minimize the over-pressurization of Elliott West CSO Treatment Facility effluent pipeline resulting during periods of extreme flows	Under an emergency waiver, construction began in September 2008 to implement recommended modifications to the dechlorination and transition structures. Completed December 2009 No further releases have occurred
Improve flow controls input data		Installation of a portable level sensor at the EBI Control Structure	Summer 2010

Issue	Cause	Corrective Actions	Schedule
Solids Removal			
Exceedance of settleable solids limit	Solids retained in tunnel influencing later event removal calculations	Resolved dry-weather inflow from Seattle system.	July 2008
		Optimize the tunnel flushing system utilizing the gate at East Portal.	Ongoing from 2009
		Reviewing strategies for an automated flushing program.	Completed 2009
		Revised approach to cleaning solids from the wet well.	
Failure to obtain representative samples for solids calculations	The main pump sampler was too far away from the sample intake, creating a loss of suction.	Modified the sampling pipe intake to ensure collection of composite sample.	Completed in October 2007
		Relocated the dewatering composite sampler closer to dewatering sump pumps to avoid negative pressures.	Completed in October 2008.
	The effluent samples were being influenced by:	Effluent Sampling Improvement Project initiated in 2010, including:	
	• Marine solids entering the effluent outfall and settling in the transition structure.	• Moving the effluent sample pump or its intake line upstream of the flap gate to eliminate marine sediments influence	October 2011
		• Low tide conditions – inadequate pool depth for sample collection will likely require relocating effluent sample pump or sample intake line upstream.	Summer 2010
	• Solids remaining from previous events due to slow drainage resulting from bent shaft on drain gate.	• Change valves controlling C2 water addition at sampling tee, to stop sample contamination.	October 2010
		• Installation of a portable skid-mounted AC-powered peristaltic pump to safely collect grab samples if the sample pump fails or line plugs.	August 2011
		• Replacement of bent shaft on the drain gate	Completed August 2010
Disinfection Systems			
Fecal Coliform permit limit violations. Poor disinfection of discharged flows and excessive usage of hypochlorite.	Inadequate mixing identified.	Upgrade hypochlorite mixing equipment.	Project underway, anticipated completion October 2011.
	Premature shutdown of the hypochlorination pumps.	The time delay for the interlock-initiated shutdown of the hypochlorination pump was increased.	Resolved December 2009

Issue	Cause	Corrective Actions	Schedule
Effluent chlorine residual sampling problems November 2009.		Burned out effluent sample pump motor was rebuilt and installed.	May 2010
		High effluent residual chlorine SCADA alarm created to call out staff.	
		Implement new strategy using solenoid valve on City of Seattle water line avoiding effluent sample dilution; makeup water supply automatically reopens when discharge ends.	
		Procedural changes implemented to staff the facility for the first 4 hours of a discharge event to ensure the 4- to 8-hour fecal sample is collected at the 4-hour mark	August 2010
Dechlorination			
Inadequate dechlorination (SBS) capacity		Began stocking 38 percent sodium bisulfite in the storage tanks (as opposed to the design concentration of 25 percent sodium bisulfite) at the end of 2007.	Completed October 2008
		Increased the storage room temperature above 60ºF to prevent SBS crystallization.	
Loss of dechlorination during January 8, 2009 event.	Crystallization of SBS caused by prolonged ground freezing temperatures resulted in plugging of line between storage tank and day tank.	The transfer line was cleared.	Resolved February 2009
		Cleanouts were installed at key locations on the transfer line to allow jetting of the line to remove the crystal deposits.	
		Procedure initiated to flush the transfer line prior to cold weather events.	
		Installed pressure gauge on the transfer line to monitor for possible line constrictions.	January 2011
Disinfection/Dechlorination System Controls & Sampling			
Existing sampling system design, location, needs to be improved for representative sampling		Install pre-dechlorination sampling system improvements.	Completed December 2009

