CITY OF SPOKANE

CSO Plan Amendment

FINAL

CH2MHILL®

CSO Plan Amendment

FINAL

The purpose of the City of Spokane Combined Sewer Overflow (CSO) Plan Amendment is to advance reductions in CSO and to amend the City's 2005 CSO Plan. This 2013 Plan Amendment documents modifications to the City's CSO Program as a result of changes to applicable regulations, improvements in computer modeling tools, information about the actual performance of CSO storage facilities already built, implementation of the Spokane County Reclamation Facility, and other progress made on CSO control within the City. This document guides the City's CSO Program as of January 2014.

What is a Combined Sewer Overflow, or CSO?

A combined sewer overflow occurs when a large amount of stormwater (rainfall that hits the ground and runs off surfaces, rather than infiltrating into the ground) enters the sewer system and combines with sewage, ultimately exceeding the capacity of the combined sewer pipe, and overflows the system into the receiving water through a pipe called a CSO outfall.

Why does Spokane have CSOs?

The City of Spokane's first piped sewage system was built in the first decades of the City's founding. As Spokane has developed, many additional miles of sewer were built and more and more sewage and stormwater flows were routed to this single combined system.

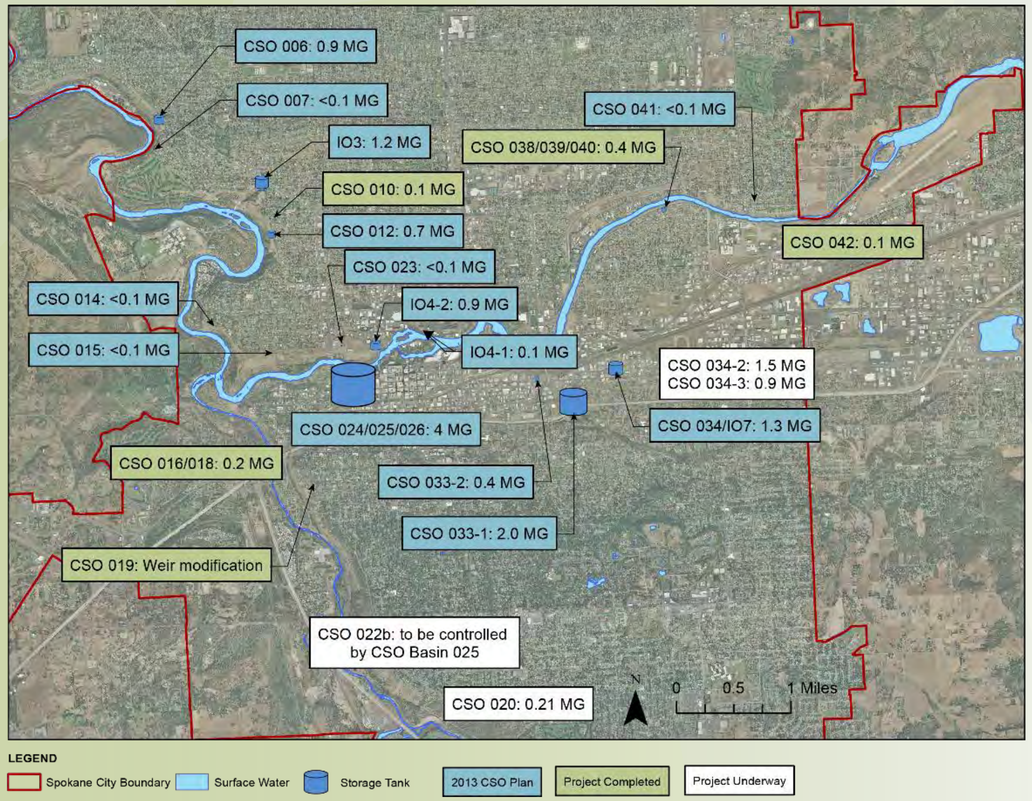
Over the years, the City of Spokane has implemented projects to separate stormwater and sewage systems in parts of the City, to build CSO storage facilities, and to maximize the combined sewage treated at the City's Riverside Park Water Reclamation Facility (RPWRF). Efforts to manage CSOs continue with this 2013 CSO Plan Amendment.

CH2MHILL

What's Next for CSO Control in Spokane?

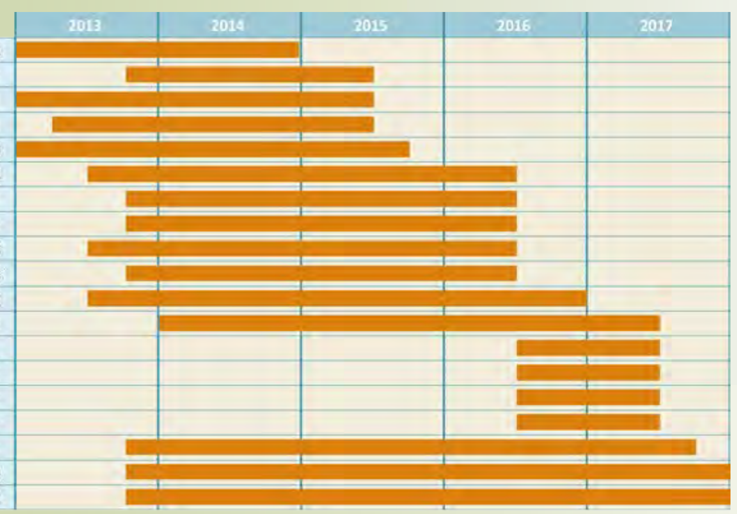
This 2013 CSO Plan Amendment specifies capital projects that will reduce both CSO frequency and volume. The locations of these projects are shown on the map included here. Projects are currently underway to control CSO outfalls 20 and 24. In addition, two storage projects are underway that will help to control CSO outfall 34, with an additional project planned for implementation by the end of 2017 that will control that outfall.

These capital projects and programmatic activities are investments in the City of Spokane's Clean Water initiative focused at achieving a cleaner river faster. The timeline included here summarizes the anticipated implementation schedule for these projects. Current and future projects in this 2013 CSO Plan are expected to cost a total of $183 million. Although the projects in the 2013 CSO Plan represent a cost savings estimated at more than $100 million as compared to the projects in the 2005 CSO Plan, these clean water investments still require a significant financial investment. The City is actively identifying other potential sources of funding from outside the City and is developing a funding strategy to further reduce the burden on its ratepayers from what was projected in the 2005 CSO Plan. In Spokane, the median household income is only 70 percent of the statewide average, so it is critical to find ways to make investments cost-effective and more affordable for ratepayers. Specifics of the impacts to rate payers of this CSO Program and other elements of the City's Integrated Clean Water Strategy will be included in the 2014 Integrated Plan.



The 2013 CSO Plan Amendment includes several current and future projects that will bring remaining uncontrolled CSO outfalls into compliance with the frequency-based performance standard. In addition to the projects already underway, 11 new storage facilities and 4 improvements to existing regulators are planned.

Project / Outfall	Size (millions of gallons)	Capital Cost ($M)
34-3	0.9	14.8
33-2	0.4	5.5
20	0.2	4.3
24	0.1	2.1
34-2	1.5	17.9
6	0.9	11.4
14	0.1	1.7
15	0.1	1.5
I-03 NW	1.2	12.8
I-04 M	0.1	10.8
33-1	2.1	27.2
I-04 D	0.9	3.3
7	0.01	0.5
23-1	0.005	0.6
23-2	0.005	0.6
41	0.01	1.3
12	0.7	8.7
34 and I-07	1.2	15.9
24 & 25 & 26	4.0	42.2
Total	14.3	183.0



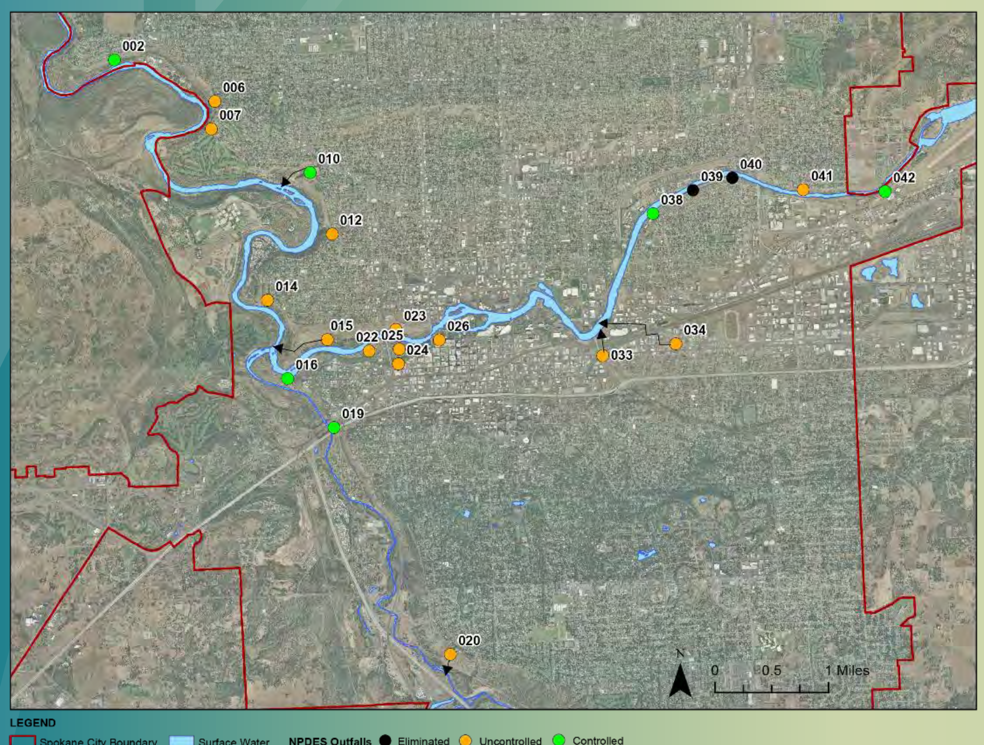
The City plans to implement CSO control projects to bring its remaining uncontrolled outfalls into compliance by the end of 2017. This schedule is dependent on obtaining outside assistance with funding these projects. Maximizing return on investment is a priority for the City, on behalf of its ratepayers

Questions or Comments on this CSO Plan Amendment?
City of Spokane CSO Program Contact:
Marlene Feist
City of Spokane Utilities Communications Manager
509-625-6505
mfeist@spokanecity.org

Status of CSO Control in the City of Spokane

During 2012, 251 individual overflow events conveyed an estimated 73 million gallons (MG) of combined sewage from the combined system through the City's 22 CSO outfalls into receiving waters. As of December 2013, the average annual overflow volume over the past 12 years is 52 MG. Although this is a significant reduction in annual overflow volume as compared with more than 500 MG per year in the 1980s, the City still has more work to do.

Of the City's 22 CSO outfalls, 2 have been physically eliminated and 6 have been addressed through implementation of CSO storage facilities and weir modifications built over the last decade, leaving 14 uncontrolled outfalls. Activities specified in this CSO Plan Amendment focus on reducing the frequency and volume of CSOs at the remaining 14 CSO outfalls.



The City of Spokane has 22 permitted CSO outfalls located throughout the City. Of these 22, 14 remain uncontrolled as of 2012.

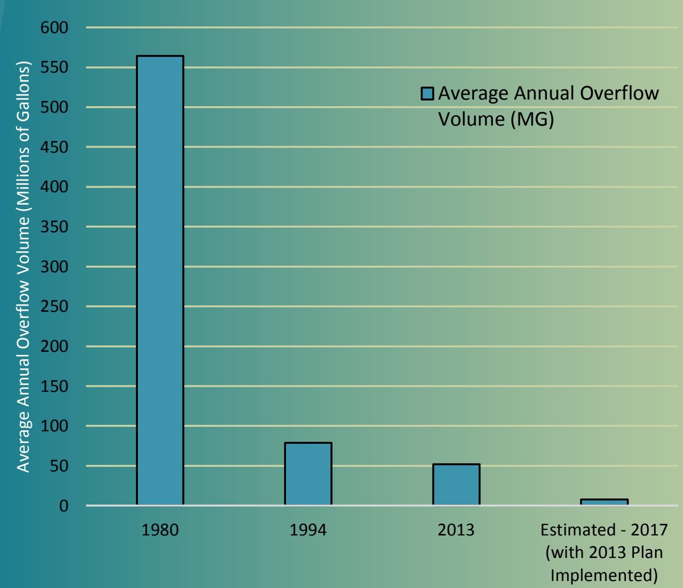
A Focus on CSO Control

A CSO outfall is considered "controlled" if it meets the frequency-based performance standard in the City's CSO permit of not more than one discharge event per year on average based on a 20-year moving averaging period. An outfall is uncontrolled if it does not meet this performance standard. Of the City's 22 permitted CSO outfalls, 14 remain uncontrolled. This CSO Plan Amendment focuses on controlling these remaining uncontrolled outfalls.

Regulatory Requirements

The City of Spokane operates its CSO Control program within the National Pollutant Discharge Elimination System (NPDES) permit program as authorized by the Clean Water Act (CWA). The Washington State Department of Ecology (Ecology) administers the NPDES program on behalf of the United States Environmental Protection Agency (USEPA). The City of Spokane's current NPDES permit (Permit No. WA-002447-3, effective July 1, 2011, expiration date June 30, 2016) specifies a frequency-based performance standard for controlled CSOs as not more than one discharge event per year on average based on a 20-year moving averaging period, determined annually. This NPDES permit also requires the City of Spokane to bring all remaining CSO outfalls into compliance with this performance standard, and all final state and federal requirements applicable to such discharges, by December 31, 2017.

In addition to the City of Spokane's NPDES permit, other regulations apply, including the Washington State Water Pollution Control Law, the USEPA CSO Control Policy (including the Nine Minimum Controls), the Total Maximum Daily Load for the Spokane River, and Washington State Water Quality Standards, which are also referred to in the NPDES permit.



The average annual combined sewage overflow volume to Spokane's receiving waters has been reduced significantly from pre-1980s amounts of over 500 MG per year. With implementation of this 2013 CSO Plan Amendment, the average annual overflow volume is estimated to drop even further.

Integrated Clean Water Strategy

This CSO Plan Amendment is consistent with the City of Spokane's Integrated Clean Water Strategy to achieve the goal of a Cleaner River Faster. Concurrent with preparation of this CSO Plan Amendment, the City is proceeding with a planning process to integrate all the City's clean water investments, including those for CSOs, stormwater, and municipal wastewater treatment at the City's Riverside Park Water Reclamation Facility (RPWRF). The City is preparing an Integrated Plan document to summarize its Integrated Clean Water Strategy, which is the result of the integrated planning process. This CSO Plan Amendment focuses on control of CSOs using conventional "gray" methods of storage and conveyance improvements. The Integrated Plan will describe the City's proposed plan to implement Green Stormwater Infrastructure (GSI) as both a CSO and a stormwater management tool.

City of Spokane CSO Plan Amendment – FINAL

Prepared by: CH2M HILL

Amy M. Carlson, P.E.

CH2M HILL
March 2014
Amy M. Carlson, P.E.

AMY M. CARLSON
STATE OF WASHINGTON
42769
REGISTERED
PROFESSIONAL ENGINEER

Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

AACE	American Association of Cost Engineering
AFI	allowance for indeterminates
C3	Conceptual Cost Calculator
cfs	cubic feet per second
CSO	combined sewer overflow
CTE	Consoer Townsend Envirodyne Engineers (now operating as AECOM)
CWA	Clean Water Act
Ecology	Washington State Department of Ecology
GI	Green Infrastructure
I/I	infiltration and inflow
MG	million gallons
mgd	million gallons per day
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
RCW	Revised Code of Washington
RPWRF	Riverside Park Water Reclamation Facility
SCS	Soil Conservation Service
USEPA	United States Environmental Protection Agency
WAC	Washington Administrative Code

Introduction and Background

The purpose of the City of Spokane's 2013 Combined Sewer Overflow (CSO) Plan Amendment is to document modifications to the City's CSO Program. These modifications are the result of revised requirements in the City's 2011 Spokane National Pollutant Discharge Elimination System (NPDES) permit for CSOs, improvements to planning tools (specifically computer models, monitoring data, and meteorological records), additional information about the performance of built storage facilities and weir modifications, and other progress made on CSO control within the City of Spokane (including resulting improvements to CSO control status). This document amends the 2005 Combined Sewer Overflow Reduction System Wide Alternative Report, which has served as the City's CSO planning document since 2005. The principal change to the 2005 Plan as a result of these revised requirements and additional information is revision of storage facility volumes necessary to control the outfalls to the NPDES performance standard of one overflow per year on a 20-year moving averaging period.

This 2013 CSO Plan Amendment is intended to guide the City's CSO Program starting in January 2014. The analyses described in this 2013 CSO Plan Amendment were based on monitoring data through December 2012 and computer modeling simulations through July 2013. Status of on-going projects are as of December 31, 2013.

REGULATORY REQUIREMENTS

The City of Spokane operates its CSO Control program within the NPDES permit program as authorized by the 1972 amendments to the Federal Water Pollution Control Act (known as the Clean Water Act [CWA]). The Washington State Department of Ecology (Ecology) has authority to administer the NPDES program on behalf of the United States Environmental Protection Agency (USEPA). In addition to the City of Spokane's NPDES permit, other regulations apply, including, but not limited to, the Washington State Water Pollution Control Law, the USEPA CSO Control Policy (including Nine Minimum Controls) (USEPA, 1994), and Washington State Water Quality Standards (Chapter 173-201A of the Washington Administrative Code [WAC]).

The City's current NPDES permit (Permit No. WA-002447-3, effective July 1, 2011, expiration date June 30, 2016) (Ecology, 2011) specifies a performance standard for controlled CSOs as not more than one discharge event per year based on a 20-year moving averaging period. This is an update from the City's March 2000 NPDES permit valid in 2005, which specified a performance standard of not more than one discharge event per year on average based on a 5-year moving averaging period. The WAC specifies the performance standards that are then carried out in the NPDES permits.

HISTORY OF CITY OF SPOKANE CSO CONTROL

Historical CSO Planning Efforts and System Improvements

Prior to the 2005 CSO Plan, the City of Spokane developed a Combined Sewer Action Plan (Esvelt and Saxon, 1972), a Facilities Planning Report for Sewer Overflow Abatement (City of Spokane, 1979) and a Combined Sewer Overflow Reduction Plan (Bovay, 1994). In 1999, the City began implementing its 1994 CSO Reduction Program to bring all remaining CSO outfalls into compliance with WAC 173-245 by December 31, 2017. This program yielded a reduction in annual overflow events from approximately 1,000 per year to an average of approximately 250 events per year, mostly due to sewer separation projects. After these separation projects, much of the south side of Spokane was still served by combined sewer systems. Following this capital investment, the 2005 System Wide Plan was prepared and approved.

CSO Reduction Efforts Since 2000

The City of Spokane has constructed a total of six (6) CSO control facilities located at CSO outfalls 2, 10, 16, 19, 38, and 42. In addition to building CSO control facilities, the City has made weir modifications to regulators of CSO outfalls 6, 7, 12, 14, 15, 25, 26, 39, and 40. These weir modifications consisted of replacing the old flow regulators with control vaults. These vaults contain a hydroslide controlling flow into the interceptor, and an overflow weir to the river. These are effectively a CSO control facility without the storage tank. These vaults replaced a dam at CSO outfall 26, a side dam at CSO outfall 25, and a leaping weir at CSO outfalls 6, 7, 12, 14, 15, 39, and 40.

The City has physically eliminated CSO outfalls 3b, 16a, 16c, 18, 39, and 40, with CSO outfalls 39 and 40 eliminated most recently in January 2013. Outfalls 16a and 16c were not believed to have been functional, but were physically eliminated for certainty. Control status of these outfalls is summarized in Table 1.

In addition to constructed facilities, weir modifications, and outfall eliminations, the City of Spokane performs CSO reduction activities specified in the Nine Minimum Controls in USEPA's CSO policy. These include operations and maintenance (O&M), collection system infiltration and inflow (I/I) reduction, and optimization of wet weather treatment at the City's Riverside

Park Water Reclamation Facility (RPWRF). The City summarizes its activities and efforts specified in the Nine Minimum Controls through required annual reporting, most recently in its 2012 CSO Annual Report (City of Spokane, 2013).

SPOKANE CSO CONTROL STATUS

The City of Spokane has twenty-two (22) NPDES-permitted outfalls. Of those twenty-two (22) NPDES-permitted outfalls, two (2) have been physically eliminated (39 and 40) and six (6) have been addressed through implementation of CSO control facilities (2, 10, 16, 19, 38, and 42). Monitoring of these facilities since implementation indicates that these outfalls all meet the performance standard of no more than one discharge event per year on a 20-year moving average as specified in the City's NPDES permit. In addition to the six outfalls addressed by project implementation, CSO outfall 22 appears to comply with the performance standard but will be addressed in an on-going CSO Control project discussed later in this Plan Amendment. Including CSO outfall 22, fourteen (14) uncontrolled outfalls remain. Figure 1 shows the outfalls that are controlled and those that remain uncontrolled based on monitoring data through December 2012.

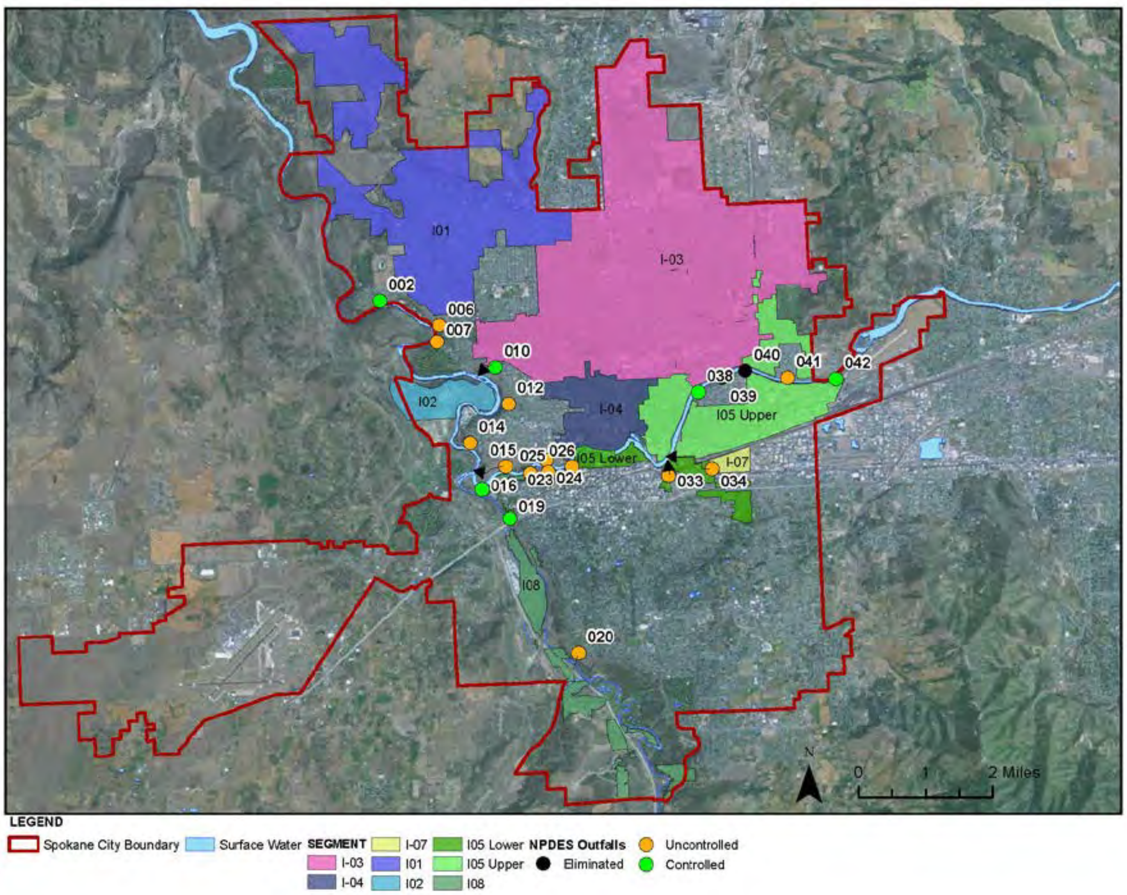


FIGURE 1. NPDES-PERMITTED CSO OUTFALLS AND INCOMPLETE SEPARATION AREAS IN THE CITY OF SPOKANE

As documented by the City in its 2012 CSO Annual Report, 251 individual overflow events across the system produced an estimated 73 million gallons (MG) of combined sewage overflowed into receiving waters, primarily the Spokane River, between January 1 and December 31, 2012 (City of Spokane, 2013). Table 1 shows the measured number of overflow events per year over the last 13 years, illustrating the variability from year to year.

Projects are currently under way in several of Spokane's CSO basins, including basins 20, 22, 24 and 34. Improvements in CSO basin 20 will bring that outfall into compliance through outfall elimination. A separation project is under way in CSO basin 22. The upbasin substorage projects under way in both CSO basins 24 and 34 are part of a multi-tank compliance strategy, so alone will not bring those outfalls into compliance with the performance standard. Additional projects that will be required to bring CSO basins 34 and 24 into compliance are described in this 2013 CSO Plan Amendment.

TABLE 1

Summary of City of Spokane CSO Control Status through December 2012

CSO Outfall Number*	Overflow Events Per Year													Monitored CSOs per year on average	Meets Performance Standard (average of 1/yr)	Built Facilities (year online)
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012			
2	0	3	16	0	0	0	0	0	0	0	0	0	0	0.0**	Yes**	2003
6	3	17	16	24	32	23	35	23	21	27	30	21	30	25.8	No	
7	NM	8	27	14	11	15	18	9	6	13	11	5	7	10.6	No	
10	0	8	10	10	7	13	17	8	6	12	13	8	1	1.0**	Yes**	2012
12	10	23	11	34	31	26	39	25	22	32	33	15	23	27.7	No	
14	NM	NM	29	20	11	21	36	17	16	18	1	0	3	14.0	No	
15	1	5	11	11	10	14	17	5	9	12	2	3	2	8.3	No	
16	NM	0	9	11	9	14	16	5	0	0	0	0	0	0.0**	Yes**	2007
19	NM	0	6	0	1	0	1	2	0	1	0	0	0	0.0**	Yes**	2010
20	NM	NM	NM	NM	1	0	0	0	0	1	0	0	2	0.4	Yes	
22	0	1	5	2	3	1	1	1	2	0	0	0	0	1.3	No	
23	3	16	20	20	17	18	28	18	16	17	16	0	12	16.5	No	
24	5	15	33	33	19	27	31	16	15	20	28	22	29	24.0	No	
25	NM	0	5	44	19	18	31	15	17	20	20	16	22	18.9	No	
26	4	16	20	24	20	20	33	16	20	27	30	21	33	23.3	No	
33	7	34	38	38	22	36	33	21	14	24	25	19	29	27.8	No	
34	2	15	18	18	19	14	27	11	16	24	17	17	24	18.3	No	
38	1	9	10	14	12	6	8	7	4	14	16	3	17	0.0**	Yes**	2012
39***	1	3	2	5	5	9	4	3	2	4	8	1	2	NA	Yes****	
40***	5	17	19	21	17	9	6	4	4	6	6	1	0	NA	Yes****	
41	NM	0	9	10	12	12	13	7	7	13	22	13	15	11.1	No	
42	0	1	0	0	0	10	3	0	2	0	0	0	0	0.0**	Yes**	2009
TOTAL	42	191	314	353	278	306	397	213	199	285	278	165	251			

Notes:

**Outfall 3 (abandoned in 2003) and outfall 18 (abandoned in 2000) are not listed here.*

***Monitored CSOs/year with facility in place. Outfall has met performance standard since facility was built (year built specified).*

****Outfall physically eliminated in January 2013; overflows occurring in 2012 at CSO 39 occurred before the outfall was eliminated.*

*****Considered to meet performance standard now that outfall is eliminated.*

Source: Adapted from 2012 CSO Annual Report (City of Spokane, 2013), Table 6.

NM = not measured (so no monitoring data available).

RELATIONSHIP TO SPOKANE'S INTEGRATED CLEAN WATER STRATEGY

This 2013 CSO Plan Amendment is consistent with the City of Spokane's Integrated Clean Water Strategy to achieve the goal of a Cleaner River Faster, recognizing the importance of the health of the Spokane River to the City, the greater region, and the state. This CSO Plan Amendment focuses on control of CSOs using conventional "gray" methods of storage and conveyance improvements. Concurrent with preparation of this amendment, the City is conducting a planning process to integrate all of its clean water investments, including those for CSOs, for stormwater, and for municipal wastewater treatment at the RPWRF. The City is preparing an Integrated Plan consistent with the USEPA's Integrated Planning Framework published in June of 2012. The Integrated Plan document will summarize Spokane's Integrated Clean Water Strategy, the result of the integrated planning process. The Integrated Plan document will describe the City's proposed portfolio of clean water investments for CSOs, stormwater, and municipal wastewater treatment. The Integrated Plan will describe the City's plan to include Green Infrastructure (GI) as both a CSO and a stormwater management tool.

2013 CSO PLAN AMENDMENT DOCUMENT ORGANIZATION

The seven chapters of this 2013 CSO Plan Amendment are as follows:

1. Introduction and Background
2. Approach
3. System Wide Alternative Development
4. Screening Criteria and Screening Process
5. Selection of CSO Reduction Alternatives in Each Basin
6. Evaluation of Refined CSO Reduction Alternatives
7. Preferred CSO Reduction Alternative

Only those descriptions or elements that have changed from the 2005 Plan will be summarized in each chapter.

Table 2 presents the chapters in this CSO Plan Amendment where Ecology's required CSO reduction plan elements are addressed (per WAC 173-245-040).

TABLE 2

Comparison of Washington State Department of Ecology CSO Reduction Plan Elements and CSO Plan Amendment Chapters

CSO Reduction Plan Element (per WAC 173-245-040)	CSO Plan Amendment Chapter (or other source)
(1) The CSO reduction plan must be sufficiently complete so that plans and specifications can be developed from it for projects that may proceed into design within two (2) years of plan submittal. Sufficient detail of any remaining projects must be provided so that detailed engineering reports can be prepared in the future.	Chapter 7
(2) CSO reduction plans shall include the following information, together with any other relevant data as requested by the department: (a) Documentation of CSO activity. Municipalities shall complete a field assessment and mathematical modeling study to establish each CSO's location, baseline annual frequency, and baseline annual volume; to characterize each discharge; and to estimate historical impact	Flow monitoring and sampling: City of Spokane 2012 Annual CSO Report Modelling: 2005 CSO Plan and Chapters 3 and 6 of this Plan
(2) (b) To achieve the greatest reasonable reduction at each CSO site, control/treatment alternatives that shall receive consideration include, but are not limited to: (i) Use of best management practices, sewer use ordinances, pretreatment programs, and sewer maintenance programs to reduce pollutants, reduce infiltration, and delay and reduce inflow; and (ii) In-line and off-line storage with at least primary treatment and disinfection at the secondary sewage treatment facility that is served by the combined sewer; or (iii) Increased sewer capacity to the secondary sewage treatment facility that shall provide at least primary treatment and disinfection; or (iv) At-site treatment equal to at least primary treatment, and adequate offshore submerged discharge. At-site treatment may include a disinfection requirement at CSO sites that are near or that impact water supply intakes, potentially harvestable shellfish areas, and primary contact recreation areas; or (v) Storm sewer/sanitary sewer separation.	2005 CSO Plan and Chapter 3 of this Plan
(2) (c) Analysis of selected treatment/control projects. Municipalities shall conduct an assessment of the treatment/control project or combination of projects proposed for each CSO site.	2005 CSO Plan and Chapters 6 and 7 of this Plan
(2) (d) Priority ranking. Each municipality shall propose a ranking of its selected treatment/control projects. The rankings must be developed considering the following criteria: (i) Highest priority must be given to reducing CSOs that discharge near water supply intakes, public primary contact recreation areas, and potentially harvestable shellfish areas; (ii) A cost-effectiveness analysis of the proposed projects. This can include a determination of the monetary cost per annual mass pollutant reduction, per annual volume reduction, and/or per annual frequency reduction achieved by each project; (iii) Documented, probable, and potential environmental impacts of the existing CSO discharges.	Chapter 7 of this Plan and the 2014 Integrated Plan
(2) (e) Municipalities shall propose a schedule for achieving "the greatest reasonable reduction of combined sewer overflows at the earliest possible date." (Revised Code of Washington [RCW] 90.48.480.)	Chapter 7 of this Plan and the 2014 Integrated Plan

Approach

This 2013 CSO Plan Amendment focuses on what has changed since the 2005 CSO Plan, with the principal change being to the control volumes and regulator settings in CSO basins. The approach to revising control volumes and regulator settings is described in this chapter. Appendix A includes more information on the rationale behind the City's revision of control volumes and regulator settings. This chapter also includes a description of the City's approach to sizing storage facilities in the incomplete separation areas, which will aid in meeting the frequency-based CSO performance standard in other parts of the City and will help protect critical collection system infrastructure. More information is provided about incomplete separation areas, including a definition and general description, later in this section.

PREVIOUS APPROACH TO SIZING CSO FACILITIES

The City's previous approach to sizing CSO facilities was developed in 2002 as part of the City's work in developing its 2005 CSO Plan, and is documented in "Precipitation and Snowmelt Analyses and Design Event Development for CSO Reduction Alternative Evaluation," prepared by Consoer Townsend Envirodyne Engineers (CTE) (now operating as AECOM) in 2002 (CTE, 2002).

In the 2002 Precipitation and Snowmelt Analysis report, the rationale was outlined for the design storm approach following Ecology's regulations (Chapter 173-245 of WAC), referring to "control of each CSO such that an average of one untreated discharge may occur per year." At that time, the guidelines for determining whether or not a CSO outfall was controlled was based on one untreated discharge per year per outfall, based on a 5-year moving average.

The City's approach to sizing CSO storage facilities in the 2005 CSO Plan can be summarized as the following:

- Calculate volume generated by a 2-year, 24-hour Soil Conservation Service (SCS) Type II precipitation plus snowmelt event, made up of independent rainfall and snowmelt totals that together have a combined probability of occurrence of 50 percent in any given year (Pr(rainfall) x Pr(snowmelt) = 50%), providing a 97 percent chance of meeting the one overflow per year threshold when overflows are averaged over 5 years.
- Subtract volume that could be sent to the wastewater treatment plant during the event, leaving the volume of storage needed for that concurrent precipitation plus snowmelt event.
- Verify storage facility volume using storms in a 5-year period of record. The 5-year period 1957-1961 was chosen based on statistical analysis of the then-available period of record (1948-2001 at Spokane International Airport), using a combination of factors: wettest, most back-to-back storms, and ranking of sixth largest storm over a moving 5-year period.

The City placed 15 precipitation gauges throughout individual CSO basins. These data, together with monitored flows in sewer trunklines, indicated that the 2-year, 24-hour Type II event plus snowmelt was predicting significantly larger runoff volumes than the systems were experiencing for various return frequency events. Consequently, the design storm approach documented in the 2002 Precipitation and Snowmelt Analysis report was modified in subsequent basin-specific planning and preliminary design efforts using a Beta factor applied to the design storm. For example, in the preliminary design report for CSO basin 6 prepared in 2009 after the 2002 CTE report, it was acknowledged that the use of the 2-year, 24-hour SCS Type II rainfall plus snowmelt storm may be too conservative. A 10-year precipitation record from 1950-1959 (instead of the prescribed 5-year record) was used to verify the design storm. At that time, it was recommended that a Phase 1 storage facility be sized to store a Beta-adjusted SCS Type I storm distribution of the 2-year, 24-hour event, and that Phase 1 storage facility be constructed in a first phase, with a second phase (Phase 2) of storage only built if needed to contain volume from the original SCS Type II storm distribution (AECOM, 2009).

REVISED APPROACH TO SIZING CSO FACILITIES

The approach taken to revise the City's CSO Facilities (as documented in this 2013 CSO Plan Amendment) for its remaining uncontrolled outfalls was as follows, listed here and described in detail below:

- Develop conceptual control volumes (and regulator settings) using basin-scale computer simulations (event model using 1.2-year Type II storm) validated using historical CSO monitoring data and historical interceptor monitoring data.
- Verify and revise (if necessary) the conceptual control volumes (and regulator settings) using basin-scale computer simulations (continuous model using 20 years of measured precipitation data) in accordance with the current NPDES permit Section 13B requirements.

- Determine control volumes in each basin based on the verified and revised control volumes and regulator settings and considering risk and uncertainty

The City is proceeding with system-wide continuous modeling that will tie together all the individual basin models and provide a verification of the performance of the City's entire combined sewer system as a whole. This effort is in progress.

Conceptual Control Volumes

In each uncontrolled basin, the City used three sources of information to develop conceptual control volumes: historical CSO monitoring data (as documented in CSO monthly reports), historical interceptor monitoring data, and computer simulations using a 1.2-year Type II storm event. These three sources of information together provided a more robust result than using a single source of information.

The 2-year Type II precipitation/snowmelt event used in the computer model to determine control volumes previous to this 2013 CSO Plan Amendment is made up of independent rainfall and snowmelt totals that together have a combined probability of occurrence of 50 percent in any given year (Pr(rainfall) x Pr(snowmelt) = 50%), providing a 97 percent chance of meeting the one overflow per year performance standard when overflows are averaged over 5 years (AECOM, 2013). For this 2013 CSO Plan Amendment, a 1.2-year Type II event was used to size facilities. The size of event used in this 2013 CSO Plan Amendment reflects a 20-year averaging period (as specified in the City's 2011 NPDES CSO permit). A 1.2-year Type II storm event yields a 97 percent confidence of compliance result over the 20-year averaging period. This 1.2-year Type II event is precipitation only and does not include snowmelt. More information on the storm used in the event model is included in Appendix B.

A calibrated basin model was used to simulate the response to the 1.2-year Type II event in each basin. The model output of a hydrograph overflowing to the river was used to calculate the estimated storage volume that would have been necessary to control that event, called the control volume. These modeled control volumes were calculated iteratively as the regulator flow settings were adjusted basin by basin to stay within a designated flow ceiling in the downstream interceptor of 120 million gallons per day (mgd). The purpose of this flow ceiling in the interceptor is to protect the City's critical infrastructure. This interceptor and the flow ceiling are discussed in detail later in this Plan.

After control volumes and regulator settings were calculated using the 1.2-year event model, CSO monitoring data and interceptor flow monitoring data were used to confirm these results. To validate using the CSO monitoring data, a list of all historical CSO event volumes from 2001-2012 was compiled and ranked by volume. Then, the storage volume corresponding to 11 CSO events in those 12 years was estimated and compared with the 1.2-year storm event modeling results. To confirm using historical flow monitoring data, the volume of the 20 largest CSO events occurring from 2003-2012 was estimated. Then, the storage volume necessary to control to one overflow per year over a 20-year period at a 95 percent confidence level was estimated and compared to the 1.2-year storm event modeling results. The conceptual control volumes summarized in this Plan were a result of the 1.2- year storm event modeling results confirmed using these two other sources of information. More information on the process of confirming the modeled control volumes using these two sources of information is included in Appendix C. These conceptual control volumes were then verified using a long-term continuous simulation described next.

Verified Control Volumes Through Continuous Simulation

By implementing a verification using a 20-year continuous simulation, the City has taken a long-term, performance-based approach to CSO storage facility sizing representative of the 20-year moving averaging period specified in the NPDES permit. The conceptual control volumes from the 1.2-year event model were used as facility storage volumes in the 20-year continuous model. Summary statistics from the continuous model provided estimates of the number of overflows, and the volume of each overflow, over the 20-year period with that size of facility in place.

A 20-year precipitation record was developed for use in the continuous simulation model. The City has 1-minute precipitation data from a number of gauges located throughout the City. Hourly precipitation data from the Spokane Airport was used to supplement this 1-minute, in-city precipitation data when needed for a complete 20-year record because most of these gauges have been in service for less than 20 years. For each individual basin model, data from proximate gauges was used, reflecting the spatial non-uniformity of precipitation across the City. Table 3 summarizes the precipitation events during this 20- year period. This 20-year precipitation record was then input into the City's current modeling platform for the 20-year continuous simulation. Appendix D contains additional information on the development of this 20-year precipitation record. Figure 2 shows the locations of the individual in-city precipitation gauges listed in Table 3.

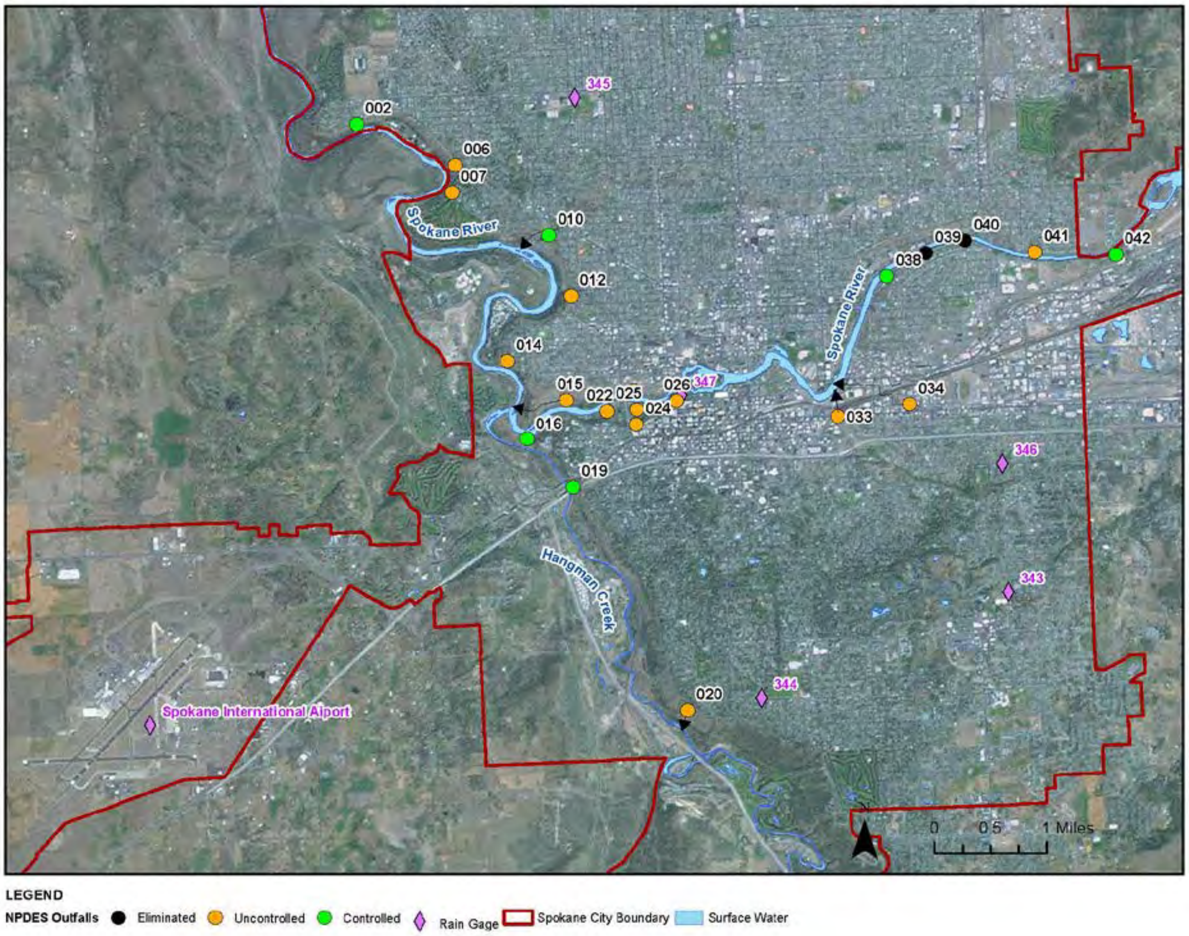


FIGURE 2. LOCATIONS OF PRECIPITATION GAUGES WITHIN THE CITY OF SPOKANE

TABLE 3

Summary Statistics of the 20-year Precipitation Dataset for Use in Continuous Modeling

Precipitation Gauge	No. of Storms with >10-year Return Period	Mean Annual Rainfall (inches)	Mean Annual No. of Storms*
343 (23rd Ave. and Ray St.)	6	19.1	65
344 (37th Ave. and Division St.)	4	14.6	65
345 (Shadle water tower)	1	14.3	67
346 (Hartson Ave. and Ray St.)	3	17.3	67
347 (Spokane Falls Blvd. and Post St. – City Hall)	1	14.0	62

**24-hr minimum inter-event time used for definition of statistically independent storms.*

The use of a continuous model to predict annual performance of CSO facilities is required under the City's NPDES permit and is consistent with the approach taken by other CSO communities across the Country. This approach allows the City to evaluate CSO compliance based on a 20-year moving average, matching the City's NPDES permit compliance period.

INCOMPLETE SEPARATION AREAS

Within the City of Spokane, several incomplete separation areas exist that have no means of overflow to the river (and therefore have no CSO outfall or regulator structure) (Figure 1). Instead, all wet weather discharges directly to the interceptor and is conveyed to the RPWRF. Stormwater separation projects have been implemented in these basins between 1980 and 1993, and some since 2010 but complete separation has not been achieved. Although these are not CSO basins, because there are no outfalls (CSO-permitted or otherwise), these incomplete separation areas significantly affect CSO control and are part of CSO management because flows from these areas take up peak flow capacity in the interceptor that would otherwise be available for wet weather flows entering from CSO basins. This CSO Plan Amendment documents the City's plans to build storage tanks in these incomplete separation areas. In addition to freeing up interceptor capacity for combined sewage, these tanks also protect the interceptor, which is a piece of critical infrastructure. These tanks planned for the incomplete separation areas are referred to in this plan as interceptor protection facilities. The City has taken a more conservative approach to storage facility sizing in these incomplete separation areas, as compared to the CSO basins, because there is no overflow relief available to protect the interceptor.

A process similar to that used in the CSO basins was used to develop conceptual control volumes in each incomplete separation area. Instead of using a 1.2-year design storm event, a 10-year design storm event was used, recognizing that the risk tolerance of the City was low for allowing big storms to enter the interceptor, and that the conveyance capacity of the piped collection system within the basins is generally intended to meet the 10-year event. The facility storage volume needed to contain the 10-year event was input into the 20-year continuous simulation. Instead of a threshold target number of overflow events in 20 years, the target for these incomplete separation areas was to have no exceedances of the facility volume over the 20-year period. That is, the planned storage facility volume would contain all of the events experienced over the 20-year period, with no flows beyond the regulator capacity entering the interceptor.

REFINING CONTROL VOLUMES CONSIDERING RISK AND UNCERTAINTY

Characterizing uncertainty is important to determine risk tolerance in any specific CSO basin or incomplete separation area. If there is a large amount of uncertainty in any one basin, the City can choose to provide a "cushion" by upsizing the storage facility to increase the likelihood of meeting the performance standard of one overflow per year per outfall on a moving 20-year average.

The City conducted a comprehensive analysis on each CSO basin and incomplete separation and classified each as "low risk," "medium risk," or "high risk" based on uncertainty inherent in planning tools, future growth, and risk to the interceptor. Basins that are deemed low risk have identified "safety outs" and have widespread opportunities for the addition of GI should a tank be built too small to meet the performance standard. Medium-risk basins have physical space constraints and therefore fewer "safety out" opportunities, and have limited opportunities for GI. High risk basins have limited "safety out" opportunities, limited opportunities for GI, and high uncertainty around planning tools or growth. The target overflow is 18 overflow events over 20 years for low risk basins, 15 overflow events over 20 years for medium-risk basins, and 10 overflow events in 20 years for high risk basins. This risk designation informed the decision on the target number of overflows over a 20-year period, as approximated with the 20-year continuous model, which in turn informed the decision on control volumes presented in this Plan.

DEVELOP 2013 CSO PROGRAM PROJECTS AND IMPLEMENTATION PLAN

After control volumes were determined, individual projects were developed (or updated from the 2005 CSO Plan) with estimates of cost and a schedule for implementation.

System Wide Alternative Development

Several different technologies are used by combined sewer communities for CSO control. These include storage, GI, I&I reduction, inter-basin flow transfer, and treatment. This 2013 CSO Plan Amendment refines the 2005 CSO Plan and is not re-evaluating the recommended technologies. The 2005 CSO Plan recommended storage facilities and stormwater separation projects in some basins to control CSOs. The 2013 CSO Plan Amendment is focusing on resizing the storage facilities based on the new performance standard and modeling results. (The 2014 Integrated Plan will include GI.) This chapter describes the revision of control volumes for each CSO basin and the determination of storage facility volumes in the incomplete separation areas. This chapter also describes the City's I&I reduction program and smaller projects that aid in CSO compliance, such as weir modifications.