Issue	Cause	Corrective Actions	Schedule
Repeated permit limit exceedances		The Chlorination-Dechlorination Improvements project initiated to:	
		Install a feedback loop control for disinfection and dechlorination systems to optimize chemical usage and permit compliance.	Summer 2010
		Install flow meters on the hypochlorite and bisulfite pumps.	
		Install an initial chlorine demand analyzer at the Elliott West CSO Control Facility.	
		Provide chemical dose monitoring.	
		Install chlorination and dechlorination feedback loop controls.	
		Improve the chlorination injection system.	
		Modify sodium hypochlorite dosing pump control system to resolve auto start failure.	End of 2011
		Install a chlorine analyzer to measure immediate chlorine demand and modify dosing program.	End of 2012
		Install new sample pump.	July 2010
		Implement procedures, so that the pump is regularly inspected and tested during low flow conditions.	
		Add key spare parts for hypochlorite pump to inventory.	
		Add control logic for minimum hypochlorite flow.	
		Add diffusers to the current hypochlorite application point to better disperse hypochlorite.	
		Add modifications to the SBS system plumbing, similar to what was done with the hypochlorite to enable capacity checks and calibration.	

Figure 9-1. Stop Log Installation at Valley Connection from East Lake Union

9.3.2 Denny Way Regulator

The associated Denny Way Regulator CSO site has not met the control standard since the facilities came on-line in May 2005. Investigation suggests that two of the inputs – Denny Local and Denny Lake Union – are overflowing more than intended. The investigation recommended removal of the lower Denny Local weir, lowering of the upper Denny Lake Union weir by 0.15 feet, and modification of the Elliott West pump ramp-up strategy to improve flow into the facility. The weir modifications were completed on July 22, 2011; pump strategy modifications are in the planning stage. These improvements cannot be tested until sufficiently large storms occur in the next wet season.

Table 9-4 presents the Denny Way Regulator issues, corresponding causes, actions completed or planned to correct the issues, and the schedule. These issues are being addressed to bring the facility into permit compliance.

Denny Way Regulator Improvements Schedule

Test effectiveness of weir modifications and changed pumping strategy over 2011 to 2012 wet season; evaluate if storms of sufficient size trigger overflows. As one marker, in 2010 the "one-per-year" event required approximately 2 inches of rain over 83 hours.

Table 9-4. Denny Regulator Issues, Causes, Corrective Actions, and Schedule

Issue	Cause	Corrective Actions	Schedule
Has not achieved one untreated discharge per year (average) standard	Control system not effective.	Removed lower Denny Local weir. Lowered upper Denny Lake Union weir by 0.15 ft.	July 2011
		Modification of the Elliott West pump ramp-up strategy to improve flow into the facility.	Implement strategy October 2011 Test effectiveness over 2011 to 2012 wet season

9.3.3 Dexter Ave Regulator

The associated Dexter Ave Regulator CSO site also continues to have frequent, but much smaller overflows since the Mercer/Elliott West CSO Control System came on-line. The Facilities Plan had noted that control system adjustments might be needed to bring the CSO site into full control after the new facilities were in place. Investigation has highlighted the control challenges of this CSO site. The upstream service area is highly impervious, and most of the stormwater is routed quickly into the combined sewer system, causing extremely rapid rises to high peak flows. The goal of control system refinement at the Dexter CSO site is to maximize use of upstream storage and transfer to the Mercer Tunnel and downstream conveyance while minimizing overflows. This requires the maximum allowable upstream level be set as high as possible. As a result, there is little vertical difference between maximizing the use of upstream storage and possible flooding, as well as maximizing downstream conveyance and causing overflow at the downstream weir. These narrow vertical operational ranges for control of the gate may decrease modulation precision. These conditions also require the regulator gate to move quickly, but avoid overshooting its optimal position during rapid changes in flow. However, the regulator gate is large and difficult to modulate without releasing large amounts of the stored upstream flow volume.

Increasingly subtle changes to the algorithms have been added to achieve the control objective. In early 2007, a new programmable logic controller (PLC) with new programming was installed. This modification to the algorithm added feed-forward control using upstream interceptor levels to the regulator gate control algorithm that had been based only on downstream interceptor levels. Later in 2007, modulation of the gate based on the downstream interceptor level was added to the algorithm.