STORAGE AS THE SYSTEM WIDE ALTERNATIVE

The City of Spokane has CSO reduction projects currently under way in CSO basins 20, 22, 24, and 34. Improvements in CSO basin 20 will bring that outfall into compliance through outfall elimination. A separation project is under way in CSO basin 22. The upbasin substorage projects under way in both CSO basins 24 and 34 are part of a multi-tank compliance strategy.

The City has fourteen (14) remaining uncontrolled outfalls. Of the remaining uncontrolled outfalls, one outfall will be eliminated (CSO outfall 20) and one outfall will be controlled by stormwater separation (CSO outfall 22) after these on-going projects are completed. Therefore, this chapter (and this Plan) focus on control volumes for the remaining twelve (12) uncontrolled outfalls (see Figure 1).

Table 4 lists the facility sizing from the 2005 CSO Plan for the 12 CSO outfalls that remain uncontrolled as of 2013 (and will not be addressed by CSO projects currently under way). The projects under way in CSO basin 34 are part of a compliance strategy, but alone won't bring that outfall into compliance. An additional project will be required to bring CSO basin 34 into compliance. Therefore, CSO basin 34 is included in the list of remaining twelve (12) uncontrolled outfalls in Table 4.

TABLE 4

CSO Storage Facility Conceptual Control Volumes and Regulator Settings

CSO Outfall	CSO Control Volume (MG)		Regulator Setting (mgd)	
	2005 Plan	2013 Conceptual Control Volume (1.2-year Design Storm Event) (AECOM, 2013)	2005 Plan	2013 Conceptual Control Volume (1.2-year Design Storm Event) (AECOM, 2013)
6	2.5	1.0	6.1	2.3
7	0.2	0.005	3.2	6.0
12	0.5 (12-1) 0.6 (12-2)	0.7	6.5	2.7
14	0.2	0.1	0.9	0.9
15	0 (sewer separation)	0.1	NA	2.5
23	0.2 (23-1) 1.4 (23-2)	0.001 (23-1) 0.008 (23-2)	1.0 (23-1) 0.5 (23-2)	5.4 (23-1) 5.6 (23-2)
24	0.8 (24-1) 5.2 (24-2 & 25)	2.0	25.8 (24-1) 9.5 (24-2)	9.5
25			0.5	
26	6.7 (26-1) 0.4 (26-2)	2.0	32.3 (26-1) 6.5 (26-2)	31.5
33	0.1 (33a) 3.9 (33b) 0.2 (33c) 0.8 (33d)	2.3 (33-1)** 0.3 (33-2)	0.9 (33a) 9.9 (33b) 1.0 (33c) 0.6 (33d)	6.3 (33-1) 0.9 (33-2)
34*	2.8	2.3	1.9 (34-1)	19.8
41	0 (sewer separation)	0.005	NA	5.8

Notes:

**2013 CSO Plan Includes management of incomplete separation area IO7.*

***33-1 consists of sub-basins 33a, 33b, and 33c. 33-2 consists of subbasin 33d.*

Note that the conceptual control volumes (and regulator settings) in this table have been updated based on continuous model verification and risk decisions, and are then presented as preferred alternative control volumes in subsequent chapters of this report.

Note that the current project concept for CSO control at CSO Basins 24 and 25 consist of a shared control facility. This will not result in elimination of either of these outfalls.

The 2005 Plan included tanks for 34-4, 34-5, and 34-6. These tanks were eliminated and are therefore not included in this 2013 Plan upon additional modeling of CSO Basin 34. Modeling conducted for the 2005 Plan indicated that there may be surface flooding in several locations in CSO Basin 34, and the 2005 Plan recommended building several mid-basin substorage facilities as a result. Upon expanding the model to include additional pipes, and validation with reported basement backups, it was determined that these areas do not in fact experience surface flooding. Because of this, the City eliminated control facilities 34-4, 34-5, and 34-6.

Table 4 includes the conceptual control volumes for this 2013 CSO Plan Amendment from the 1.2-year event model (confirmed using CSO monitoring data and interceptor flow monitoring data). Figure 3 shows a comparison of the results from the 1.2-year event model as compared to these two methods of confirmation. The three methods yielded similar results except for CSO basins 24, 25, and 26. This inconsistency will be addressed during the preliminary design phase of the project(s) planned in those CSO basins. The cause for the differences in control volumes was compounding instrumentation errors due to the configuration of the CSO Basin 26 control structure that affected the flow monitoring data but not the modeling. Additional modeling and analysis will be conducted during the preliminary design phase for CSO Basins 24, 25, and 26 to address this inconsistency.

The reduction in the size of control facility 34-1 in this 2013 Plan compared to the 2005 Plan shown in Table 4 is due to a combination of the following:

- Longer compliance averaging period (20 years instead of 5 year),
- Refinement of the collection system hydraulic model to include more of the collection system network in CSO Basin 34, which had the effect of reducing some the peak flows estimated by the model,
- Inclusion of the substorage facilities 34-2 and 34-3 in the modeling, which were sized based on a 2-year/24-hr design storm, and resulted in a smaller required control facility volume at 34-1, and
- Reduction in flow in the interceptor from the construction of the Spokane County Water Reclamation Facility and agreed upon operational practices (no bypasses during wet weather)

The technical memorandum included in Appendix B provides the documentation for the control volumes and regulator settings from the 1.2-year design storm event modeling. Note that the conceptual control volumes (and regulator settings) in Table 4 have been updated based on continuous model verification and risk decisions and are presented as preferred alternative control volumes in subsequent chapters of this report.

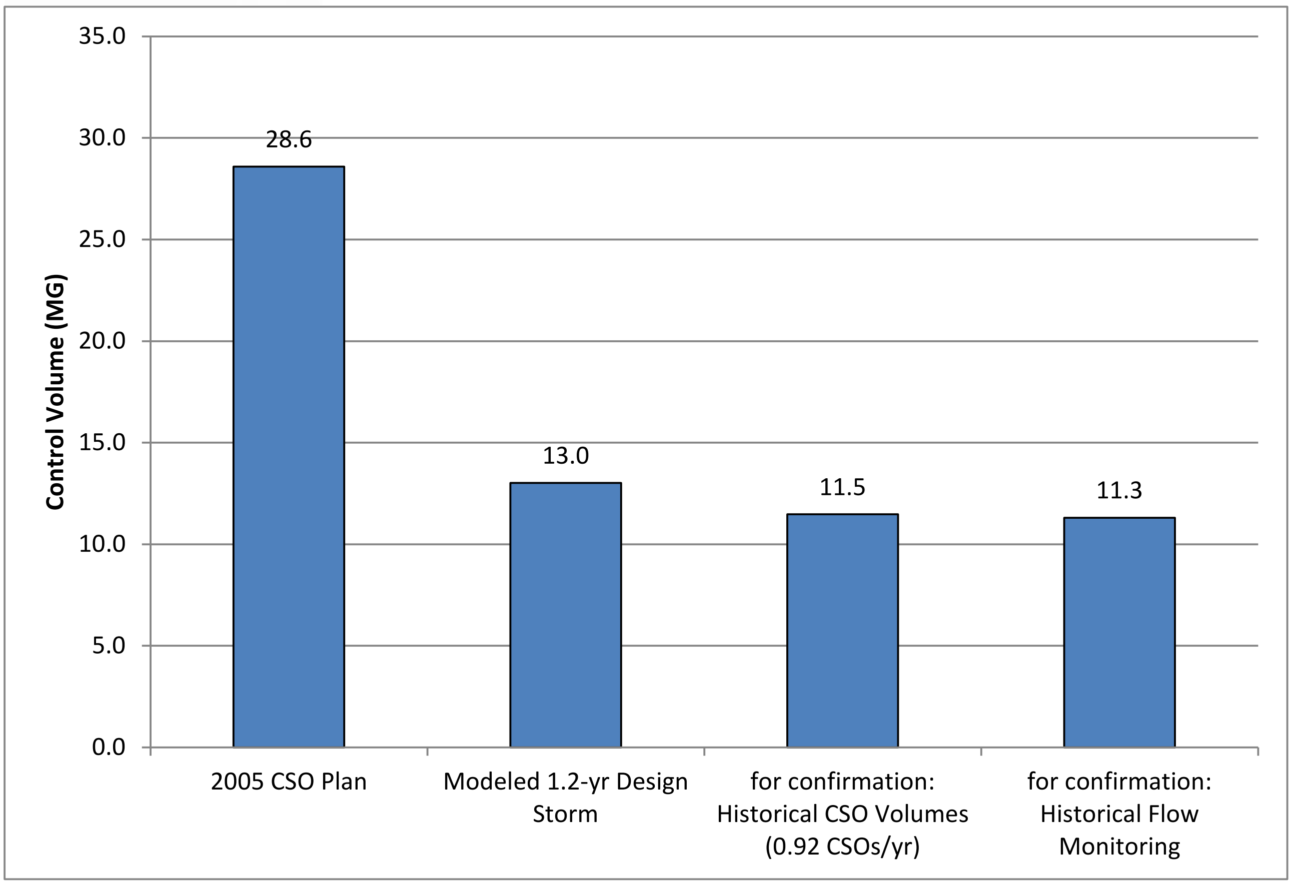


FIGURE 3. COMPARISON OF 1.2-YEAR EVENT MODEL RESULTS TO CONFIRMATION METHOD RESULTS

INCOMPLETE SEPARATION AREAS

Reducing peak flows from incomplete separation areas is a key element of CSO management because these areas currently take up valuable capacity in the interceptor that could be better used to reduce CSO events elsewhere in the system. Table 5 shows the results of the 10-year design storm event model specifying the necessary interceptor protection storage facility volumes to contain the 10-year event in the incomplete separation areas.

TABLE 5

Interceptor Protection Storage Facilities – Conceptual Volumes

Incomplete Separation Area	Facility Volume (MG)	
	2005 Plan	Conceptual Volume (10-year Design Storm Event) (AECOM, 2013)
IO3	0.279 (I03-1) 0.759 (I03-2)	1.840
IO4-1	0.221	0.145
IO4-2	3.375	1.220
IO7*	NA	NA
TOTAL	4.634	3.205

Notes:
** Management of incomplete separation area IO7 accomplished with joint storage facility planned for CSO basin 34, so volume accounted for in CSO basin 34 volume (see Table 4). Also note that IO7 was discovered and delineated after the 2005 CSO Plan, and therefore does not have a 2005 Plan facility volume specified.*

ADDITIONAL ELEMENTS OF SPOKANE'S CSO PROGRAM

In addition to the planned storage facilities presented above, the City has several storage facilities that are currently in design or construction. These storage facilities are:

- CSO Basin 20: The City is currently designing a 0.2-MG storage facility in CSO basin 20 in south Spokane. The City also plans to eliminate the CSO outfall for basin 20, because it discharges to the sensitive Latah Creek and poses safety problems and an erosion risk.
- CSO Basin 24: The City is currently designing three sub-storage facilities ranging in size from 15,000 gallons to 31,000 gallons, as well as two stormwater separation projects using drywells. These projects will aid in control of this outfall, which may ultimately be controlled with a storage facility shared with CSO basins 25 and 26.
- CSO Basin 34: The City is currently constructing a 0.9-MG storage facility and a 1.5-MG storage facility in this basin. Both facilities will be located in the middle of the basin, and are being constructed to reduce localized basement flooding and to reduce CSO events. These projects will aid in control of this outfall, which will be ultimately controlled with an additional storage facility to manage CSOs in CSO basin 34 and wet weather flows in incomplete separation area IO7.

The City is required to comply with the Nine Minimum Controls as required by the USEPA's CSO Control Policy. The status of the City's programs to address the Nine Minimum Controls is documented in the City's 2012 CSO Annual Report (City of Spokane, 2013).

In addition to implementing the Nine Minimum Controls, the City has undertaken a program to systematically identify and eliminate sources of river I&I. When the flow in the Spokane River exceeds 22,000 cubic feet per second (cfs), flow monitoring data at the RPWRF indicate a significant increase in flow caused by river water entering the sewer system. The City has already made significant progress in identifying and eliminating these sources over the past 15 years, as seen through the increase in the Spokane River onset flow rate for I&I events from 15,000 cfs in the mid-1990s to the aforementioned 22,000 cfs. To further reduce these occurrences, the City will conduct a thorough review of existing data, collect flow monitoring data, and address problem areas as they are identified.

Screening Criteria and Screening Process

This chapter discusses the screening criteria and the decision-making process used to determine the preferred alternative for CSO control for this CSO Plan Amendment.

The criteria used to determine the project to be implemented in each CSO basin and in each incomplete separation area, were:

- Project technical feasibility (geotechnical, structural, hydraulic)
- Life-cycle cost, including both total project cost (capital) and O&M cost
- In CSO basins, the ability to meet the CSO performance standard in that basin of one overflow per year over a 20-year averaging period
- Ability to address uncertainty and mitigate risk to critical infrastructure, and

- Ability to construct by the 2017 CSO Program Implementation deadline

The first two criteria were evaluated during development of conceptual control volumes and regulator settings. The last three criteria were evaluated during the validation and refinement of these control volumes .

Selection of CSO Reduction Projects in Each Basin and Conceptual Control Volumes

The purpose of this chapter is to document the selected basin solution in each of the CSO basins and incomplete separation areas. These basin solutions, together with on-going CSO reduction programs and projects, make up the system wide alternative described in Chapter 3.

As discussed in Chapter 3, this 2013 CSO Plan Amendment only considers gray basin solutions for CSO control, such as storage and regulator adjustments. Other technologies, such as GI, will be evaluated in the 2014 Integrated Plan. The screening process in the 2013 CSO Plan Amendment consisted of developing and evaluating various combinations of gray basin solutions. For several basins, there was only one feasible gray basin solution considered, while other basins had feasible combinations of one or two storage tanks. Table 6 presents a summary of the basin solutions considered in each basin, a brief description of each basin solution, the selected basin solution, and justification for selection based on technical feasibility and cost. Table 6 shows the conceptual control volumes for each CSO basin based on the 1.2-year event model. The preferred alternative control volumes (and validation) are described in the next chapters.

Total capital costs and life-cycle costs were estimated using a spreadsheet-based tool that develops Class 4 cost estimates as defined by the American Association of Cost Engineering (AACE). Class 4 estimates are generally prepared based on limited detailed information, and subsequently have wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1 percent to 5 percent complete, and would include storage capacity, schematic diagrams, indicated layout and preliminary engineered structure and equipment lists. Typical accuracy ranges for Class 4 estimates are -15 percent to -30 percent on the low side, and +20 percent to +50 percent on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. All costs were calculated in April 2013 dollars.

Construction costs were estimated based on preliminary quantities and unit costs, and included a 10 percent markup for indeterminates (AFI), a 1 percent markup for permit fees, and an 8.7 percent markup for sales tax. The construction cost was then converted into a total capital cost by adding a 25 percent markup for soft costs (design, construction management, and administration), and a 30 percent markup for construction scope contingency.

Life-cycle costs considered the total capital cost of the project, commissioning cost, annual O&M cost, additional flow monitoring, replacement cost, reduction in Spokane Parks Department stormwater fee revenue, land acquisition costs for property not already owned by the City, and additional treatment cost at the RPWRF. Life-cycle costs were calculated over a 25-year time period and used a 2 percent discount rate.

Evaluation of Refined CSO Reduction Alternatives

This chapter documents the verification of the conceptual control volumes developed as part of the preferred system wide alternative of storage using the 20-year continuous modeling simulation and consideration of risk and uncertainty. Revisions as compared to the conceptual, system-wide alternative developed in Chapter 3 are documented here.

CONTINUOUS MODEL VERIFICATION OF CONCEPTUAL CONTROL VOLUMES

The conceptual control volumes from the 1.2-year event model (see Table 4) were used as initial facility storage volumes in the 20-year continuous model. Summary statistics from the continuous model provided estimates of the number of overflows, and the volume of each overflow, over the 20-year period with that size of facility in place. Figures 4 and 5 show a graphical example of these results for CSO basins 6 and 26, respectively. Figure 4 shows that the control volume for CSO basin 6 estimated using the 1.2-year storm event model yielded 10 overflows in 20 years with the continuous model, which is half of the frequency of the performance standard of 20 overflows in 20 years. Figure 5 shows that the control volume for CSO basin 26 estimated using the 1.2-year storm event model yielded 16 overflows in 20 years with the continuous model. (Appendix E contains graphs for all other CSO basins.) Table 7 shows the number of overflows over 20 years predicted by the 20-year continuous model assuming the control volume from the 1.2 year event model for each of the CSO basins.

TABLE 6.

Summary of Conceptual Control Volumes

Basin	Basin Solution	Description (Assuming conceptual control volumes and regulator settings)*	Total Project Cost ($M)** for ConceptualControl Volumes	Life-Cycle Cost ($M)*** for ConceptualControl Volumes	Selected Basin Solution for Recommended Preferred System Wide Alternative?	Justification
006	Storage Only (1 Tank)	Consists of a 1.0-MG storage tank, along with approximately 2,700 LF of new conveyance.	$12.70	$11.86	Yes	No other gray basin solutions technically feasible.
007	Regulator Adjustment	Consists of adjusting the regulator flow control setting from the current setting of 1.0 mgd to a new setting of approximately 4.0 mgd. Also includes 5,000 gallons of storage and minor conveyance improvements.	$0.52	$0.41	Yes	No other gray basin solutions technically feasible.
012	Storage Only (1 Tank)	Consists of a 0.7-MG storage tank, along with approximately 4,000 LF of new conveyance.	$8.69	$8.08	Yes	No other gray basin solutions technically feasible.
014 & 015	Storage Only (2 Tanks)	CSO basin 014 consists of a 0.1-MG storage pipe, along with approximately 250 LF of new conveyance. CSO basin 015 consists of a 0.1-MG storage tank, along with approximately 250 LF of new conveyance.	$4.53	$5.11	Yes	Lowest cost basin solution.
	Storage Only (1 Tank)	Consists of a 0.2-MG storage tank located in CSO basin 015, along with approximately 4,000 LF of new conveyance.	$7.39	$7.02	No	More expensive than the two-tank basin solution, largely because of the cost of conveying CSO basin 014 to the new storage tank.
023	Regulator Adjustment	Consists of adjusting the regulator flow control setting from the current setting of 1.0 mgd to a new setting of approximately 4.0 mgd, and the addition of 0.001 MG of storage. Also includes construction of a new regulator structure to basin I04 with a regulator flow control setting of 5.6 mgd, and the addition of 0.008-MG of storage.	$1.14	$1.04	Yes	No other gray basin solutions technically feasible.
024, 025, & 026	Storage Only (2 Tanks)	CSO basin 024 & 025 consists of a 2.0-MG storage tank, along with approximately 1,900 LF of new conveyance. CSO basin 026 consists of a 2.0-MG storage tank, along with approximately 2,900 LF of new conveyance.	$41.91	$42.07	Yes	Although the one-tank basin solution is less expensive, finding a suitable location to site a 4.02-MG storage tank may not be possible. As such, the recommended preferred basin solution is to proceed with two tanks.
	Storage Only (1 Tank)	Consists of a 4.0-MG storage tank located in CSO basin 025, along with approximately 3,100 LF of new conveyance.	$33.90	$33.59	No	
033	Storage Only (2 Tanks)	CSO subbasins 033a, b, and c consist of a 2.3-MG storage tank, along with approximately 4,100 LF of new conveyance.	$34.15	$33.70	Yes	No other gray basin solutions technically feasible.

Basin	Basin Solution	Description (Assuming conceptual control volumes and regulator settings)*	Total Project Cost ($M)** for ConceptualControl Volumes	Life-Cycle Cost ($M)*** for ConceptualControl Volumes	Selected Basin Solution for Recommended Preferred System Wide Alternative?	Justification
		CSO subbasin 033d consists of a 0.3-MG storage tank, along with approximately 450 LF of new conveyance.				
034	Storage Only (2 Tanks)	CSO basin 034 consists of a 2.3-MG storage tank, along with approximately 100 LF of new conveyance. This CSO basin 034 includes management of incomplete separation area IO7. Incomplete separation area IO7 consists of a 0.5-MG storage tank, along with approximately 100 LF of new conveyance.	$31.60	$30.12	No	More expensive than the two-tank basin solution.
	Storage Only (1 Tank)	Consists of a 4.0-MG storage tank located in incomplete separation area IO7, along with approximately 300 LF of new conveyance.	$27.38	$27.21	Yes	Lowest cost basin solution, and also provides incomplete separation area IO7 a relief point while potentially resulting in smaller overflow volumes because of possible offsets in basin responses to storm events.
041	Regulator Adjustment	Consists of adjusting the regulator flow control setting from the current setting of 0.7-mgd to a new setting of approximately 5.8 mgd. Also includes 5,000 gallons of storage and approximately 951 LF of new conveyance.	$1.28	$1.03	Yes	No other gray basin solutions technically feasible.
IO3	Storage Only (1 Tank)	Consists of a 1.8-MG storage tank, along with approximately 300 LF of new conveyance.	$16.27	$15.19	Yes	No other gray basin solutions technically feasible.
IO4	Storage Only (2 Tanks)	Incomplete separation area IO4 consists of two storage tanks. A 1.2-MG storage tank would be located in the east portion of the area, and a 0.1- MG tank would be located in the west portion of the basin. Also included would be approximately 200 LF of new conveyance.	$16.79	$17.34	Yes	No other gray basin solutions technically feasible.