The 2007 to 2008 wet season indicated that these control modifications had not sufficiently reduced the overflow frequency; the interceptor level filter time constant was adjusted to correct gate, flow, and level oscillations. This was implemented in October 2008 and tested through the 2008 to 2009 wet season.

In 2009, the algorithm was changed to refine the modulation set-points and ranges, the regulator gate start position was changed to 50- to 60-percent open, and the set point for the float switch actuating the bypass gate was adjusted. These adjustments were evaluated over the 2009 to 2010 wet season.

In 2010, the level set points for the regulator gate start position were further adjusted.

During 2011, further control modifications are being tested and evaluated. These are described in the *Control of Dexter CSO Memorandum*, which is included in Appendix I.1.

To reduce and smooth the flows coming to the Dexter Ave Regulator, King County is also in discussions to participate in stormwater management projects with WSDOT for their Viaduct replacement, as well as with Seattle Center to implement green stormwater infrastructure projects. It is expected that these will benefit Dexter CSO control.

King County is working closely with major projects in the Dexter Ave CSO basin, including the North Access Viaduct (Washington State Department of Transportation, WSDOT), Mercer Street West (Seattle Department of Transportation, SDOT), and Seattle Center Capital Improvements.

Both transportation projects will detain stormwater from new and replaced impervious surfaces to meet the City of Seattle Drainage Code. Once 30-percent design is reached on these projects, SDOT and WSDOT will provide King County with total stormwater detention volumes.

Seattle Center is currently embarking on a long-term capital improvement program to replace and upgrade facilities. Stakeholders are interested in implementing GSI on the Seattle Center campus to the maximum extent feasible. King County and Seattle Center are working on plans to mitigate impervious surfaces on campus. Specific projects have not been identified. Seattle Center is 69 acres, and there is a total of 58 acres of impervious areas in hardscape and roof area. As part of a memorandum of agreement, the CSO control program will work closely with Seattle Center to identify projects to mitigate stormwater including bioretention, green roofs, and permeable pavements. Approximately 10- to 20-percent of the impervious surfaces would reduce stormwater volume from Seattle Center into the combined sewer system. Once projects have been identified, volume reduction to the combined sewer system can be modeled and used to optimize the existing system.

These stormwater management and GSI projects are under the lead of other agencies. King County can facilitate their completion but does not have control over the schedules. All dates provided here are estimates. King County prepared the *GSI Program Memorandum*, which describes these programs and projects to reduce stormwater flows in the Dexter Ave CSO Basin; this memorandum is included in Appendix I.2.

Table 9-5 presents the Dexter Ave Regulator issues, corresponding causes, actions completed or planned to correct the issues, and the schedule. These issues are being addressed to bring the facility into permit compliance.

Dexter Improvements Schedule

Monitor control system modification effectiveness over 2011 to 2012 wet season.

- WSDOT Project:
  - Stormwater management facilities on line – approximately 2015
  - Verification of flow reduction benefit at Dexter Ave CSO site – 2018, depending on rain
- Seattle Mercer Project:

- Stormwater management facilities on line – approximately 2016
- Verification of flow reduction benefit at Dexter Ave CSO site – 2019, depending on rain

- Seattle Center Project:
  - Completion of GSI projects – between 2012 and 2024
  - Verification of flow reduction benefit at Dexter Ave CSO site – report in each annual report with assessment in each Plan Update

Table 9-5. Dexter Ave Regulator Issues, Causes, Corrective Actions, and Schedules