Notes:

** Conceptuall control volumes based on the 1.2-year design storm event (and verified using flow monitoring data and monthly CSO reports)*

***Total Project Cost estimates for conceptual control volumes include capital costs, soft costs (engineering, etc.), but not O&M costs*

****Life-cycle costs for conceptual control volumes considered the total capital cost of the project, commissioning cost, annual O&M cost, additional flow monitoring cost, replacement cost, reduction in Spokane Parks Department stormwater fees, land acquisition costs for property not already owned by the City, and additional treatment cost at the RPWRF. Life-cycle costs were calculated over a 25-year time period and used a 2% discount rate.*

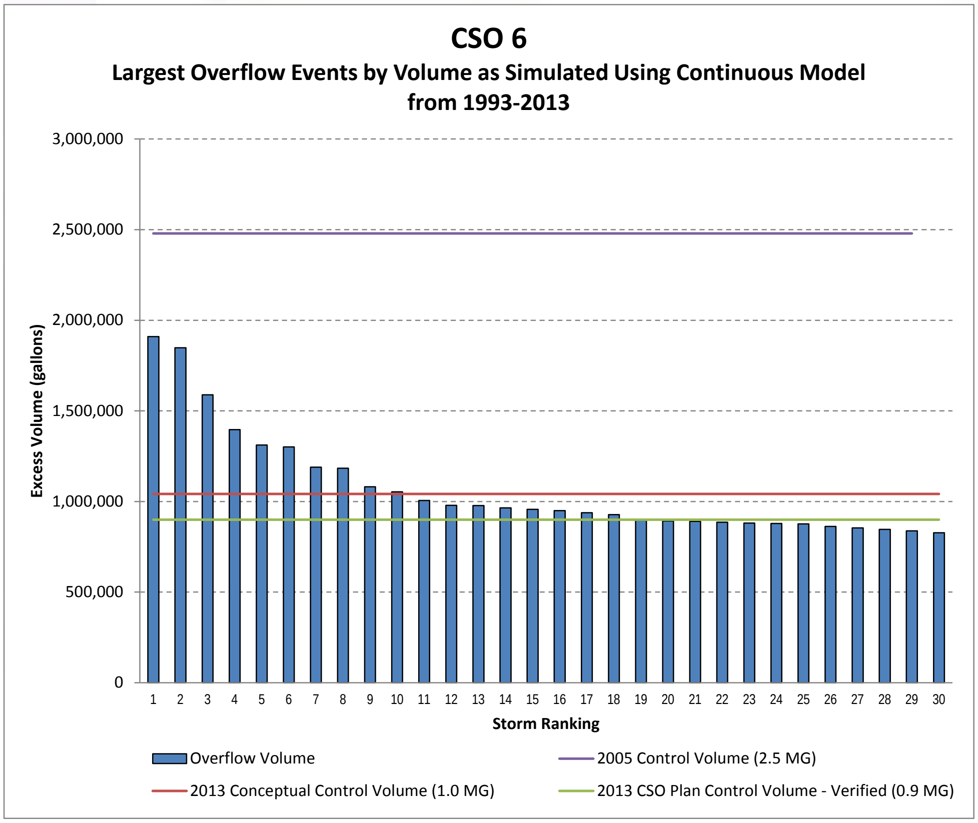


FIGURE 4. BASIS OF CONTROL VOLUME, CSO BASIN 6

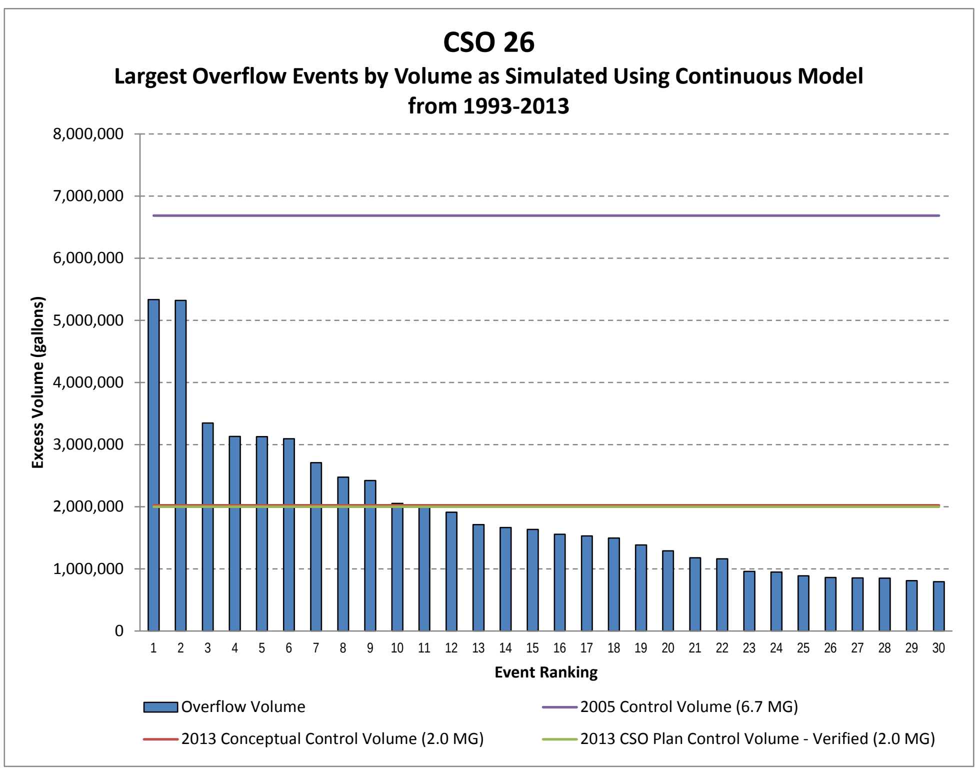


FIGURE 5. BASIS OF CONTROL VOLUME, CSO BASIN 26

TABLE 7

Verification of Conceptual CSO Control Volumes and Regulator Settings

CSO Outfall	Conceptual Control Volume (MG) (1.2-year Design Storm Event)	Number of CSO Events over 20 years (as estimated using the 20-year continuous model on the Conceptual Control Volume)	Risk (low, medium, high)	Target Overflow Frequency (events over 20 years), with considering Risk Tolerance	2013 CSO Plan Amendment Control Volume (verified with 20-year continuous model, considering risk and uncertainty) (MG)	2013 CSO Plan Amendment Regulator Setting (verified with 20-year continuous model, considering risk and uncertainty) (mgd)
6	1.0	10	Low	18	0.9	2.3
7	0.005	9	Low	18	0.005	4.0 (decreased to meet target overflow)
12	0.7	19	Low	18	0.7	2.7
14	0.1	8	Low	18	0.05	0.9
15	0.1	6	Medium	15	0.06	2.5
23	0.001 (23-1) 0.008 (23-2)	8	Low	18	23-1: 0.005 23-2: 0.005	23-1: 9.5 23-2: 31.5
24	2.0	16	High	16	2.0	9.5
25						
26	2.0	10	High	10	2.0	31.5
33	2.3 (33-1)** 0.3 (33-2)	33-1: 22 33-2: 30	Medium	18	33-1: 2.1 33-2: 0.4	33-1: 8.3 (increased to meet target overflow) 33-2: 0.9
34**	2.3	5	Low	18	1.2 (combined 34 and IO7)	34: 19.8 IO7: 3.0
41	0.005	4	Medium	13-18 (reflecting uncertainty in results)	0.01	2.7

Notes:

**After Verification (20-year continuous simulation) and consideration of risk and uncertainty.*

***Includes management of incomplete separation area IO7.*

***33-1 consists of subbasins 33a, 33b, and 33c. 33-2 serves subbasin 33d.*

Interceptor protection tanks planned for the incomplete separation areas were sized using a similar approach to the CSO storage facility sizing. Table 8 shows the number of overflows over 20 years predicted by the 20-year continuous model using the facility sizing from the 10-year event model for each of the incomplete separation areas. Figure 6 shows the continuous simulation results for incomplete separation area IO3, showing the 10-year design storm storage volume as compared to the volumes of wet weather flow generated by the events during the 20-year model duration. (Appendix E contains graphs for all other incomplete separation areas.) Because the storage volume envisioned for this incomplete separation area in 2005 CSO Plan was based on a vastly different assumption and less was known then about the contribution of this basin to the interceptor, the volume conceptualized in 2005 is not shown in Figure 6.

TABLE 8

Verification of Conceptual Interceptor Protection Storage Facility Volumes in Incomplete Separation Areas

Incomplete Separation Area	Conceptual Control Volume (10 Year Design Storm Event) (MG)	Number of Times the Facility Was Used) (estimated using the 20-year continuous model)	Number of times facility volume was exceed (estimated using the 20-year continuous model)	Risk (low, medium, high)	Target Frequency that Volume is exceeded (events over 20 years)	2013 CSO Plan Storage Facility Volume (MG) (verified with 20-yr continuous model, considering risk and uncertainty)	2013 CSO Plan Amendment Regulator Setting (mgd)
IO3	1.8	>30	0	High	0	1.2	11.4
IO4-1	0.1	3	0	High	0	0.9	3.2
IO4-2	1.2	22	0	High	0	0.1	5.5
IO7*	0.5		0	High	0	Included in Table 7 (CSO 34)	

Notes:

***IO7 storage facility volume is incorporated in CSO basin 34 storage facility, because one single storage facility site is planned to manage both incomplete separation area IO7 and CSO basin 34.*

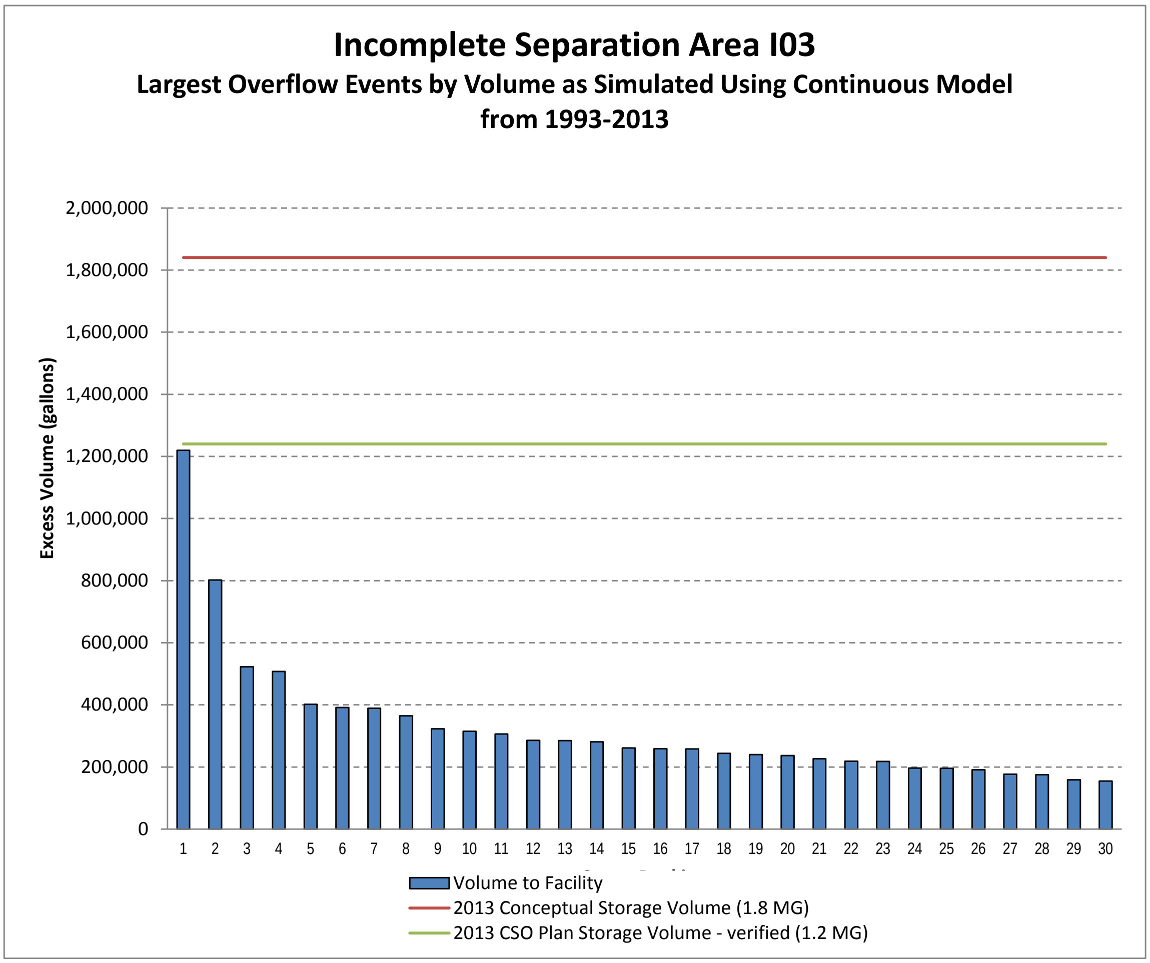


FIGURE 6. BASIS OF STORAGE VOLUME, INCOMPLETE SEPARATION AREA IO3

CHARACTERIZING RISK AND UNCERTAINTY

Key areas of risk and uncertainty considered in this CSO Plan Amendment include:

- Future growth
- Climate change
- Uncertainty inherent in planning tools (flow monitoring data, model platform, etc.)
- Risk to critical infrastructure (interceptor)

Future Growth

There is uncertainty around where, and if, population growth will occur. The City's Comprehensive Plan presents projected growth for Spokane County over a 20-year planning period. Growth is anticipated in certain neighborhoods, including the Kendall Yards development in CSO basin 15. Also, the recent development of Hazel's Creek and plans for stormwater management projects around the KXLY radio towers will open up future development of the Southside areas.

Although City code allows for only the sanitary flows to enter the collection system and not the wet-weather flows, this could still be a considerable additional sanitary, or dry weather, flow to the system should growth occur. To consider future growth, the computer simulations of individual basins are based on 2030 growth conditions varied basin by basin. Should future growth increase from these anticipated levels, the City can increase the size of the storage facility or else implement GI in the basin to stay in compliance with the CSO performance standard of one overflow per year per outfall on a moving 20-year averaging period. The feasibility of expanding an existing storage tank or implementing GI is considered when assigning a risk tolerance level for each basin, described later in this chapter.

Climate Change

According to available literature, anticipated changes to precipitation within the City of Spokane by 2050 include an increase of total annual precipitation by 2-3 percent, and an increase in annual average temperature of 2-5 degrees Fahrenheit (Washington Climate Preparation and Adaptation Work Group, 2007). By 2050, total annual precipitation is expected to increase by about 2 percent to 3 percent, with low model outliers predicting a small decrease, and high model outliers predicting an increase of up to 10 percent. Seasonal patterns show a decrease in overall precipitation in summer (June-July-August-September), with the largest increases in late fall and early winter (October-November-December) (SimCLIM results) (CLIMsystems, 2013). More extreme and earlier winter storms are expected for the Pacific Northwest (Salathe et al., 2013). However, even with an overall precipitation decrease in summer, individual event intensity is likely to increase. Extreme event depth is predicted to increase by about 12 percent during most months (SimCLIM results). In general, extreme precipitation event frequency is expected to increase (Salathe et al., 2013), with a 13 percent increase in number of days with over one inch precipitation (Mote et al., 2013).

Annual average temperature is expected to increase within the City of Spokane by 2 to 5 degrees F by 2050. The largest temperature increases are expected in the summer months; winter temperature increases are expected to be slightly less than the average annual increase (SimCLIM results). Even a modest increase in winter temperatures may shift what would have been snow events to rain or rain-on-snow events (Salathe et al., 2013), compounding the impacts of increased winter precipitation on urban hydrology.

Uncertainty around climate change is not currently addressed in CSO facility sizing. The current 20-year precipitation record used in the continuous model simulation is actual measured precipitation from 1993-2013 and is not artificially adjusted to reflect anticipated future changes to precipitation (or temperature). In the future, the City will develop an adaptive management process to address climate change for each basin. The City will continue to monitor and analyze rainfall and collect CSO performance data. Each basin will have an adaptive management strategy of additional storage. For basins where GI is feasible, implementation of GI retrofits will also be considered for adaptive management. Additional storage may include a second construction phase to increase the size of an existing facility, or additional sites for a new storage facility.

Planning Tools

There is uncertainty inherent in planning tools, including flow monitoring data. This uncertainty can vary from basin to basin. Flow monitoring programs and CSO reporting came on-line at different times, giving different record durations for each basin. In addition, many of the overflow weirs in the City were at one time leaping weirs, which are difficult to monitor accurately. The modeling platform itself has a certain amount of uncertainty. This may –vary by basin if the model for a particular basin is more of a "skeleton" model rather than a model of most, or all, of the collection system pipes in that basin. Uncertainty in planning tools affects the City's risk tolerance in that particular basin. Should these planning tools under-predict the storage volume needed to meet the performance standard, the City can increase the size of the storage facility or implement GI in the basin. The feasibility of expanding an existing storage tank or implementing GI is considered when assigning a risk tolerance for each basin, described later in this chapter.

Risk Mitigation for Critical Interceptor Infrastructure

The lower portion of the City's main interceptor (referred to as IO2) runs along Aubrey L. White Parkway and carries about 90 percent of the sanitary and wet weather flows reaching the RPWRF. Failure of the interceptor would have a significant impact on the Spokane River and its users for a relatively long duration until the interceptor could be fixed. Protection of this critical infrastructure is paramount for the City. Although complete failure has not occurred, there have been a two near misses, including most recently in 1996 and in 2006 when washouts occurred that threatened to undermine the interceptor to the extent that the interceptor itself was at risk. The following actions are part of the City's risk mitigation strategy for the interceptor:

- Construction of Interceptor Protection Tanks (storage tanks) in the incomplete separation areas (IO3, IO4-1, IO4-2, and IO7)
- Reduction of regulator settings to limit flow from the combined system to 120 mgd versus an interceptor capacity of 130 mgd
- Addressing inflow into the interceptor from the Spokane River during high-river conditions

Building interceptor protection tanks and regulator structures in the incomplete separation areas are a key part of interceptor protection. The incomplete separation areas do not have outfalls and do not have regulator structures, meaning that any runoff that makes it to the piped collection system in these areas enters the interceptor and flows to the RPWRF. New regulator structures and interceptor protection tanks are part of this CSO Plan Amendment for the incomplete separation areas. Regulator structures would limit the flows to the interceptor, sending any excess to the interceptor protection tanks. Once the capacity of these tanks is exceeded, the excess would flow into the interceptor and on to the RPWRF. Each of these incomplete separation areas are considered high risk because of the consequence of exceeding the capacity of the planned interceptor protection tanks. Although exceeding the capacity of CSO storage tanks can occur up to one time per year to stay within the CSO performance standard, the City's threshold for exceeding the storage volume of the interceptor protection tanks is zero per year.

During this CSO planning process, the regulator settings for all CSO basins and incomplete separation areas were set to keep under this 120 mgd ceiling to protect the interceptor. This 120 mgd ceiling will be exceeded in the case of significant events exceeding the capacity of the interceptor protection tanks; hence, the 10 mgd cushion between the 120 mgd ceiling and the 130 mgd capacity of the interceptor. Should it be determined after implementation of the CSO Control Plan that the 120 mgd threshold does not provide enough protection, GI can be implemented, storage facilities can be upsized, and/or regulator settings can be reduced, allowing less flow to the interceptor.

REFINING CONCEPTUAL CONTROL VOLUMES AND REGULATOR SETTINGS FOR RISK AND UNCERTAINTY

Uncertainty from a variety of sources described earlier influenced the City's decision on risk tolerance in individual CSO basins and incomplete separation areas. The City's decision was based on this uncertainty, and on the presence or absence of a 'safety out,' or a backup plan, should a built facility not be large enough to meet the performance standard of one overflow per year per outfall over a 20-year moving averaging period. Tables 7 and 8 show the risk designation and corresponding target overflow frequency for each of the CSO basins (Table 7) and incomplete separation areas (Table 8). The target overflow frequency for low risk basins is 18 overflow events over 20 years, 15 overflow events over 20 years for medium risk basins, and 10 overflow events in 20 years for high risk basins.

Once the risk in each basin or area was determined and the target overflow frequency was determined, the results of the 20-year continuous model were used to calculate the facility volume that would have provided that target overflow frequency. For example, Figure 4 for low risk CSO basin 6 shows that the facility storage volume that would have allowed 18 CSO events over 20 years is 0.90-MG. In Figure 5 for high risk CSO basin 26, the facility storage volume that would have allowed 10 CSO events over 20 years is 2.0 MG. Figure 6 for high risk incomplete separation area IO3 shows the storage facility volume of 1.2 MG, which is the volume necessary to contain all the events during the 20-year modeled period with no cushion. Storage facility volumes for each of the other incomplete separation areas were sized similarly as for incomplete separation area IO3. Note that incomplete separation area IO7 will share a facility with CSO basin 34. Incomplete separation area IO7 and CSO basin 34 are listed separately (one in Table 7 and the other in Table 8) because of the different risk tolerances in each basin.

Preferred CSO Reduction Alternative

The purpose of this chapter is to summarize the preferred alternative within each CSO basin and within each incomplete separation area as part of the revised City of Spokane CSO Program. An implementation plan and schedule are also presented in this chapter.

2013 CSO PROGRAM PROJECTS

The verified control volumes for each of eleven (11) new CSO storage and interceptor protection storage facilities, and the four (4) new regulator improvements are shown in Table 9. The eleven (11) new storage facilities and four (4) new regulator improvements will provide 11.7 MG of additional storage and cost approximately $144 million in capital costs.

TABLE 9

Projects in the 2013 CSO Plan Amendment

CSO Basin or Incomplete Separation Area	2005 CSO Reduction System Wide Alternative Report		2013 CSO Plan Amendment Preferred System Wide Alternative		Notes
	Control Volume (MG)	Total Capital Cost* ($M)	Control Volume (MG)	Total Capital Cost** ($M)	
6	2.48	$13.13	0.900	$11.38	2013 CSO Plan: 1 tank
7	0.16	$1.49	0.005	$0.52	2013 CSO Plan: regulator improvements
10	0.22	$1.89	0.137	$1.17	Storage tank completed in 2011
12	0.48 (12-1) 0.60 (12-2)	$3.55 $4.85	0.689 Tank Eliminated	$8.69 Tank Eliminated	2013 CSO Plan: 1 tank
14	0.22	$1.94	0.051	$1.66	2013 CSO Plan: 1 tank
15	--	$5.17	0.056	$1.50	2005 recommendation was sewer separation. 2013 CSO Plan: 1 tank
16 & 18	0.32	$2.91	0.19	$1.97	Storage tank completed in 2007
19	--	$0.21	0.003	$0.29	Weir modification completed in 2010
20	0.25	$2.22	0.21	$4.30	Under way
22	--	$0.21	--	--	small separation project planned, cost to be determined
23	0.17 (23-1) 1.35 (23-2)	$1.56 $8.22	0.005 (23-1) 0.005 (23-2)	$0.50 $0.64	2013 CSO Plan: 2 regulator improvements
24	--	--	0.09 (3 sub-storage tanks + stormwater separation)	--	Under way
24 & 25	0.79 (24-1) 5.25 (24-2 & 25)	$5.63 $25.20	Tank Eliminated 2.00	Tank Eliminated $20.19	2013 CSO Plan: 1 tank, shared amongst 24, 25, 26
26	6.68 (26-1) 0.39 (26-2)	$33.73 $5.25	2.00 Tank Eliminated	$22.03 Tank Eliminated	
33	0.138 (33a) 3.863 (33b) 0.221 (33c) 0.773 (33d)	$1.29 $19.27 $1.97 $5.33	2.04 (33a,b,&c, aka 33-1) -- -- 0.42 (33d, aka 33-2)	$27.16 -- -- $5.50	2013 CSO Plan: 2 tanks
34	2.80 (34-1) 1.32 (34-2) 7.08 (34-3) 1.40 (34-4) 0.59 (34-5) 2.44 (34-6)	$18.50 $8.14 $31.12 $8.50 $4.26 $13.28	1.26 (34-1) 1.50 (34-2) 0.88 (34-3) Tank Eliminated Tank Eliminated Tank Eliminated	$15.89 $17.85 $14.78 Tank Eliminated Tank Eliminated Tank Eliminated	2013 CSO Plan: 1 tank (for 34-1, shared with IO7) 34-2 and 34-3 are currently under way.
38, 39, & 40	0.42	$3.36	0.43	$4.69	Completed
41	--	$4.32	0.01	$1.28	2013 CSO Plan: 1 regulator improvement

CSO Basin or Incomplete Separation Area	2005 CSO Reduction System Wide Alternative Report		2013 CSO Plan Amendment Preferred System Wide Alternative		Notes
	Control Volume (MG)	Total Capital Cost* ($M)	Control Volume (MG)	Total Capital Cost** ($M)	
					2005 recommendation was sewer separation.
42	0.14	$1.30	0.11	$0.97	Completed
IO3	0.28 (IO3-1) 0.76 (IO3-2)	$2.32 $5.13	1.24 Tank Eliminated	$12.80 Tank Eliminated	2013 CSO Plan: 1 tank
IO4	3.38 (IO4-1) 0.22 (IO4-2)	$16.75 $1.93	0.88 0.1	$10.83 $3.34	2013 CSO Plan: 2 tanks
IO7	--	--	Included with CSO basin 034	Included with CSO basin 034	2013 CSO Plan: share tank with CSO basin 34
Post Street	0.20	$2.07	Tank Eliminated	Tank Eliminated	
RPWRF	12.94	$47.10	Tank Eliminated	Tank Eliminated	
TOTAL	58	$313	15.2	$192	
CSO Projects (breakdown by status):					
Projects Completed			*0.9*	*$9*	*CSO outfalls 10, 016, 18, 19, 38, 39, 40, and 42*
Projects Under Way			*2.6*	*$39*	*To address, or partially address CSO outfalls 20, 22, 24, and 34*
Future Storage Facilities and Regulator Improvement Projects			*11.7*	*$144*	*11 tanks, 4 regulator projects (CSO outfalls 06, 07, 12, 14, 15, 23, 24, 25, 26, 33, 34, 41, and incomplete separation areas IO3, IO4, IO7)*
2013 CSO Plan Amendment Projects (Under Way or Future Projects)			*14.3*	*$183*	

Notes:
**Costs from the 2005 CSO Plan were inflated from 2003 to April 2013 dollars.*
***Costs for Completed Projects were provided by City of Spokane. Costs for Projects Under way were estimated by City staff and communicated to CH2M HILL as construction costs; then indeterminates, contingency, tax, and soft costs were added. Costs for the eleven (11) new storage facilities and four (4) new regulator improvements under this 2013 Plan were developed by CH2M HILL using the spreadsheet-based tool Conceptual Cost Calculator (C3) and are Class 4 cost estimates defined by the AACE, which provide between a -15% to -30% accuracy on the low side and a +20% to +50% accuracy on the high side. Construction costs include 10% for indeterminates (AFI), 1% for permit fees, and 8.7% for sales tax. The construction cost was then converted into a total capital cost by adding 25% for soft costs, and 30% for construction contingency.*

In addition to the planned storage facilities and regulator improvements, Table 9 shows the storage facilities and other improvements that the City has already completed to address CSO outfalls 10, 16, 18, 19, 38, 39, 40, and 42, and those facilities and improvements under way that will address outfalls 20 and 22b and to partially address CSO outfall 34. The projects under way to address 20 and 22 and to partially address CSO outfall 34 will provide 2.6MG and will cost approximately $39 million in total capital costs. The projects already built to address CSO outfalls 10, 16, 18, 19, 38, 39, 40, and 42 provided 0.9-MG in storage and cost approximately $9 million. Figure 7 shows the current and future projects in this 2013 CSO Plan Amendment.