Issue	Cause	Corrective Action	Schedule
Has not achieved one untreated discharge per year (average) standard	Control system not effective	New PLC with new programming, including feed-forward control using upstream interceptor level, installed.	2007
		Modulation of the gate based on the downstream interceptor level was added to the algorithm.	2007
		Interceptor level filter time constant adjusted to correct gate, flow, and level oscillations.	October 2008
		Algorithm was changed to refine the modulation set-points and ranges. Regulator gate start position was changed to 50- to 60-percent open. Set point for the float switch actuating the bypass gate.	2009
		Level set-points for the regulator gate start position adjusted.	2010
	Upstream service area is highly impervious with extremely rapid rises to high peak flows.	Participate in Stormwater management and Green Stormwater Infrastructure projects with WSDOT Viaduct, Seattle Mercer Street, and Seattle Center projects.	WSDOT project complete – approximately 2015 Seattle Mercer project complete – approximately 2016 Seattle Center project complete – incrementally between 2012 and 2024

9.4 Harbor Ave CSO Site

"Control" has now been defined as one untreated discharge per year on a 20-year moving average. For new facilities lacking 20 years of measured performance, modeled data for how the facility would have performed under those previous years' rainfall is substituted. Each year of new measured performance is added the oldest year of modeled data is dropped. In one case – Harbor Ave CSO site – modeling for the project was done in about 1994 – well before this new control definition was set. The old model is no longer available to perform the retrospective modeling. The current newly-calibrated model does not predict the Harbor Ave CSO site to be in control. Measured data, however, does indicate it is controlled. This may be an error in the new model, so King County is exploring the differences between the model and measured data. King County has not designated the Harbor Ave CSO site as controlled at this time. However, there is no indication that a control project is needed.

Table 9-6 presents the Harbor Ave CSO site issue, corresponding cause, actions completed or planned to correct the issue, and the schedule. These issues are being addressed to bring the facility into permit compliance.

9.4.1 Harbor Improvements Schedule

Recalibrate model for area – Complete December 2019.

Table 9-6. Harbor Ave CSO Site Issues, Causes, Corrections, and Schedule

Issue	Cause	Corrections	Schedule
Inability to show control using modeled data in 20-year average		Monitoring indicates facility is controlled.	Continue monitoring; recalibrate model for basin after CSO Control Plan Update is completed.

9.5 Henderson/MLK CSO Treatment Facility

The Henderson/MLK CSO Treatment Facility project was implemented to control the Henderson and Martin Luther King (MLK) CSO sites into Lake Washington and the Norfolk CSO site into the Duwamish River. King County upgraded the Henderson Pump Station and constructed a large storage and treatment tunnel between Henderson Street and Norfolk Street in the Rainier Valley. The facilities were designed to provide primary clarification, chlorinate and dechlorinate flows that exceed the capacity of the storage and treatment tunnel, and discharge treated flows at the Norfolk CSO site in the Duwamish Waterway. The design assumed that this discharge would occur approximately two to four times per year. Base flows, settled solids, and stored flows from the tunnel are conveyed to the South Treatment Plant at Renton or to the West Point Wastewater Treatment Plant, depending on capacity in the Elliott Bay Interceptor, for secondary treatment.

The project was completed in May 2005 but did not operate during its first season. Following adjustments made in 2006 to the influent gate control programming, the Henderson Tunnel began filling and treating CSOs. The disinfection system has continued to require refinement to meet very low chlorine permit limits for the river while maintaining disinfection. Optimization of the disinfection and dechlorination systems will continue to be a challenge. This is due to the limited CSO events available for fine-tuning, as well as the difficulties of measuring the chlorine residual for feedback control. Currently, the hypochlorite and bisulfite pumps are only flow-paced, though there is an initially high dose of hypochlorite to address the "first flush" phenomenon. In late January 2009, a new amperometric low-level chlorine analyzer was installed at the MLK outlet regulator structure. This analyzer will be used to monitor the final effluent chlorine residuals. It is capable of measuring total combined chlorine at or below the permit limit of 39 micrograms per liter. This unit has been used successfully at King County's Carkeek CSO Treatment Plant. This online analyzer will replace the manual DPD method; however, the manual DPD colorimetric method will be used during a discharge event to verify calibration of the online analyzer.