Table 9 includes the facilities that were part of the system wide alternative from the 2005 CSO Plan (AECOM, 2005). The costs shown in Table 9 were taken from the 2005 CSO Plan and inflated to April 2013 dollars for these comparison purposes. The actual volume and cost for projects that have been completed since the 2005 CSO Plan were provided by the City of Spokane. Costs for the eleven (11) new storage facilities and four (4) new regulator improvements under this 2013 Plan were developed by CH2M HILL using a spreadsheet-based tool described earlier in this report (Chapter 2).

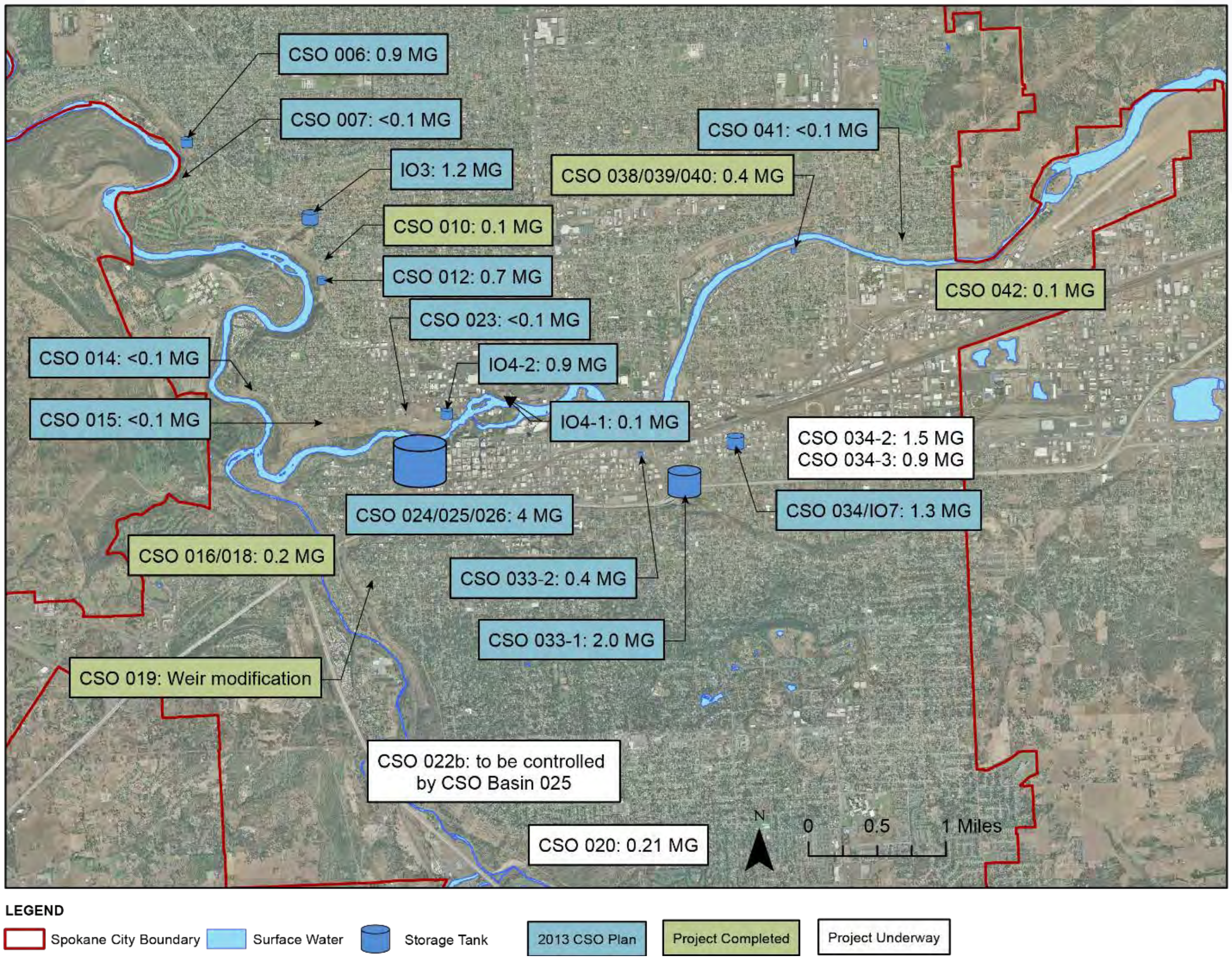


FIGURE 7. PROJECTS IN THIS 2013 CSO PLAN AMENDMENT

Figure 8 shows a total of the estimated 2013 CSO Plan project costs and storage facility volumes for the completed projects, those under way, and those future planned eleven (11) new storage facilities and four (4) regulator improvements. The 2013 CSO Plan, with the on-going and new projects, will provide approximately 14 MG of storage and cost approximately $183 million. Figure 9 shows the anticipated performance of the 2013 CSO Plan (once implemented) in terms of CSO event frequency and volume on an average annual basis.

Estimates of life-cycle costs are useful to the City of Spokane for planning purposes. Table 10 summarizes the life-cycle costs for the eleven (11) new storage facilities and four (4) regulator improvements. Life-cycle costs are based on a 25-year life-cycle. These life-cycle costs include the capital costs, the O&M costs, and are shown in terms of net present value (NPV) using a 2 percent discount rate.

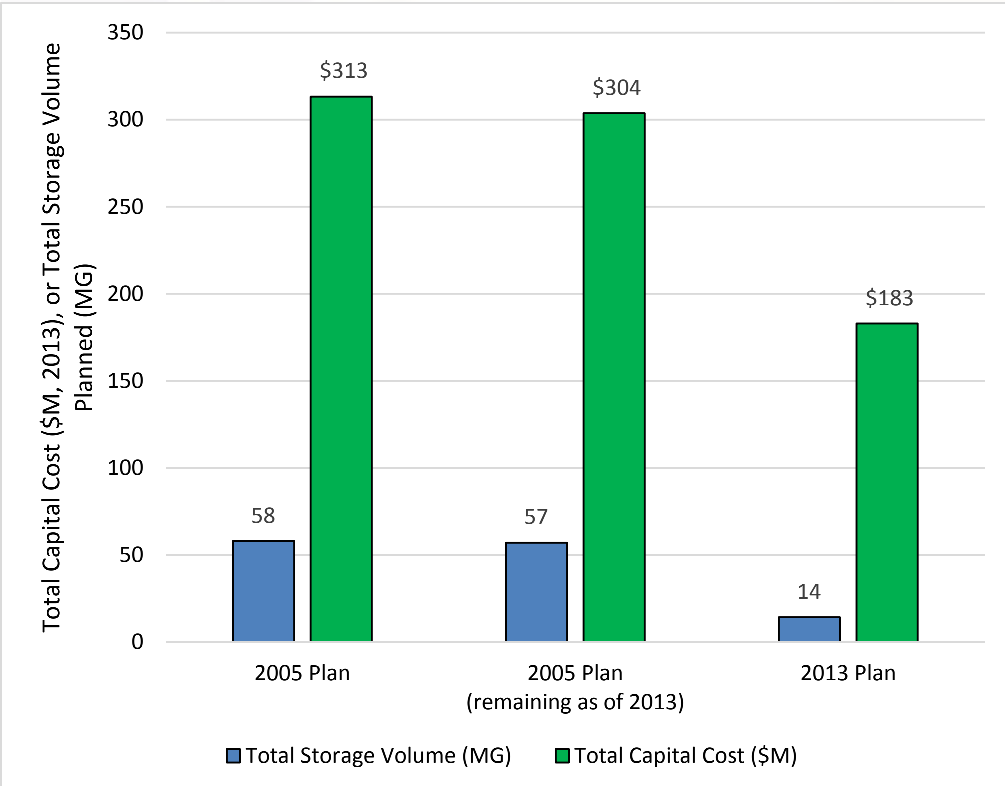


FIGURE 8. ESTIMATED CAPITAL COST OF THE 2013 CSO PLAN, AS COMPARED TO THE 2005 PLAN

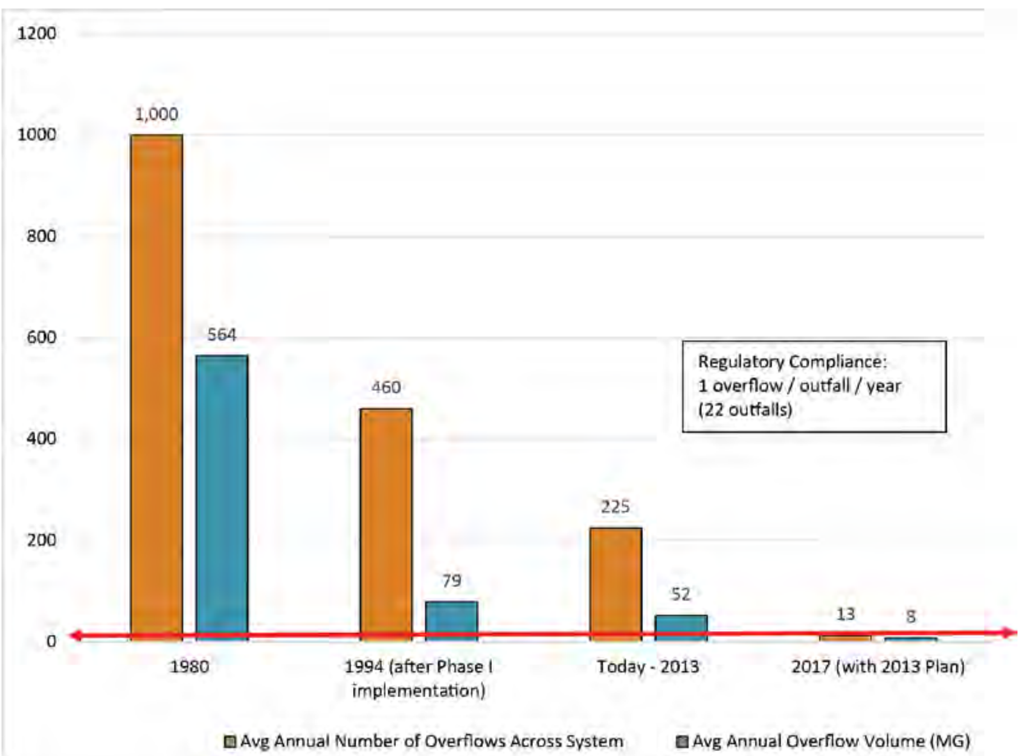


FIGURE 9. ANTICIPATED AVERAGE ANNUAL CSO EVENT FREQUENCY AND CSO VOLUME FOLLOWING IMPLEMENTATION OF THIS 2013 PLAN

TABLE 10

Estimated Life-Cycle Costs of Future Projects in the 2013 CSO Plan Amendment

CSO Basin or Incomplete Separation Area	Control Volume (MG)	Planned Facility	Total Capital Cost* ($M)	Life-Cycle Cost** (NPV) ($M)
6	0.90	Storage Tank (1)	$11.4	$10.3
7	0.01	Regulator, small storage (1)	$0.5	$0.4
12	0.69	Storage Tank (1)	$8.7	$8.1
14	0.05	Storage Tank (1)	$1.7	$1.83
15	0.05	Storage Tank (1)	$1.5	$1.61
23	0.01 (23-1) 0.01 (23-2)	Regulators, small storages (2)	$0.5 $0.6	$0.4 $0.6
24 & 25	2.00	Storage Tank (1)	$42.2	$34.1
26	2.00			
33	2.04 (33a,b,&c, aka 33-1) 0.42 (33d, aka 33-2)	Storage Tanks (2)	$27.2 $5.5	$27.2 $5.7
34 and IO7	1.26 (34-1)	Storage Tank (1)	$15.9	$16.5
41	0.01	Regulator, small storage (1)	$1.3	$1.0
IO3	1.24	Storage Tank (1)	$12.8	$15.2
IO4	0.90 0.10	Storage Tanks (2)	$10.8 $3.3	$10.7 $4.4
TOTAL	11.7	11 Storage Tanks, 4 regulator improvements	$144	$131

Notes:

** Costs developed by CH2M HILL are Class 4 cost estimates defined by the AACE, which provide between a -15% to -30% accuracy on the low side and a +20% to +50% accuracy on the high side. Construction costs include a 10% multiplier for indeterminates (AFI), a 1% multiplier for permit fees, and an 8.7% multiplier for sales tax. The construction cost was then converted into a total capital cost by adding a 25% multiplier for soft costs, and a 30% multiplier for construction contingency.*

***NPV life-cycle costs are based on a 25-year life cycle, estimates of O&M costs, and a 2% discount rate. Life-cycle costs considered the total capital cost of the project, commissioning cost, annual O&M cost, additional flow monitoring cost, replacement cost, reduction in Spokane Parks Department stormwater fees, land acquisition costs for property not already owned by the City, and additional treatment cost at the RPWRF.*

ADAPTIVE MANAGEMENT OF THIS 2013 CSO PLAN

Figure 9 shows the anticipated system performance following implementation of this 2013 CSO Plan. The City is preparing to implement a process for adapting this 2013 CSO Plan based on new information or changing circumstances. New information could include improvements to planning tools. Changing circumstances could include climate change over time, or failure to meet the performance standard. The City is working on additional improvements to planning tools. In addition, the City will further address risk and uncertainty during preliminary and final design of individual facilities. Lastly, the City is prepared to adapt its 2013 CSO Program as needed based on performance of implemented CSO projects.

Improvements to Planning Tools

The City is proceeding with system wide continuous modeling that will tie together all the individual basin models and provide an estimate of the performance of the City's entire combined sewer system. This system-wide continuous modeling will simulate performance of the new facilities over the 20-year period from 1993-2013, and also will simulate the performance of existing, already-built facilities over this same time period. This effort is in progress and the results will be documented in the City's 2014 Integrated Plan.

Address Risk and Uncertainty During Preliminary Design and Design

The City will develop and implement a process to further address risk and uncertainty from a variety of sources during the preliminary design and final design stages of each project. This process will include:

- ***Climate change***: Allocating space on the site for second phase construction for increasing the size of the storage facility volume in this CSO Plan Amendment, identifying additional storage site locations, and determining the basin where GI will reduce storage volume requirements.
- ***Revise Regulator Settings***: For high-risk CSO basins with limited "safety out" opportunities, the system may benefit from an increased regulator setting, sending more flow to the interceptor. It will be important to balance this basin need with potential impacts to the critical interceptor infrastructure downstream. The system wide continuous modeling that is under way that will be documented in the 2014 Integrated Plan will help inform this decision-making.
- ***Address Inconsistencies in Planning Tools***: For CSO Basins 24, 25, and 26, the 1.2-year design storm event model predicted a control volume that could not be reconciled with the flow monitoring data and CSO reports. This discrepancy will be addressed during preliminary design.

Adaptation Based on Performance

If the projects shown in Table 10 are built and fail to meet the performance standard of one overflow per year per outfall based on a 20-year moving averaging period, the City will take steps to address this by implementing a "safety out." In the development of the projects for each basin, a "safety out" was developed for each basin. For most basins the safety out consists of constructing GI to reduce the amount of runoff entering the combined sewer system, or to construct additional storage. Additional storage could be either added to the already constructed storage facility, or added at a new location. The feasibility of this "safety out" was considered when assigning the relative low, medium, and high risk designation (and subsequent overflow frequency target) to each basin as described earlier in this 2013 Plan.

If any CSO outfall has more than one discharge in a given year the City will evaluate the cause, and this will be documented in the Annual Report. The threshold for adding additional storage or green infrastructure will depend on what is causing the excessive CSO discharges and the magnitude of the excessive CSO discharges. In order to be able to properly evaluate the performance of the new CSO control facilities, the City will include flow monitoring at the regulator structure and inside of storage facilities. This data can be used to optimize the performance of these facilities, and to investigate the causes of excessive CSO discharges.

When results of the system-wide continuous simulation verification are available, the City will update the estimated frequency of overflows and document these in the facility predesign and design reports, the Annual CSO Reports, and any future CSO Plans.

IMPLEMENTATION SCHEDULE AND IMPACT TO RATE PAYERS

Figure 10 presents an implementation schedule that demonstrates all of the City's remaining uncontrolled CSO outfalls being brought into control by the end of 2017, in accordance with the City's NPDES permit.

The projects in this CSO Program are investments in the City of Spokane's Clean Water initiative focused on achieving a Cleaner River Faster. Although the projects in this 2013 CSO Plan represent a cost savings estimated at more than $100 million compared to the projects in the 2005 CSO Plan, these clean water investments still require a significant financial investment. The City is actively identifying potential sources of funding to further reduce the burden on its ratepayers. Specifics of the impacts to rate payers of the CSO Program and other elements of the City's Integrated Clean Water Strategy will be included in the 2014 Integrated Plan.

Project / Outfall	Size (millions of gallons)	Capital Cost ($M)
34-3	0.9	14.8
33-2	0.4	5.5
20	0.2	4.3
24	0.1	2.1
34-2	1.5	17.9
6	0.9	11.4
14	0.1	1.7
15	0.1	1.5
I-03 NW	1.2	12.8
I-04 M	0.1	10.8
33-1	2.1	27.2
I-04 D	0.9	3.3
7	0.01	0.5
23-1	0.005	0.6
23-2	0.005	0.6
41	0.01	1.3
12	0.7	8.7
34 and I-07	1.2	15.9
24 & 25 & 26	4.0	42.2
Total	**14.3**	**183.0**

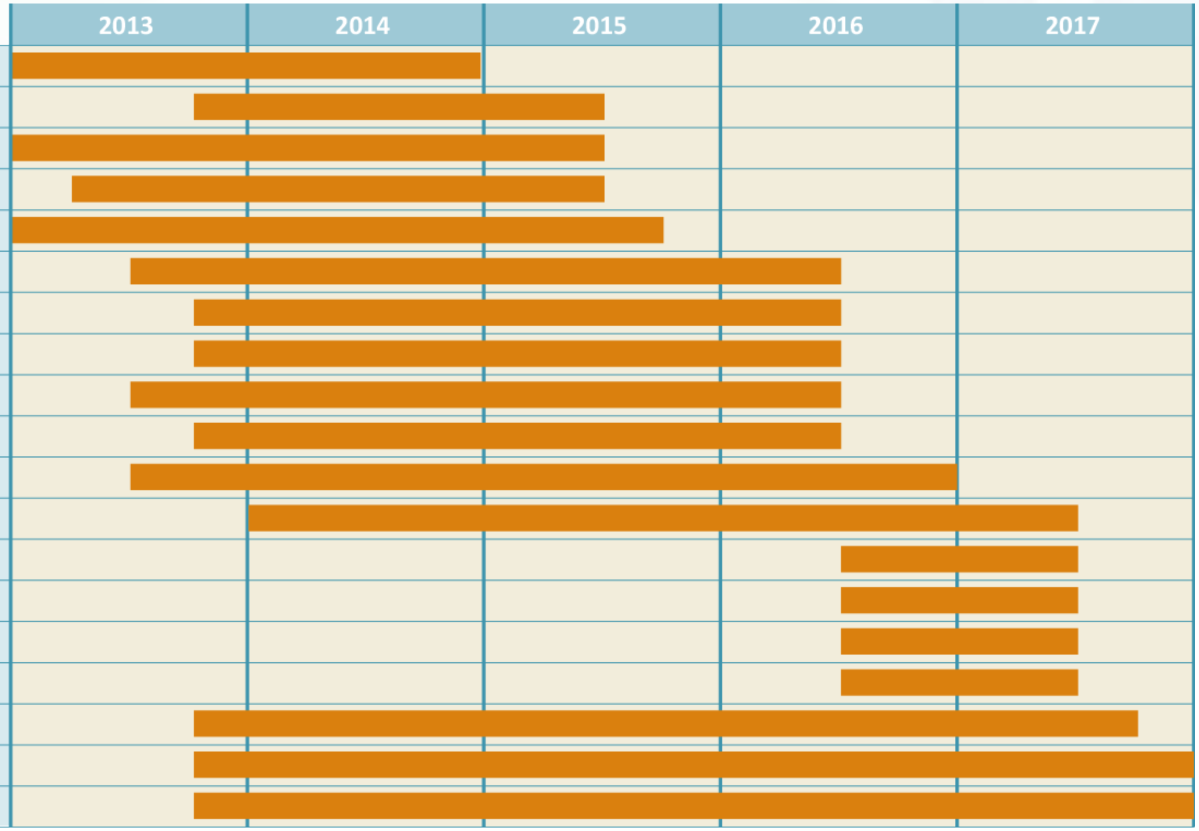


FIGURE 10. 2013 CSO PLAN AMENDMENT IMPLEMENTATION SCHEDULE

References

AECOM, 2005. CSO Reduction System Wide Alternative Report. Prepared for the City of Spokane. December, 2005.

AECOM, 2009. CSO Basin 6 Preliminary Design Engineering Report. Prepared for the City of Spokane. March, 2009.

AECOM, 2013. Interceptor Re-optimization Analysis Memorandum. Prepared for the City of Spokane. October 21, 2013.

Bovay, 1994. Combined Sewer Overflow Reduction Plan.

CLIMsystems. 2013. Data and analysis from SimCLIM 2.5 using results from an ensemble of 21 Global Circulation Models, pattern downscaled to regional scale for the state of Washington.

CTE, 2002. Precipitation and Snowmelt Analyses and Design Event Development for CSO Reduction Alternative Evaluation. Prepared for the City of Spokane. February 5, 2002.

Esvelt and Saxon, 1972. Combined Sewer Action Plan.

Mote, P., A. Snover, S. Capalbo, S.D. Eigenbrode, P. Glick, J. Littell, R. Raymondi, S. Reeder. 2013. Chapter 21 – Northwest of the National Climate Assessment. Draft for Public Comment. January 2011. http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-chap21-northwest.pdf

Salathe, E.P., A.F. Hamlet, C.F. Mass, M. Stumbaugh, S. Lee and R. Steed. 2013. *Estimates of 21st Century Flood Risk in the Pacific Northwest Based on Regional Climate Model Simulations*. http://www.atmos.washington.edu/~salathe/papers/full/Salathe_2013.pdf

City of Spokane, 1979. Facilities Planning Report for Sewer Overflow Abatement.

City of Spokane, 2013. CSO Annual Report – FY 2012. September 30, 2013.

United States Environmental Protection Agency (USEPA). 1994. USEPA CSO Control Policy

Washington Climate Preparation and Adaptation Work Group. 2007. *Draft Climate Change Scenarios for the Spokane Area*. http://www.landscouncil.org/documents/Climate_Change/Draft%20Climate%20Change%20Scenarios%20for%20the%20Spokane%20Area.pdf

Washington State Department of Ecology (Ecology). 2011. NPDES Waste Discharge Permit No. WA-002447-3. Issued July 1, 2011.

APPENDIX A

Revised Approach to Facility Sizing

Approach for Sizing CSO Storage Facilities in the City of Spokane

PREPARED FOR: City of Spokane
COPY TO: Jennifer Price/CH2M HILL
File
PREPARED BY: Jennifer Price/CH2M HILL
Amy Carlson, PE/CH2M HILL
Santtu Winter, PE/CH2M HILL
REVIEWED BY Bill Mori/CH2M HILL
DATE: August 7, 2013
PROJECT NAME: Integrated Clean Water Plan
PROJECT NUMBER: 382918.T7.02.06

Purpose

The purpose of this technical memorandum is to discuss the City of Spokane's (City) design storm used for sizing combined sewer overflow (CSO) control facilities. The determination of CSO storage facility volume has significant impacts on meeting the currently applicable performance standard in the City's National Pollutant Discharge Elimination System (NPDES) CSO permit of not more than one discharge event per year per outfall on average based on a 20-year moving average. This memorandum was completed as part of Work Task 6.1 of the Spokane Integrated Plan assistance provided by CH2M HILL.