In summer 2010, the City of Seattle discovered that several of the sanitary sewer connections from a new housing project in southeast Seattle were improperly connected to a section of the City of Seattle's stormwater system that discharged to Lake Washington. The City of Seattle asked to temporarily discharge this contaminated stormwater flow to the sanitary system until the problem could be remedied. In early October, the stormwater system was connected into the City of Seattle's sanitary system just upstream of the Henderson/MLK CSO Treatment Facility. With a projected maximum flow of 5 MGD, this temporary connection may have resulted in the Henderson/MLK CSO Treatment Facility operating more often and discharging more treated CSOs than without the temporary connection. As of May 2011, all of the illicit housing connections were repaired. The temporary connections between the City of Seattle's stormwater and sanitary systems were removed by August 2, 2011.

Any improvements required to this facility are viewed by King County as ongoing routine operations and maintenance under the NPDES permit. This facility is considered completed and controlled.

The Henderson Pump Station CSO site, MLK CSO site, and Norfolk CSO site are considered by King County to be controlled. Table 9-7 presents the Henderson/MLK CSO site issues, corresponding causes, actions completed to correct the issues, and the schedule.

9.5.1 Henderson Improvements Schedule

None pending

Table 9-7. Henderson/MLK CSO Treatment Facility

Issue	Cause	Corrections	Schedule
Tunnel did not operate in first year despite adequate rainfall	Programming was not signaling the need for the regulator gate to close.	Adjustments made in 2006 to the regulator gate control programming	Completed 2006
Fecal Coliform and Residual Chlorine permit exceedances	Feedback controls not sensitive enough to low levels of chlorine	New amperometric low-level chlorine analyzer was installed at the MLK outlet regulator structure.	January 2009

Missed Samples		Training program has been updated to formalize and better document the annual refresher training. Training to be provided prior to each wet season and as needed during the wet season.	Ongoing
	Low flow volume – composite did not work. High-inlet alarm did not enunciate.	Procedures changed – for short duration events, will collect a grab sample regardless. Alarm reestablished.	October 2011

This page left blank intentionally.

10.0. REFERENCES

10.1 Program Review Technical Memoranda

Technical Memorandum 540, Environmental and Habitat Priorities

Technical Memorandum 620, Cost Estimating Methodology for CSO Control Facilities

Technical Memorandum 800, Green Stormwater Infrastructure Feasibility Evaluation

Technical Memorandum 700, Treatment Technology Selection

Approach to Triple-Bottom-Line Analysis Technical Memorandum

10.2 Other Sources

City of Seattle. 2009. Director's Rule 17-2009, SPU 2009-005, Volume III, Stormwater Flow Control and Water Quality Treatment Technical Requirements Manual. http://www.cityofseattle.net/dpd/Codes/StormwaterCode/DirectorsRules/default.asp.

Great City. Green infrastructure Web page. http://www.greatcity.org/campaigns/green-infrastructure/. Accessed October 21, 2009.

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

Kennedy, Lori, Holmes, Lydia, and McDonald, Steve. 2007. Low Impact Development: San Francisco's Green Approach to Stormwater Management. Proceedings of the Water Environment Federation, WEFTEC 2007. Session 1 through Session 10, 723–737(15). Water Environment Federation.

King County. 1998. RWSP Executive's Preferred Plan. King County Department of Natural Resources. April 1998.

King County Department of Natural Resources and Parks, Wastewater Treatment Division. 2008. Technical Memorandum207.1, CSO Beach Project GIS Analysis. Seattle, WA.

King County Department of Natural Resources and Parks, Wastewater Treatment Division. 2009. Technical Memorandum 600.1, CSO Beach Projects, Green Infrastructure GIS Analysis. Seattle, WA.

King County Department of Natural Resources and Parks, Wastewater Treatment Division. 2010. Technical Memorandum 600.3, CSO Beach Projects, Modeling for GSI Options. Seattle, WA.

Seattle Public Utilities (SPU). 2009. Memorandum on Determining Connectivity of Downspouts to the Combined Sewer. June 4, 2009.

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

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

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

Water Environment Research Foundation. 2009. SW2R08, BMP and LID Whole Life Cost Models: Version 2.0.