Summary

This memorandum describes the design storm approach previously used by the City of Spokane to size CSO storage facilities. This memorandum then outlines changes to regulations and describes built CSO facility performance. An updated approach to CSO facility sizing is recommended.

Introduction

The City of Spokane's previous approach to sizing CSO facilities was developed in 2002 as part of the City's work in developing their current CSO Plan, and is documented in "Precipitation and Snowmelt Analyses and Design Event Development for CSO Reduction Alternative Evaluation," prepared by Consoer Townsend Envirodyne Engineers (CTE) (now operating as AECOM) in 2002.

In the 2002 Alternative Evaluation report, the rationale outlined for the design storm approach as the Washington State Department of Ecology's (Ecology) regulations (Chapter 173-245 of the Washington Administrative Code [WAC]), referring to "control of each CSO such that an average of one untreated discharge may occur per year." At that time, the guidance for determining whether or not a CSO outfall was controlled was based on one untreated discharge per year per outfall, based on a 5-year rolling average. The 5-year rolling average was also referenced in the 1998 guidance from Ecology (Ecology, 1998), which stated, "To ensure that an adequate once-per-year statistic is determined, the record should span at least five to six years with an average annual rainfall approximately equal to the long-term average."

The approach can be summarized as the following:

- Calculate volume generated by a "combined" 2-year, 24-hour Soil Conservation Service (SCS) Type II precipitation/snowmelt event, made up of independent rainfall and snowmelt totals that together have a combined probability of occurrence of 50 percent in any given year (Pr(rainfall) x Pr(snowmelt) = 50%), providing a 97 percent chance of meeting the one-overflow-per-year threshold when overflows are averaged over 5 years.
- Subtract volume that could be sent to the wastewater treatment plant during the event, leaving the volume of storage needed for that "combined" event.
- Verify storage facility volume using storms in a 5-year period of record. The 5-year period 1957-1961 was chosen based on statistical analysis of the then-available period of record (1948-2001 at Spokane International Airport), using a combination of factors: wettest, most back-to-back storms, and ranking of sixth largest storm over a rolling 5-year period.

The design storm approach documented in the 2002 Alternative Evaluation report was modified in subsequent basin-specific planning efforts. For example, in the preliminary design report for CSO Basin 06 prepared in 2009 after the 2002 CTE report, it was acknowledged that the use of the 2-year, 24-hour SCS Type II rainfall+snowmelt storm may be too conservative. A 10-year precipitation record from 1950-1959 (instead of the prescribed 5-year record) was used to verify the design storm. It was then recommended that storage to contain a SCS Type I storm distribution of the 2-year, 24 hour event be constructed in a first phase, with a second phase (if needed) of storage built to contain volume from the original SCS Type II storm distribution (AECOM, 2009). The first phase volume would be 1.2 million gallons (MG).

Current Applicable Regulations

The City of Spokane's current NPDES permit (Permit No. WA-002447-3, effective July 1, 2011, expiration date June 30, 2016) specifies a performance standard for controlled CSOs as not more than one discharge event per year on average based on a 20-year moving averaging period. The WAC specifies the performance standards that are then carried out in the NPDES permits.

Independent from the performance standard, the NPDES permit also specifies CSO reporting requirements; specifically, a CSO report requirement (S12, Paragraph B.):

> <u>B. Combined Sewer Overflow Report</u>
> The Permittee shall submit annually a CSO Report to the Department for review and approval, which complies with the performance standards of WAC 173-245 and must include documentation of compliance with the Nine Minimum Controls for CSOs described in Section S13.C. The performance standard will apply to all CSO outfalls which have been identified by the Permittee in the CSO Reduction Plan Amendment as meeting the "greatest reasonable reduction." The performance standard is derived from the State regulatory requirements as specified in WAC 173-245-020(22). The performance standard for controlled CSOs is not more than one discharge event per year on average. Compliance with the performance standard will be based on a 20-year moving averaging period, including past years and the current year. **When the period of data collection is less than 20 years, the averaging period will include all past years for which flow monitoring data was collected. The Permittee must report the average number of discharge events per controlled outfall per year based on a 20-year moving average to be reported in the annual report**. Compliance with the performance standard is determined annually.

In addition to the performance standard and reporting requirements, post-construction monitoring is required under the NPDES permit. An EPA Region X letter to King County dated May 10, 2012, specifically requires post-construction monitoring in addition to federal and state legal requirements. The City of Seattle also is implementing a Post-Construction Monitoring Plan.

In addition to the City of Spokane's NPDES permit, other regulations apply, including:

- United States Environmental Protection Agency (USEPA) Combined Sewer Overflow Control Policy
- Clean Water Act
- Washington State Water Quality Standards

Sizing Approach Used by Other CSO Communities in Washington State

NPDES permits for CSO communities in Washington State specify a frequency-based performance standard per WAC 173-245. The WAC specifies the performance standards, which are then carried out in the NPDES permits. Seattle and King County's NPDES CSO permits contain the same language as Spokane's NPDES permit, specifying a one discharge event per year per outfall on average based on a 20-year moving averaging period. Seattle and King County have federal Consent Decree orders that also contain this language.

Although the current City of Spokane NPDES permit does not specifically state how to calculate the 20-year moving average for proposed new CSO reduction projects, we do know that Seattle and King County are required to use actual rainfall and a 20-year computer simulation for new CSO facilities. Ecology may likely expect Spokane to follow a similar approach. The specific City of Seattle and King County CSO facility sizing requirements are defined as follows, with language found in both City of Seattle's and King County's CSO consent decrees (IV. Definitions, No. 9, item dd; in King County's consent decree, item ee). In Seattle's consent decree:

> "Twenty Year Moving Average" or "20-Year Moving Average" shall mean the average number of untreated discharge events per CSO Outfall over a twenty year period for purposes of compliance with WAC 173-245-020(22). For previously Controlled CSO Outfalls and where monitoring records exist for the past 20 consecutive years, the twenty year moving average shall mean the average number of untreated discharges per CSO Outfall over the 20 year record. On an annual basis, the twenty year moving average will be calculated and includes the current monitored year and each of the previous 19 years of monitored CSO data. For CSO reduction projects and Controlled CSO Outfalls where a complete twenty year record of monitored data does not exist, missing annual CSO frequency data will be generated based on the predicted CSO frequency for a given year as established in the approved engineering report or facility plan. For each CSO reduction project, the engineering report or facility plan shall predict the CSO frequency for each CSO Outfall (s) based on long-term simulation modeling using a 20-year period of historical rainfall data, the hydraulic model, the CSO control project design and assuming the CSO control project existed throughout the 20-year period. For CSO reduction projects, the level of control is the number of discharge events per CSO Outfall per year that are estimated to occur based on the designed CSO control project over a 20 year period. The level of control will be estimated for each year for a period of 20 years in the engineering report or facility plan. For the time period between the approval of the engineering report and the CSO reduction project's Construction Completion date, the City shall use the same model for the approved design along with the corresponding rainfall data for this period of time to derive

CSO frequencies. This information will be submitted as an amendment to the engineering report or facility plan. For CSO reduction projects, the 20-year moving average will use the approved level of control, on an annual basis, for each of the preceding years for which monitored data does not exist in conjunction with monitored data after the CSO control project has been constructed.

For their CSO conceptual alternative evaluation, the City of Seattle uses a continuous modeling simulation approach for sizing its CSO storage facilities, running simulations of 31 to 34 years depending on precipitation data availability, which varies by site. The initial sizing volume for the CSO facility was determined by ranking the CSO events by volume, and taking the $(N+1)^{th}$ largest CSO volume as the control volume, where “N” equals the number of years in the long-term simulation. Once the initial sizing control volume was established, alternatives for CSO control were developed for that basin. For the final CSO alternative evaluation stage, the City of Seattle performs a 20-year moving average simulation to determine if the proposed facilities will meet the performance standard. The simulations also considered long-term climate changes. As these alternatives are screened, refined, and modeled, adjustments are made to the sizing of the facilities. In addition, the facility sizing is revised during the preliminary design and design process to account for uncertainty and risk not previously considered or known.

Spokane CSO Storage Facility Performance

This design storm approach to sizing CSO storage facilities was first used for sizing a CSO storage facility to control overflows in CSO Basins 02 and 03c. No overflows have occurred from this facility since 2002, before the facility came on-line. This and the other CSO storage facilities built by the City of Spokane have met the performance standard of not more than one discharge event per year on average (Table 1). No overflow events have occurred since each storage facility has become operational. Table 2 summarizes the storm events that caused the largest overflows (by volume) during 2007-2012 at CSO outfalls 06, 12, 24/25 and 33. Note that the events with the largest recurrence interval during this 7-year period occurred on December 2, 2007 and March 15, 2012, and that snowmelt events during this 7-year period occurred on January 7, 2009 and March 26, 2012. The storms experienced during this 7-year period were smaller than the synthetic design storm used to size the facilities.

TABLE 1
To-Date Performance of Implemented CSO Storage Facilities

Facility/CSO Outfall ID	Operation Since	Number of Overflow Events Since Operational
CSO 02&03c	2003	0
CSO 010	2011	0
CSO 016	2007	0
CSO 019	2010	0
CSO 038, 039, 040	2011	0
CSO 042	2009	0

Source: City of Spokane CSO Annual Report – FY2011 (City of Spokane, 2012).

The City of Spokane plans storage facilities to control CSOs at outfalls 06, 12, 24/25 and 33. Each of these facilities is in the planning and design stages (Table 3). Table 3 shows the estimated performance of these planned CSO facilities if they had been in place and operational during the

12-year period from 2001-2012, based on the measured CSO volumes presented in the City's monthly CSO reports to Ecology.

TABLE 2
Storm Events that Caused the Largest Overflow Volumes Elsewhere in the System from 2007-2012

Date	Snow Depth (in)	Snowmelt (in)	24-hour Precipitation Total	24-hour Precipitation Recurrence (years)
12/2/2007	Not Available	Not Available	1.41	2
1/7/2009	8 - 22"	~6.3"	0.22	<2
6/19/2009	0"	0"	0.55	<2
9/17/2009	0"	0"	0.38	<2
3/11/2012	0"	0"	0.27	<2
3/15/2012	0"	0"	1.22	Approximately 2
3/26/2012	0"	Possible 2"	0.62	<2

Precipitation Source: Spokane International Airport rain gage.

TABLE 3
Estimated Performance of CSO Storage Facilities at CSO Outfalls 06, 12, 24/25 and 33 had Facilities been Sized Using Previous Design Storm, and Operational During 12-year Period: 2001-2012

CSO Outfall	Measured Number of Overflows (2001-2012)	Total Measured CSO Volume (Gallons) (2001-2012)	Pre-Design CSO Storage Facility Volume (Gallons)	Estimated Number of Overflows had the Facility been in Place (2001-2012)	Estimated CSO Volume had the Facility been in Place (Gallons) (2001-2012)
CSO 06	309	53,600,000	1,244,000	5	3,900,000
CSO 12	327	39,700,000	1,001,000	3	1,400,000
CSO 24/25	556	92,600,000	5,650,000	1	2,600,000
CSO 33	311	74,600,000	3,830,000	4	6,200,000

Source: Calculated based on monitored CSO outfall events during 2007-2012 compared to planned storage volume at each facility.

The measured CSO volumes from 2001 to 2012 can then be used to estimate the storage volume that would have been required to achieve a one CSO per year or one CSO every other year performance standard during that time period (Table 4). The information shown in Table 4 is for discussion purposes only. CH2M HILL does not recommend sizing the City's CSO facilities based solely on the measured historical CSO volumes. For example, flow into the interceptor would also be different before and after construction of the CSO facilities. Also, measured CSO volumes are subject to uncertainty, and may not represent the volume of combined sewage that was actually discharged because of uncertainties in flow monitoring. Other factors should be considered when sizing CSO facilities, including uncertainty and performance over a longer period of time (the 20 years specified in the NPDES permit).

TABLE 4
Estimated CSO Facility Storage Volumes Needed to Achieve CSO Control at CSO Outfalls 06, 12, 24/25 and 33 During 12-Year Period: 2001-2012

CSO Outfall	Planned CSO Storage Facility Volume (Gallons)	Estimated Storage Facility Volume Needed Based on Historical CSO Volumes (gallons)	
		6 CSOs in 12 Years (0.5/yr)	11 CSOs in 12 Years (0.92/yr)
CSO 06	1,244,000	1,016,000	813,000
CSO 12	1,001,000	767,000	654,000
CSO 24/25	5,650,000	2,506,000	1,898,000
CSO 33	3,830,000	2,792,000	1,996,000

Conclusions

CSO Facilities built according to the previous design storm approach are oversized. That, and the performance standard in the City's NPDES CSO permit is now not more than one discharge event per year per outfall on average based on a 20-year moving average instead of a 5-year moving average. Therefore, CH2M HILL recommends an updated approach to CSO facility sizing as described below.

Recommendations

Recommendations are organized by the CSO reporting requirements specified in the City's NPDES permit, CSO facility sizing based on CSO performance requirement of the one overflow per year per outfall based on a 20-year moving average, and requesting approval from Ecology for an updated approach on facility sizing and the submittal of a CSO Plan Amendment. The recommendations on a phased approach to facility sizing considering schedule constraints are also given. CH2M HILL's recommendations are based on the current CSO regulatory environment in the State of Washington, and our collective experience working with CSO communities in Washington and across the country.

CSO Reporting

- Prepare the annual CSO report based on the 20-year moving average for determining the control status (controlled or uncontrolled) for each CSO outfall as required in the NPDES permit S12B. The 20-year data should include actual overflow monitoring data supplemented by continuous computer simulations for years that flow data are unavailable. This recommendation also requires the preparation of a 20-year (or longer) precipitation record (see recommendation under CSO Facility Sizing). The City could consider asking Ecology if the 12 years of available monitoring data are sufficient rather than using the 20-year continuous simulation.

CSO Facility Sizing

It is the City's decision whether or not to stay with the current and Ecology-approved design storm approach to CSO storage facility sizing, but it must be approved by Ecology. The impacts involved in continuing with the current design storm approach are:

- Ecology and USEPA have directed the City of Seattle and King County in their July 2013 consent decrees to size their respective CSO control facilities based on a continuous hydraulic CSO model using historical rainfall data and a moving 20-year average for CSO control. At the minimum, Ecology will require the City of Spokane to demonstrate that the design storm approach does not result in performance less than the 20-year moving average method, which will require continuous modeling.

- The City will over-size storage facilities as compared to the NPDES performance standard, spending more money than needed to meet the NPDES state requirements.

The impacts involved in taking a long-term, 20-year moving average, performance-based approach to facility sizing are:

- Ecology has approved the City of Spokane's design storm approach to sizing CSO storage facilities. Changing the facility sizing approach would require approval by Ecology. The City will need to prepare and submit a CSO Plan Amendment for Ecology approval.
- Additional study (modeling, development of 20-year precipitation record) is required, taking more time and budget.

Should the City of Spokane decide to take a long-term, performance-based approach to CSO storage facility sizing, CH2M HILL recommends the following:

- Characterize expected annual performance over the 20-year moving averaging period using a long-term continuous simulation model as specified in the City's NPDES permit and for consistency in sizing approach used by other CSO communities in Washington. (Note that characterizing required storage facility volume over a longer period of time could result in smaller facility sizes. For example, periods of time with higher-than-average amounts of CSOs would be averaged out over longer periods of time, reducing the impact that they have in increasing the storage facility volume.)
- Develop a long-term (>20-year) precipitation record with both rainfall and snowmelt for use as input into the continuous simulation model, extending the record through 2012 (to validate sizing of already-implemented CSO storage facilities). Use data from local rain gages to reflect spatial non-uniformity of precipitation across the City. Maximize the length of the precipitation record (depending on available data). Use precipitation data from the smallest time intervals available (1-minute, 10-minute, and 15-minute) to accurately reflect periods of high-intensity precipitation. Verify that the long-term precipitation record represents types of storms that cause overflows (summer high-intensity thunderstorms and rain-on-snow triggering snowmelt with frozen ground conditions).
- Perform a long-term continuous simulation using a long-term precipitation record using the City's current modeling platform (or consider upgrading from XPSWMM to SWMM Version22, which better accounts for groundwater and evaporation, and also is more appropriate for long-term continuous simulations rather than event simulations)
- During preliminary design and design, incorporate uncertainty into facility sizing (sources of uncertainty: model, rainfall record, rainfall catch, flow monitoring, climate change), with one possible option to apply an uncertainty factor to the precipitation record (for example, in Seattle: precipitation x 1.06) and identify the impact of this 6 percent increase in precipitation on facility sizing, then use this in "knee-of-the-curve" cost analysis for use in decision making.

CSO Plan Amendment

Should the City decide to revise their approach to facility sizing, CH2M HILL recommends the following:

- Prepare and submit a CSO Plan Amendment to Ecology to gain Ecology's approval of this revised approach and resulting revised CSO control plan. Coordinate with Ecology ahead of submittal on this revised facility sizing approach. This CSO Plan Amendment would include a description of this revised facility sizing approach, as well as a description of the results (outfall control volumes) and planned projects (storage facilities, other capital projects), and a project implementation phasing strategy and schedule.
- The general CSO Plan Amendment approach for determining control status, storage volume requirements, and alternative evaluation should use actual flow and rainfall data, design storm, and long-term simulations as summarized below:
  - Identify "Uncontrolled" and "Controlled" NPDES outfalls based on the NPDES Permit requirement (S12, Paragraph B.), based on actual flow monitoring data.
  - Develop and evaluate conceptual alternatives in each CSO basin based on a "Design Storm" approach. The conceptual alternative work will recommend a short list of CSO alternatives to be reviewed for selection as the recommended CSO alternative for each CSO basin in the CSO Plan Amendment.
  - Select and define the recommended CSO alternative in each basin based on a calibrated CSO model using actual overflow data and long-term (20-year) computer modeling results.
  - Prepare "knee-of-the-curve" analysis to compare cost-effectiveness (capital costs, performance) of each storage facility size option, and characterize risk and uncertainty of each option, all of which informs the City's decision on storage facility size.

Phased Approach to CSO Storage Facility Sizing

With the City's CSO Program Implementation deadline of 2017 per the City's NPDES permit, the City could decide to propose to Ecology a phased approach to facility sizing that includes both the design storm approach and the 20-year moving average continuous modeling approach:

- Phase I: Develop conceptual sizing of CSO storage facilities using the City's existing event model with a revised synthetic precipitation event (SCS Type II 1.2-year precipitation event, providing a 97 percent chance of meeting the one-overflow-per-year threshold when overflows are averaged over 20 years). Use these conceptual facility sizes and the event model to screen basin alternatives during CSO Plan Amendment development.
- Phase II: Verify conceptual sizing of CSO storage facilities and preferred basin alternatives using a continuous model simulation for each CSO basin based on the long-term record of precipitation. Use long-term (>20 year), continuous model simulation to verify that the preferred CSO alternative meets the one overflow per year per outfall on a 20-year moving averaging period at each outfall in the system. Document results and any modifications to conceptual sizing in the CSO Plan Amendment.
- Phase III: During individual facility preliminary design and design, verify sizing using >20 years of precipitation data using the continuous model; revise facility sizing to account for uncertainty and risk not previously considered. Document in a facility plan for that CSO storage facility.

References

AECOM. 2009. *CSO Basin 6 Preliminary Design Engineering Report*. Prepared for the City of Spokane, Spokane, WA. August 23, 2009.

Consoer Townsend Envirodyne Engineers (CTE). 2002. *Precipitation and Snowmelt Analyses and Design Event Development for CSO Reduction Alternative Evaluation*. February 5.

City of Spokane. 2012. *Combined Sewer Overflow Annual Report – FY2011 for NPDES Permit No. WA-002447-3.* September 28.

United States District Court for the Western District of Washington. 2013. United States of America and the State of Washington v. The City of Seattle, Washington. Civil Action Case 2:13-cv-00678 Document 2-1 filed 04/16/13. Consent Decree. 75 pp.

United States District Court for the Western District of Washington. 2013. United States of America and the State of Washington v. King County, Washington. Civil Action Case 2:13-cv-00677 Document 2-1 filed 04/16/13. Consent Decree. 75 pp.

Washington State Department of Ecology (Ecology). 1998. *Criteria for Sewage Works Design*.

Washington State Department of Ecology (Ecology). 2011. *National Pollutant Discharge Elimination System Waste Discharge Permit No. WA-002447-3 for City of Spokane Riverside Park Water Reclamation Facility and Combined Sewer Overflows (CSOs).* Issued June 23, 2011. Effective July 1, 2011. Expiration Date: June 30, 2016.

Washington State Department of Ecology. 2012a. *January 2012 Discharge Monitoring Report (DMR) for Permit Number WA0024473*. Spokane, WA. February 15, 2012.

Washington State Department of Ecology. 2012b. *April 2012 Discharge Monitoring Report (DMR) for Permit Number WA0024473*. Spokane, WA. May 15, 2012.

Washington State Department of Ecology. 2012c. *August 2012 Discharge Monitoring Report (DMR) for Permit Number WA0024473*. Spokane, WA. September 15, 2012.

Acronyms and Abbreviations

City	City of Spokane
CSO	combined sewer overflow
CTE	Consoer Townsend Envirodyne Engineers (now operating as AECOM)
Ecology	Washington State Department of Ecology
MG	million gallons
NPDES	National Pollutant Discharge Elimination System
SCS	Soil Conservation Service
USEPA	United States Environmental Protection Agency
WAC	Washington Administrative Code

APPENDIX B

Conceptual Control Volumes (1.2-year event model)

AECOM

140 S. Arthur Street, Suite 500, Spokane, Washington 99202-2260
T 509.535.5454 F 509-535-5725 www.aecom.com

DUANE C. STUDER
STATE OF WASHINGTON
31931
REGISTERED
PROFESSIONAL ENGINEER
10-21-13

Memorandum

Date:	October 21, 2013
To:	Mike Taylor, PE; Marcia Davis, PE; Lars Hendron, PE; City of Spokane
From:	Duane Studer, PE and Jessica Bean, PE
Subject:	**Interceptor Re-optimization Analysis** **FINAL**

Distribution: S. Winter, A. Carlson, J. Price, C. Kuperstein, G. Shrope, K. Ames, K. Eller

This memorandum presents the results of an analysis to optimize City of Spokane interceptor system capacity. Capacity was optimized utilizing estimated total wet weather system storage volume as it relates to approximate costs for construction of improvements.

Background

In 2012, EPA presented the Integrated Municipal Stormwater and Wastewater Planning Approach Framework to assist municipalities in achieving water quality objectives through identification of comprehensive efficiencies across diverse utility and infrastructure capital improvements. Subsequently, The City of Spokane has established a goal aligned with a framework to reprioritize its capital projects based on an Integrated Planning approach.

NPDES Permit

City of Spokane CSO discharge outfalls are permitted through the National Pollutant Discharge Elimination System (NPDES). Within the permit, CSO regulator identification, locations, and compliance requirements are defined. In 2011, a revised NPDES permit was issued to the City of Spokane. The 2011 NPDES permit explicitly provides for a 20-year moving average for measuring compliance with the CSO performance standard. Previously, the averaging period was not defined, but was interpreted as a 5-year period to match the NPDES permitting cycle.

Basis of Design Rainfall Event

Combined Sewer Overflow (CSO) reduction facility planning and evaluation entails a risk-based approach where a particular return period (or return frequency) precipitation event, potentially coupled with snowmelt, is used. This is due to the unpredictability of rainfall in terms of both time and quantity. The particular precipitation event, i.e., the design storm or design event is then applied to a given area to calculate runoff flows or other hydrologic and hydraulic impacts. Other methods of evaluation involve continuous simulation over multiple months or years of actual precipitation record, but that is planned for other upcoming evaluations related to CSO and Integrated Planning.

Frequency: The selection of the appropriate return frequency for the design storm is critical to ensuring that appropriate conveyance, storage, and treatment facilities are sized to meet CSO regulations. As presented in the *Precipitation and Snowmelt Analysis and Design Event Development for CSO Reduction Alternative Evaluation* (AECOM, 2002), the selection of the design event return frequency is governed by a binomial distribution (Linsley, et al.) that takes into account the number of exceedance events occurring over a given period of years. The explicit definition for compliance in the NPDES Permit update of an averaging period of 20-years resulted in a recalculation of the CSO design storm event initially established for an averaging period of 5 years.

In the case of combined sewer overflows, the concern is defining a design event that meets the cited regulations which limit the number of CSO overflows per outfall per year. Where maximum number of annual overflows per year equals one when averaged over N-years, the binomial distribution expression can be simplified by substituting the number of exceedance events equal to the number of years in the period, N to be:

$$J_k = p^k$$

Where: J_k = probability that an event with average probability p will be exceeded exactly k times during an N-year period

p = 1/T = average annual probability of occurrence of a given event

T = return frequency in years

k = number of exceedance events occurring over an N-year period

N = number of years of concern.

The original analysis indicated that with a 2-year return frequency, the probability of having exactly five events occur that exceed the design event, where the exceedance is averaged over five years, is only 3%, or conversely a 97% chance of compliance.

However, using a 20-year period defined in the 2011 NPDES Permit, the calculation results in a required return frequency of 1.2-years to achieve a 97% confidence of compliance. Sensitivity of the calculation was checked for a 95% confidence, which yielded a 1.16-year frequency. For simplicity, a 1.2-year storm frequency was chosen for wet weather simulations using a design storm in this analysis.

Duration and temporal distribution: The duration of the design event for determination of storage volume was previously established to occur in 24-hrs for most Spokane CSO basins (*Precipitation and Snowmelt Analysis and Design Event Development for CSO Reduction Alternative Evaluation* (AECOM, 2002)), and was used for design storm volume determination. The same temporal distribution of the design storm that was also established in section 2.3 of the Design Event Development Memorandum (2002) is used in this evaluation, which is the NRCS Type II distribution.

Storm depth: Design storm depth or volume to be applied to hydrologic models in this analysis was extrapolated from Washington Department of Transportation (WSDOT) published rainfall intensity-duration-frequency (i-D-f) curves, which are established for use when designing hydrologic facilities. A natural logarithm curve fitting analysis of the Spokane hydrologic i-D-f coefficients was performed to estimate (r^2 greater than 0.97) the 1.2-year 24-hour storm depth of 0.88 inches for this analysis.

Spatial variation (Beta Factor): Because of documented variations City rain gages located throughout the service area, a spatial relationship was established (*Precipitation and Snowmelt Analysis and Design Event Development for CSO Reduction Alternative Evaluation* (AECOM, 2002)). A spatial adjustment factor was developed as a "Beta factor" for rainfall volume for each CSO basin. This "customization" of a design event to each CSO basin addresses differences in rainfall patterns between each basin. The original Beta factor circa 2002 was updated to reflect collection of additional data, with a higher correlation and confidence of a predictable relationship, and as documented in the *Precipitation and Snowmelt Analysis and Design Event Development for CSO Reduction Alternative Evaluation draft* (AECOM, August 2009). The Beta factor 2009 is used for this analysis.

Snowmelt: The Spokane climate of arid summers and costal winters combined with the "inland" orientation of this region create circumstances where prolonged periods of freezing temperatures in the winter supports snow fall interspersed with intermittent periods of warmth. The accompanied melting of snow coupled with frozen ground conditions may, depending on the amount of accumulated snow, result in substantial runoff. This snowmelt event can result in runoff entering the combined sewer system (CSS) during either dry weather or a “rain-on-snowmelt” combination event. Past analysis have conservatively utilized a combined snowmelt and rainfall design event. Historically, data analysis by City Wastewater Management Department has indicated that Spokane typically doesn’t experience CSO inducing snowmelt events more than once a year. For this reason, the City has elected to use a less conservative approach for the integrated planning effort. This analysis utilizes a 1.2 year design storm without snowmelt.

Previous Interceptor Analysis

The 1994 CSO Reduction Plan evaluated the collection, interceptor, and CSO outfall systems through flow monitoring and hydraulic model analyses based on CDM-SWMM. Subsequent to the 1994 CSO Reduction Plan, a system wide analysis was conducted which focused on CSO compliance through interceptor flow management. This was completed in 2005 and was supported by a more comprehensive modeling effort (Combined Sewer Overflow Reduction System Wide Alternative Report (CTE|AECOM, December 2005) using XP-SWMM and ArcGIS.

In 2012, a system wide re-evaluation of interceptor settings was completed using an extended and recalibrated model. As presented in the interceptor System Wide Re-evaluation memorandum (AECOM, 2013) the analysis was based on a 2009 adjusted CSO Design Event, and resulted in optimized flow controls from each of the CSO basins to minimize storage requirements, while maximizing flows in the interceptor. The results from this re-evaluation effort were used as a basis for comparison to this analysis.

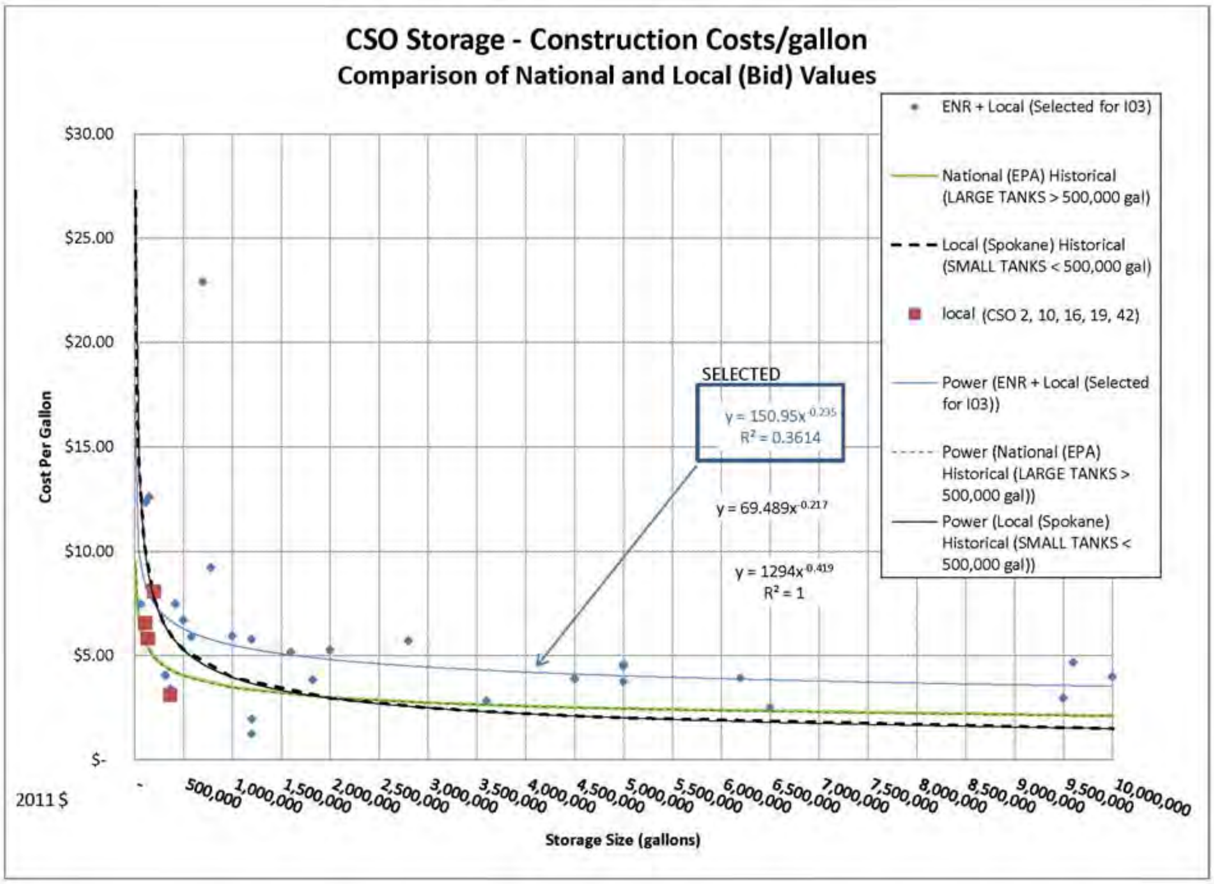
Assumptions

The following key assumptions were used to proceed with the analysis (see Appendix for complete list):

1. Base wastewater flow (sanitary) and infiltration/inflow condition is projected to include population growth and development to the year 2030 (equivalent to previously developed growth values for year 2020 as defined by City planning staff recommendation).
2. System Wide Report designation flow control settings, as updated by the System wide Re-evaluation analysis (AECOM, 2013) will be used as an initial basis for comparison.
3. Design event rainfall applied to all basins consists of a system wide synthetic NRCS Type II storm; 1.2-year return frequency, and duration of 24 hours.
4. The unregulated areas tributary to Interceptor Segment I03, Interceptor Segment I04, Interceptor Segment I07, and the Post Street Bypass Sewer will utilize a storm of 1.2 year return frequency of 24 hour duration. The Wet Weather Design Event (5yr 24hr design storm with NRCS Type II distribution including 0.5 year snowmelt) as defined in the Unregulated Area Wet Weather Design Event Memo (CTE, 2005) is <u>not</u> used in this analysis.
5. Rainfall depth is spatially adjusted with predetermined Beta factors, applied system wide.
6. Full flow pipe conditions are used to determine capacity for simulation results using a Manning’s roughness factor “n” set equal to 0.013.
7. Effects of proposed stormwater separation (e.g. to drywells) for (CSO basins 6, 7, 12, 14, 15, &23) were not represented in the base system wide model.
8. Previously proposed subsidiary storage in the upstream portions of CSO basins and unregulated areas were not yet simulated.
9. Spokane County and the City of Airway Heights have constructed water reclamation facilities that reduced their base waste water flow (BWF) contribution to certain segments of the interceptor system. These interceptor inlet flow rates were adjusted to accommodate the modified (after County WRF construction) flows to determine revised CSO storage volume requirements. (Appendix, pp-30)
10. Riverside Park Water Reclamation Facility (RPWRF) has an equalization capacity of 4 million gallons for wet weather flow above 100 mgd influent rates (CH2M, May 2013).

Basis of Approximate Construction Costs

Approximate construction costs for CSO storage facilities were estimated using a cost-per-gallon derived equation shown in the graphic below. This basic cost-per-gallon construction cost equation was developed in part from data from previous local and national projects, and construction cost information contained in EPA's CSO Publications and McGraw Hill's Engineering News Record (ENR). Cost summaries are adjusted to the current year by application of representative construction cost indices (ENR), and adapted for the Spokane region using R.S. Means published construction cost adjustment factors for U.S. cities. Estimated construction costs for separation of runoff from the combined sewer system were determined using planning level average costs based on previously completed AECOM Drywell Analysis Technical Memorandums for CSO Basins 6, 7, 12, 14, 15 and 23.



Analysis and Results

The results of redefined design storm (1.2-yr, 24-hr) were initially applied to the updated model that was developed for the previously referenced System Wide Re-evaluation Analysis. This was done to provide a basis of comparison to potential Integrated Plan re-optimization alternatives. Updates to the model included Interceptor Segment I03 (I03) unregulated area modifications from infiltration & inflow (I&I) repairs completed in recent years.

Evaluation of proposed changes to the collection system was analyzed in a two step process:

1. Hydrologic and hydraulically simulated CSO and unregulated basin hydrographs (also 1.2-yr, 24-hr storm) were used to represent basic alternative characteristics and determine peak flow rates and volumes tributary to the interceptor system segments, and
2. Flow control settings were adjusted in the actual trunk and interceptor model to simulate the effect of flow transmitted to the interceptor pipe system.

Basin flow control settings were modified based on general alternative concept objectives and downstream available interceptor pipe capacity. Other considerations for developing interceptor alternatives were:

- Available site area for potential project facilities (e.g. storage)
- Proximity to other CSO regulators and the Riverside Park Water Reclamation Facility (RPWRF) as it relates to conveyance of wet weather flows in the interceptor
- Relative size of required storage volume compared to adjacent facilities.

Alternatives were modeled to reflect key parameters and assumptions as a preface to anticipated basin level integrated planning alternatives evaluation.

Alternatives

A set of alternatives for interceptor control settings was compiled based on the City's objective to reduce the number & volume of CSO storages and total cost. The alternative analysis created different system management alternatives in an attempt to optimize interceptor capacity based on the increase or decrease of flow control settings to the interceptor, resulting in acceptable CSO storage volumes while not exceeding maximum full flow capacity in the interceptor. The set of alternatives to be evaluated for optimizing the interceptor system are listed below.

Table 1. List of Interceptor Re-optimization Alternatives

Alternative	Description*
1	System Wide Re-Evaluation Scenario 3
2a	Distributed Storage (through the collection system)
2b	Centralized Storage based on CSO 33
2c	Centralized Storage based on CSO 33 *and 34*
2d	Centralized Storage based on CSO 33 and 34 without Conveyance Upgrade
3	Centralized Storage based on CSO 33 with Onsite Stormwater Separation
4a	Centralized Storage with I02 controlled to 120 mgd
4b	Centralized Storage with I02 controlled to 120 mgd & Onsite Storm Separation

* Spatial Beta factor 2009 used for all alternative simulations.

A fundamental comparison of distributed and centralized storage strategies was first considered. Variations or sensitivity of particular alternative features were used to develop other alternatives.

Alternative 1 System Wide Re-Evaluation Scenario 3. Flow control settings were set to the preferred "Scenario 3" from 2012 re-evaluation analysis as a basis of comparison for other alternatives.

Alternative 2a Distributed Storage. Flow control settings were adjusted for the 1.2-year design storm with an emphasis on utilization of interceptor capacity while maintaining storage facilities at each CSO regulator, as discussed at a collaborative May 16, 2013 meeting with the City's core technical team for integrated planning. Flow control settings on constructed facilities were reviewed for potential reduction and correspondingly more frequent use of available storage capacity, but only CSO 16, 38, and 42 appear to be candidates at this time. Initially, an option without flow control for unregulated areas was considered, but was discontinued due to especially restrictive upstream flow controls and resultant large CSO volume requirements.

Alternative 2b Centralized Storage based on CSO 33. Flow control settings were adjusted with a focus on implementing fewer, larger storage facilities. CSO 33 flow control settings were decreased to create available interceptor capacity and effectively eliminate the need for a storage facility at some of the CSO basins and unregulated areas. Resultant storage volumes less than about 5,000 gallons were considered to be integral to the flow control component requirement for a future interceptor inlet vault, and therefore virtually eliminated. For this alternative, storage was essentially eliminated (i.e. < 5,000 gallons) at Interceptor Segment I04 (I04) at Monroe Street unregulated area, CSO basins 7, 14, 23, and 41.

Alternative 2c Centralized Storage based on CSO 33 *and 34*. Flow control settings were adjusted with a focus on implementing even fewer storage facilities. CSO 33 and 34 flow control settings were decreased to create available interceptor capacity and effectively eliminate (i.e. < 5,000 gallons) the need for a storage facility at I04 Monroe Street unregulated area, CSO 7, CSO 14, *CSO 15*, CSO 23, and CSO 41.

Alternative 2d Centralized Storage based on CSO 33 and 34 without Conveyance Upgrade. Flow control settings were adjusted with a focus on implementing fewer storage facilities and also to avoid adding capacity (second) to the interceptor inlet for CSO 34-1. Although similar to Alternative 2c, CSO 34 flow control settings were decreased even further to create sufficient interceptor available interceptor capacity to effectively eliminate (i.e. < 5,000 gallons) I04 (Monroe Street) unregulated area, CSO 7, CSO 14, CSO 15, CSO 23, and CSO 41.

Alternative 3 Centralized Storage based on CSO 33 with Onsite Stormwater Separation. Flow control settings were adjusted to reduce the number of required storage facilities in combination with reduction of runoff areas to reflect onsite stormwater catch basin (CB) separation (e.g. to drywell infiltration) in portions of select CSO basins. CSO 33 flow control settings were decreased to create more available interceptor capacity. Runoff areas were reduced in residential areas of CSO basins 6, 7, 12, 14, 15, and 23 according to previous analyses described in recent technical memorandums cited in the background section. Reduction of about 50% of CSO Basin 41 runoff area for onsite stormwater separation (e.g. to drywell) was previously determined by City staff to be compliant with appropriate regulation and reasonable for planning purposes. The associated approximate construction costs were used in the comparison. Corresponding flow control settings were adjusted to effectively eliminate (i.e. < 5,000 gallons) the need for a storage facility at I04 (Monroe Street), CSO 7, CSO 14, CSO 15, CSO 23, and CSO 41. In this case, enough inflow was removed to allow the maximum flow to the interceptor from CSO 41 to be within the estimated available capacity of 2 mgd in the interceptor inlet, avoiding the necessity of its conveyance upgrade required by previous alternatives.

Alternative 4a Centralized Storage with I02 controlled to 120 mgd (variation of Alt. 2b)**.** Flow control settings were adjusted to reduce the number of required storage facilities in combination with controlling I02 peak flows to 120mgd. Large wet weather events in Spokane have resulted in interceptor I02 reaching or exceeding full pipe capacity. On one occasion the flows resulted in a washing out of part of the associate street section. Due to the potential for serious consequences of an interceptor system failure if I02 exceeds pipe capacity of 130 mgd, a safety factor for I02 conveyance was desired by City staff. As a result, a 10% safety factor for controlling flows in I02 to 120 mgd was applied. Also this alternative incorporated decreased flow control settings for CSO 33 and 34 to create available interceptor capacity and effectively eliminate (i.e. < 5,000 gallons) the need for a storage facility at I04 (Monroe Street), 7, 23, and 41, but only reduce required storage volume at CSO 15.

Alternative 4b Centralized Storage with I02 controlled to 120 mgd and Onsite Stormwater Separation (variation of Alt. 4a). Flow control settings were adjusted reduce the number of required storage facilities, control I02 peak flows to 120mgd, in combination with reduction of runoff areas to reflect onsite stormwater CB separation (e.g. to drywell infiltration) in portions of select CSO basins. CSO 33 and 34 flow control settings were decreased to create interceptor available interceptor capacity and effectively eliminate (i.e. < 5,000 gallons) the need for a storage facility at I04 (Monroe Street), 7, 14, 23, and 41, and almost eliminate the required storage volume at CSO 15 (just over 9,000 gallons required). As with Alternative 3, enough inflow was removed in CSO Basin 41 to allow the maximum flow to the interceptor to be within the estimated available capacity of 2 mgd in the interceptor inlet, avoiding the necessity of a conveyance upgrade.

Results

The results of the re-optimization alternatives are shown in the tables that follow. Table 2 lists the flow control settings, and Table 3 lists the resulting hydrograph based control volumes.
It can be noted that CSO 10, 39, and 40 had flow control settings that remained the same throughout these alternatives due to the fact that these facilities are constructed and have flow control settings that is already at practical minimum levels.

In order to provide an additional perspective for optimization at this stage of analysis, order of magnitude approximate construction costs were developed for a substantial portion of proposed facilities. This allowed a preliminary view of basic impacts from types of alternatives, such as removal of inflows, at a system wide level. To expedite results for comparison, only the costs for the storage facility, interceptor inlet, and stormwater separation costs were included. Conveyance costs associated with diverting flows to the storage, and from the storage facility to outfalls were not included. It is anticipated that a more comprehensive life cycle cost analysis will be completed during upcoming analyses at a basin level. Table 4 lists the substantially complete approximate construction costs.

Table 2. Flow Control Settings by Re-optimization Alternatives (mgd)

Basin I.D.	ALT. 1 Re-Eval. Scenario 3 Flow Control (mgd)	ALT. 2a Distributed Storage	ALT. 2b Centralized Storage based on CSO 33	ALT. 2c Centralized Storage based on CSO 33 and 34	ALT. 2d Centralized Storage (CSO 33 and 34) w/out Conveyance Upgrade	ALT. 3 Centralized Storage (CSO 33) with Onsite Stormwater Separation	ALT. 4a Centralized Storage with I02 controlled to 120 mgd	ALT. 4b Centralized Storage with I02 controlled to 120 mgd & Onsite Storm Separation
CSO 42	0.75	0.71	0.71	0.71	0.71	0.71	0.71	0.71
CSO 41	0.70	2.70	5.80	5.80	5.80	2.00	5.80	2.00
CSO 40	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
CSO 39	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
CSO 38	1.20	0.45	0.45	0.45	0.45	0.45	0.45	0.4
CSO 34	24.83	24.83	24.83	18.33	16.06	24.83	19.80	19.80
CSO 33-1	11.30	11.30	6.30	6.30	6.30	6.30	6.30	6.30
CSO 33-2	1.20	1.20	0.90	0.90	0.90	0.90	0.90	0.90
CSO 26	27.40	31.50	31.53	31.53	31.53	31.53	31.53	31.53
CSO 24/25	9.53	9.53	9.53	9.53	9.53	9.53	9.53	9.53
CSO 23-2	0.83	3.56	5.60	5.60	5.60	5.10	5.60	5.10
CSO 23-1	0.65	0.65	5.40	5.40	5.40	4.48	5.40	4.47
CSO 16	4.67	4.67	4.67	4.67	4.67	4.67	4.67	4.67
CSO 14	0.90	0.90	3.80	3.80	3.80	0.90	0.90	0.90
CSO 15	1.20	1.64	2.40	8.10	8.10	2.86	2.45	2.45
CSO 12	5.57	3.0	5.0	6.6	8.9	6.1	2.7	2.7
CSO 10	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
CSO 7	1.10	1.20	6.00	6.00	6.00	1.12	6.00	1.12
CSO 6	4.50	4.00	4.00	4.00	4.00	4.00	2.26	2.26
Unregulated Basins								
I04-1	0.97	0.97	3.20	3.20	3.20	3.20	3.20	3.20
I04-2		5.49	5.49	5.49	5.49	5.49	5.49	5.49
I03	13.70 13.70	13.70	13.70	13.70	13.70	13.70	11.40	11.40
I07	1.94	1.94	1.94	1.94	1.94	1.94	3.00	3.00

*Blue highlights indicate existing facilities.

Table 3. Hydrograph Based Control Volume by Re-optimization Alternative (gallons)

Basin I.D.	ALT. 1 Re-Eval. Scenario 3 Flow Control (gallon)	ALT. 2a Distributed Storage	ALT. 2b Centralized Storage based on CSO 33	ALT. 2c Centralized Storage based on CSO 33 and 34	ALT. 2d Centralized Storage (CSO 33 and 34) w/out Conveyance Upgrade	ALT. 3 Centralized Storage (CSO 33) with Onsite Stormwater Separation	ALT. 4a Centralized Storage with I02 controlled to 120 mgd	ALT. 4b Centralized Storage with I02 controlled to 120 mgd & Onsite Storm Separation
CSO 42	75,000	82,000	82,000	82,000	82,000	82,000	82,000	82,000
CSO 41	192,000	64,000	5,000	5,000	5,000	7,000	5,000	7,000
CSO 40	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
CSO 39	48,000	48,000	48,000	48,000	48,000	48,000	48,000	48,000
CSO 38	65,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
CSO 34	3,209,000	3,209,000	3,209,000	4,553,000	5,369,000	3,209,000	4,156,000	4,156,000
CSO 33-1	1,606,000	1,606,000	2,522,000	2,522,000	2,522,000	2,522,000	2,522,000	2,522,000
CSO 33-2	251,000	251,000	305,000	305,000	305,000	305,000	305,000	305,000
CSO 26	2,140,000	1,806,000	1,804,000	1,804,000	1,804,000	1,804,000	1,804,000	1,804,000
CSO 24/25	2,270,000	2,270,000	2,270,000	2,270,000	2,270,000	2,270,000	2,270,000	2,270,000
CSO 23-2	298,000	80,000	5,000	5,000	5,000	5,000	5,000	5,000
CSO 23-1	131,000	131,000	5,000	5,000	5,000	5,000	5,000	5,000
CSO 16	66,000	66,000	66,000	66,000	66,000	66,000	66,000	66,000
CSO 14	86,000	86,000	5,000	5,000	5,000	3,000	86,000	3,000
CSO 15	225,000	174,000	122,000	5,000	5,000	5,000	119,000	10,000
CSO 12	469,000	650,000	500,000	425,000	345,000	176,000	689,000	312,000
CSO 10	55,000	55,000	55,000	55,000	55,000	55,000	55,000	55,000
CSO 7	101,000	96,000	5,000	5,000	5,000	5,000	5,000	5,000
CSO 6	754,000	801,000	801,000	801,000	801,000	453,000	1,041,000	614,000
Subtotal (gal)	**12,091,000**	**11,645,000**	**11,979,000**	**13,131,000**	**13,867,000**	**11,190,000**	**13,433,000**	**12,439,000**
Unregulated Basin								
I04-1 (Monroe)	57,000	57,000	5,000	5,000	5,000	5,000	5,000	5,000
I04-2 (Wash.)	154,000	154,000	154,000	154,000	154,000	154,000	154,000	154,000
I03	309,000	309,000	309,000	309,000	309,000	309,000	612,000	612,000
I07	429,000	429,000	429,000	429,000	429,000	429,000	332,000	332,000
Subtotal (gal)	**949,000**	**949,000**	**897,000**	**897,000**	**897,000**	**897,000**	**1,103,000**	**1,103,000**
Basins TOTAL (gal)	13,040,000	12,594,000	12,876,000	14,028,000	14,764,000	12,087,000	14,536,000	13,542,000
RPWRF	**4,208,000**	**4,656,000**	**4,366,000**	**3,590,000**	**3,315,000**	**4,240,000**	**3,021,000**	**2,819,000**
Volume (gal) > 4 MG	**208,000**	**656,000**	**366,000**	**-**	**-**	**240,000**	**-**	**-**
Grand Total (gal)	**13,248,000**	**13,250,000**	**13,242,000**	**14,028,000**	**14,764,000**	**12,327,000**	**14,536,000**	**13,542,000**

(excludes existing 4 MG wet weather equalization capacity at RPWRF)

Table 4. Approximate Substantial Construction Cost (Order of Magnitude) by Re-optimization Alternative (CSO Basins)
(2012 $)

Basin I.D.	ALT. 1 Re-Eval. Scenario 3 Flow Control	ALT. 2a Distributed Storage	ALT. 2b Centralized Storage based on CSO 33	ALT. 2c Centralized Storage based on CSO 33 and 34	ALT. 2d Centralized Storage (CSO 33 and 34) w/out Conveyance Upgrade	ALT. 3 Centralized Storage (CSO 33) with Onsite Stormwater Separation	ALT. 4a Centralized Storage with I02 controlled to 120 mgd	ALT. 4b Centralized Storage with I02 controlled to 120 mgd & Onsite Storm Separation
CSO 42	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 41	$ 1,662,000	$ 1,717,000	$ 1,102,000	$ 1,102,000	$ 1,102,000	$ 535,000	$ 1,102,000	$ 535,000
CSO 40	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 39	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 38	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 34	$ 17,329,000	$ 17,329,000	$17,329,000	$ 21,725,000	$ 21,242,000	$ 17,329,000	$20,463,000	$ 20,463,000
CSO 33-1	$ 9,438,000	$ 9,438,000	$11,917,000	$ 11,917,000	$ 11,917,000	$ 11,917,000	$11,917,000	$ 11,917,000
CSO 33-2	$ 2,040,000	$ 2,040,000	$ 2,368,000	$ 2,368,000	$ 2,368,000	$ 2,368,000	$ 2,368,000	$ 2,368,000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 26	$ 10,510,000	$ 9,230,000	$ 9,223,000	$ 9,223,000	$ 9,223,000	$ 9,573,000	$ 9,573,000	$ 9,223,000
CSO 24/25	$ 10,993,000	$ 10,993,000	$10,993,000	$ 10,993,000	$ 10,993,000	$ 10,993,000	$10,993,000	$ 10,993,000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 23-2	$ 2,326,000	$ 971,000	$ 222,000	$ 222,000	$ 222,000	$ 1,072,000	$ 222,000	$ 1,070,000
CSO 23-1	$ 1,330,000	$ 1,330,000	$ 192,000	$ 192,000	$ 192,000	$ 192,000	$ 192,000	$ 192,000
CSO 16	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 14	$ 899,000	$ 899,000	$ 102,000	$ 102,000	$ 102,000	$ 1,326,000	$ 899,000	$ 1,326,000
CSO 15	$ 1,876,000	$ 1,541,000	$ 1,175,000	$ 202,000	$ 202,000	$ 1,702,000	$ 1,152,000	$ 1,767,000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 12	$ 3,491,000	$ 4,224,000	$ 3,656,000	$ 3,252,000	$ 2,802,000	$ 6,105,000	$ 4,416,000	$ 6,760,000
CSO 10	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
CSO 7	$ 1,017,000	$ 978,000	$ 202,000	$ 202,000	$ 202,000	$ 2,652,000	$ 202,000	$ 2,652,000
CSO 6	$ 4,732,000	$ 4,956,000	$ 4,956,000	$ 4,956,000	$ 4,956,000	$ 6,606,000	$ 6,056,000	$ 7,445,000
CSO Basin Subtotal	**$ 67,643,000**	**$ 65,646,000**	**$ 63,437,000**	**$ 66,456,000**	**$ 65,523,000**	**$ 72,370,000**	**$ 69,555,000**	**$76,711,000**

Table 5. Approximate Substantial Construction Cost by Re-optimization Alternative (Unregulated Areas) For Comparison
(2012$)

Basin I.D.	ALT. 1 Re-Eval. Scenario 3 Flow Control	ALT. 2a Distributed Storage	ALT. 2b Centralized Storage based on CSO 33	ALT. 2c Centralized Storage based on CSO 33 and 34	ALT. 2d Centralized Storage (CSO 33 and 34) w/out Conveyance Upgrade	ALT. 3 Centralized Storage (CSO 33) with Onsite Stormwater Separation	ALT. 4a Centralized Storage with I02 controlled to 120 mgd	ALT. 4b Centralized Storage with I02 controlled to 120 mgd & Onsite Storm Separation
I04-1 (monroe)	$ 656,000	$ 656,000	$ 102,000	$ 102,000	$ 102,000	$ 102,000	$ 102,000	$ 102,000
I04-2 (Wash.)	$ 1,404,000	$ 1,404,000	$ 1,404,000	$ 1,404,000	$ 1,404,000	$ 1,404,000	$ 1,404,000	$ 1,404,000
I03	$ 2,391,000	$ 2,391,000	$ 2,391,000	$ 2,391,000	$ 2,391,000	$ 2,391,000	$ 4,034,000	$ 4,034,000
I07	$ 3,074,000	$ 3,074,000	$ 3,074,000	$ 3,074,000	$ 3,074,000	$ 3,074,000	$ 2,526,000	$ 2,526,000
Unreg.Subtotal	**$ 7,525,000**	**$ 7,525,000**	**$ 6,971,000**	**$ 6,971,000**	**$ 6,971,000**	**$ 6,971,000**	**$ 8,066,000**	**$ 8,066,000**
Grand Total	$ 75,168,000	$ 73,171,000	$ 70,408,000	$ 73,427,000	$ 72,494,000	$ 79,341,000	$77,621,000	$84,777,000

Summary & Conclusions

CSO basin flow control modifications reflecting the 8 proposed alternatives were evaluated for each of the collection system basins based on various model simulations. Required storage volumes were calculated to determine impacts from proposed improvements on both CSO and unregulated basins. Rough approximations for construction costs were estimated for the substantial portions of alternatives to give an indication of overall system impact compared to storage volume requirements. These results are summarized in Figure 1.

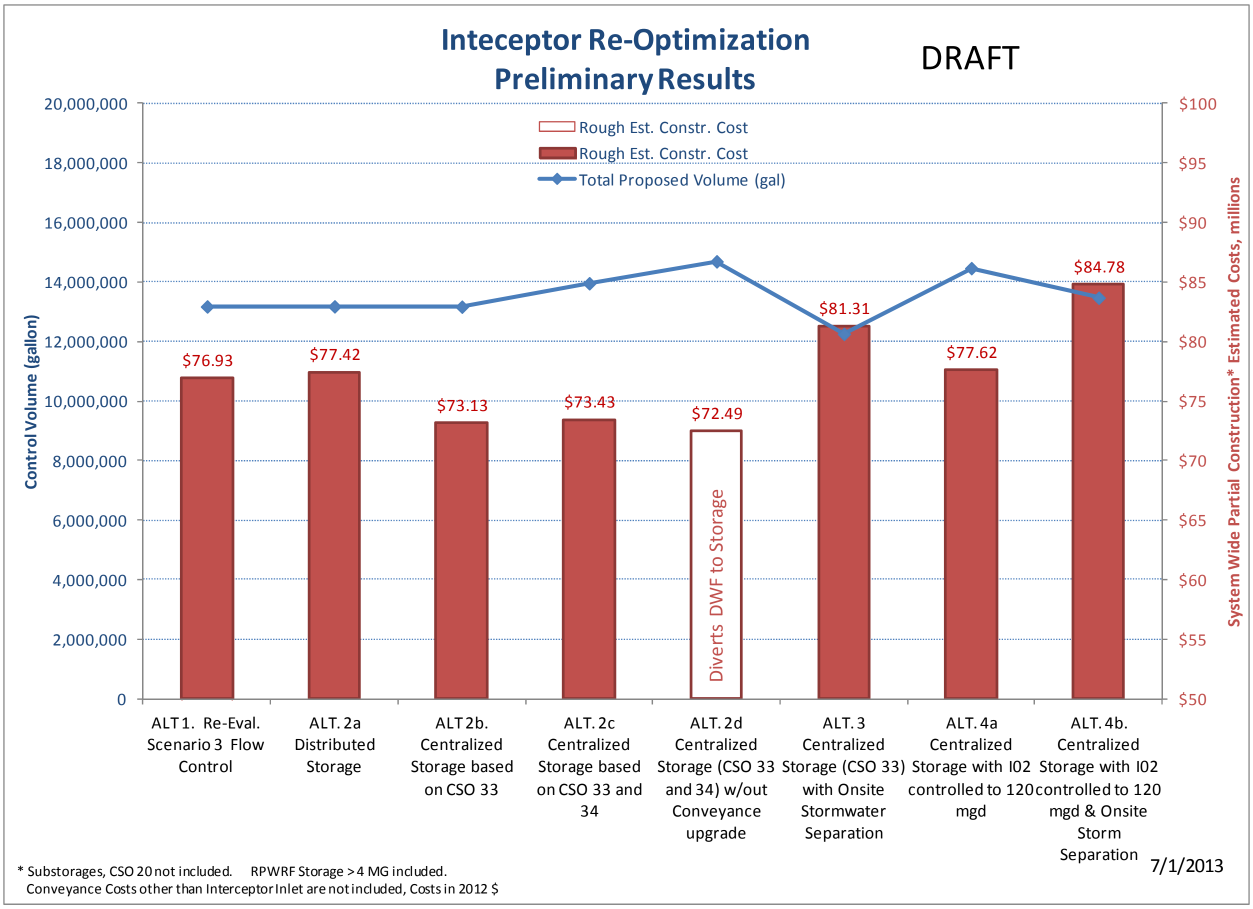


Figure 1. Summary of Alternative Storage Volume and Approximate Construction Cost

Alternative 2a required about 0.5 MG less storage than Alternative 1 for basins, but required slightly higher in total system volume including equalization at RPWRF, and has $2 million less construction cost. Alternative2b has somewhat more volume required for basins, but is slightly lower in required storage including RPWRF, and has $3 million less construction cost than Alternative2a.

Alternatives 2c and 2d are variations of Alternative2b, with increasingly more volume required for the basins and including RPWRF. Both 2c and 2d have higher construction cost than 2b. Alternative 2d was considered to have a fatal flaw in that it resulted in diversion of dry weather flows into the storage facility.

Alternative 3 reviews the sensitivity of Alternative2b of the trunk and interceptor system to removal of inflow with stormwater separation (e.g. to dry wells), and noticeably reduces overall required storage volume by almost 1 MG to 12.3 MG. However, Alternative3 results in $8 million in additional construction cost compared to Alternative2b.

Alternative 4a and 4b are variations on Alternative2b and 3, respectively, and provide a 10% safety factor for peak flows in Interceptor Segment I02. Alternative4a results in 1.2 MG of additional storage, and over $7 million in additional construction cost. Alternative4b resulted in only 0.3 MG of additional storage, but over $14 million in additional construction cost.

Other Observations

For previous analyses for CSO 6, 7, 12, 14, 15, and 23, onsite separation (e.g. CB reroute to drywell) in residential areas has been shown to be mostly cost effective when compared on the previous CSO Design Event (which included snowmelt). However, for this analysis, onsite stormwater separation seems to increase the total construction costs required for a specific basin. One key difference to remember is that for onsite separation, inflows are diverted from the CSS in entirety, not just for a given design storm. In addition, onsite separation reduces wet weather flows to the interceptor and volume transferred to the water reclamation facility for treatment.

The main capacity limiting sections of the main interceptor segments were found in I02 at or near both CSO 10 and 12 (pipes near MH 02038 and 02031). These three pipes in some combination continually were the limiting full pipe capacity sections in all alternatives, regardless of the flow control settings or onsite separation. The flow control settings of each alternative were imported into the model and the resulting available capacity of interceptor system was displayed in the HGL profiles provided in the Appendix.

Selected Alternatives for Additional Analysis

Based on the analysis and in collaboration with City and core technical team staff, it was decided to move forward with two alternatives:

- **Alternative 2b Centralized Storage based on CSO 33**.
- **Alternative 4b Centralized Storage with I02 controlled to 120 mgd and Onsite Stormwater Separation**

These two alternatives are summarized in Table 6.

Further discussion with the City and core technical team staff determined that Alterative 4a is the preferred alternative for a higher level of protection to the interceptor, and a baseline for comparing basin-level alternatives. A comparison of Alternative 2b, 4b, and 4a is presented in Table 6.

Table 7 provides a revised set of baseline storage numbers, based on simulation of subsidiary storage and higher design storm frequency, for acceptable risk of exceedance on selected facilities. The selected facilities for higher risk generally don't have relief outfalls. Additional Information about Alternative 4a can be found in the appendix.

Table 6. Summary of Preferred Re-Optimization Alternatives

Basin I.D.	**ALT. 2b** Centralized Storage based on CSO 33		**ALT. 4b** Centralized Storage with I02 controlled to 120 mgd & Onsite Storm Separation		Initial Basis for Alt. Analysis **ALT. 4a** Centralized Storage with I02 controlled to 120 mgd	
	Flow Control (mgd)	Required Volume (gallons)	Flow Control (mgd)	Required Volume (gallons)	Flow Control (mgd)	Required Volume (gallons)
CSO 42	0.71	82,000	0.71	82,000	0.71	82,000
CSO 41	5.8	5,000	2	7,000	5.8	5,000
CSO 40	0.35	50,000	0.35	50,000	0.35	50,000
CSO 39	0.35	48,000	0.35	48,000	0.35	48,000
CSO 38	0.45	120,000	0.45	120,000	0.4	120,000
CSO 34	24.83	3,209,000	19.8	4,156,000	19.8	4,156,000
CSO 33-1	6.3	2,522,000	6.3	2,522,000	6.3	2,522,000
CSO 33-2	0.9	305,000	0.9	305,000	0.9	305,000
CSO 26	31.53	1,804,000	31.53	1,804,000	31.53	1,804,000
CSO 24/25	9.53	2,270,000	9.53	2,270,000	9.53	2,270,000
CSO 23-2	5.6	5,000	5.1	5,000	5.6	5,000
CSO 23-1	5.4	5,000	4.47	5,000	5.4	5,000
CSO 16	4.67	66,000	4.67	66,000	4.67	66,000
CSO 14	3.8	5,000	0.9	3,000	0.9	86,000
CSO 15	2.4	122,000	2.45	10,000	2.45	119,000
CSO 12	5	500,000	2.7	312,000	2.7	689,000
CSO 10	0.39	55,000	0.39	55,000	0.39	55,000
CSO 7	6	5,000	1.12	5,000	6	5,000
CSO 6	4	801,000	2.26	614,000	2.26	1,041,000
I04-1	3.2	5,000	3.2	5,000	3.2	5,000
I04-2 (Wash.)	5.49	154,000	5.49	154,000	5.49	154,000
I03	13.7	309,000	11.4	612,000	11.4	612,000
I07	1.94	429,000	3	332,000	3	332,000
Basins TOTAL (gal)		**12,876,000**		**13,542,000**		**14,536,000**
RPWRF Untreated CSO Volume > 4MG (gallon)		**366,000**		**0**		**0**
Grand Total (gal)		**13,242,000**		**13,542,000**		**14,536,000**

*Volumes calculated from hydrograph in Excel.

** Based on 100 mgd treatment capacity and 4 MG of existing storage capacity for excess wet weather flows.

Table 7. Summary of Revised Alt 4a Baseline Storage Volumes

		No sub-storages		With Sub-storages		
Basin I.D.	**Design Storm Event Frequency**	**ALT. 4a** Centralized Storage with I02 controlled to 120 mgd		**Design Storm Event Frequency**	**BASELINE ALT. 4a** Centralized Storage with I02 controlled to 120 mgd Including Sub-storages Modeled	
	Year	Flow Control (mgd)	Req'd Volume (gallons)	Year	Flow Control (mgd)	Req'd Volume (gallons)
CSO 42 (0.110 MG)	1.2	0.71	82,000	1.2	0.71	82,000
CSO 41	1.2	5.8	5,000	1.2	5.8	5,000
CSO 40 (sub. So. Riverton & Regal)	1.2	0.35	50,000	1.2	0.35	50,000
CSO 39 (sub. So. Riverton & Altamont)	1.2	0.35	48,000	1.2	0.35	48,000
CSO 38	1.2	0.4	120,000	1.2	0.4	120,000
CSO 34-1 (primary Lee & Riverside)	1.2	19.8	4,156,00	1.2	19.8	3,913,000*
CSO 34-1 with I07d (26 acres)			*4,283,000*[+]	1.2	19.8	*2,276,000*[+]
CSO 34-2 (sub. Hartson & Regal)				1.2	6.16	883,000
CSO 34-3 (sub. 20th & Ray)				1.2	4.79	1,134,000
CSO 33-1 (primary 2nd & Perry)	1.2	6.3	2,264,000	1.2	6.3	2,264,000
CSO 33-2 (primary Sprague & Hatch/Sprague Way)	1.2	0.9	285,000	1.2	0.9	285,000
CSO 26 (prim. Main & Cedar)	1.2	31.53	1,839,100	1.2	31.53	2,023,000
CSO 24-1 (w/25)	1.2	9.53	2,270,000	1.2	9.53	2,000,000*
CSO 24-3 (sub. High&Browne)				10.0	2.97	22,000
CSO 24-4 (sub. High&Lamonte)				10.0	0.45	14,000
CSO 24-5 (sub. High&Sherman)				10.0	3.04	42,000[++]
CSO 24-6 (sub. High&Hatch)				10.0	4.33	157,000
CSO 20 (prim. 43rd & Garfield)				10**	8.02	206,000
CSO 23-2	1.2	5.6	8,000	1.2	5.6	8,000*
CSO 23-1	1.2	5.4	1,000	1.2	5.4	1,000*
CSO 16 (0.198 MG)	1.2	4.67	66,000	1.2	4.67	66,000
CSO 14	1.2	0.9	85,000	1.2	0.9	85,000*
CSO 15	1.2	2.45	115,000	1.2	2.45	115,000*
CSO 12	1.2	2.7	689,000	1.2	2.7	689,000
CSO 10 (0.140MG)	1.2	0.39	55,000	1.2	0.39	55,000
CSO 7	1.2	6	5,000	1.2	6	5,000
CSO 6	1.2	2.26	1,041,000	1.2	2.26	1,041,000
I04-1 (sub. Monroe)	1.2	3.2	5,000	10**	3.2	145,000
I04-2 (sub. Wash.)	1.2	5.49	154,000	10**	5.49	1,220,000
I03-1 (sub. NW Blvd. & T.J. Meenach)	1.2	11.4	612,000	10**	11.4	1,840,000*
103-2 (sub. Division)				10**	1.74	75,000
103-3 (sub. Hogan)				10**	5.17	230,000
103-4 (sub. Regal)				10**	3.55	95,000
I07 (Unreg. Helena)	1.2	3	332,000[+]	10**	3	508,000
Grand Total (gal)			**14,414,100**			**17,747,000**
			To Be Constructed:			17,326,000

*Volumes calculated from CSO Basin pre-design model with substorage facilities included, 2030 growth conditions.

+ I07d included for 34-1. (Stored volume is about 127,000 gallons for setting at peak dry weather flow + 10%).

** Unregulated Areas of I04, I03,and I07 have a volume determined using a 10 year City stds. storm. All other CSO basins have their volume determined via a 1.2-year Beta 2009 storm.

++ Subsequent analysis determined separation to onsite infiltration (e.g. drywell) was more cost effective; storage volume was not included in total.

Appendix:

- Re-optimization Assumptions Memorandum
- Alternative 2b Profiles
- Alternative 4a Additional Information & Alternative 4a Profiles
- Alternative 4b Profiles

Appendix: Interceptor Re-Optimization 2013 Modeling Assumptions Memo

AECOM
140 S. Arthur Street, Suite 500, Spokane, Washington 99202-2260
T 509-535-5454 F 509-535-5725 www.aecom.com

AECOM

MEMORANDUM

TO:	Marcia Davis, PE cc: P.M. Taylor, PE, L. Hendron, PE, G. Shrope, PE
FROM:	Duane Studer, PE
DATE:	5-14-13
SUBJECT:	**Interceptor Modeling Assumptions - System Wide Analysis Re-optimization**

The 2012 System Wide re-evaluation analysis was a refinement of the System Wide Report (2005) proposed Alternative 2a Subsequently, it is desired to reconsider allocations for external flow loads and determine the impact of the 2011 NPDES requirements for 20-year averaging CSO compliance period. This will require 1) conduct of wet weather simulations to determine the impact to the interceptor system and 2) redistribute interceptor inlet flows to match interceptor capacity as needed. To provide an initial comparative analysis, Scenario 3, designated as preferred from the System Wide Re-evaluation Memo (5-9-12), will be used.

Listed below are the parameters and assumptions to be used in the collection and interceptor system model for this simulation.

1. Base Wastewater Flow:

Base Wastewater Flow as defined in the City's Wastewater Facility Plan is based on 2030 projected sanitary flows, which are assumed same as previously estimated 2020 Growth Management Act flows, configured to vary diurnally on both an hourly and weekly basis. Actual flow monitoring data was used to calibrate modeled BWF where available.

External flows (outside the City's Service Area) are set at their external limits generally based upon negotiated connection/service agreements. A summary of these external wastewater flows are presented in Table 1.

Table 1. ***Summary of External Interceptor Base Wastewater Flow (BWF)***

Source	System Wide (2005) Report		System Wide Re-Evaluation 2012	***System Wide Re-Optimization 2013***	
	Base Condition[3]		All Conditions	**Base Condition**	**Alternate Condition**
	Average (mgd)	*Peak (mgd)*	*Average & Peak (mgd)*	***Average & Peak (mgd)***	***Average & Peak (mgd)***
NSI [1]	*4.7*	*7.0*	*0*	***10***	***8***
NVI [1]	*0*	*0*	*0*	***0***	***0***
SVI [1]	*5.3*	*8.9*	*10*	***0***	***2***
Airway Heights [2]	*0.7*	*1.0*	*0.7*	***0***	***0.7***
Fairchild AFB [2]	*0.9*	*1.0*	*1.0*	***1.0***	***1.0***

Notes:
(1) Flow rates are based on Spokane County Wastewater Facilities Plan Basis of Planning Report, Dec. 2000.The flow rates vary diurnally in Scenario 6.
(2) Flow rates are based on Airway Heights agreement maximum of 0.68 mgd and meter records for Airway Heights (0.39 mgd annual average for 2001) and Fairchild Air Force Base (0.64 mgd annual average for 2001).

C:\WorkSpace\6028xxxx IP & Interc\400 Tech\406 Civil\Analysis_Re-Opt\Interceptor Re-optimization 2013 modeling assumptions memo 051413.doc

Spokane County Wastewater Facilities Plan (Final, December 2002) shows NSI to have 4.9 mgd (annual average, with a peak hour of 10.0 mgd) under all 2020 scenarios (4.7 mgd was considered reasonable for 2020).
(3) Any flow rates from NVI or SVI that exceed the contractual flow rates to the interceptor system are assumed to be diverted to the Spokane County Wastewater Treatment Plant and not included in the flow loads to the City's interceptor system in any model simulation or analysis.

2. Groundwater Infiltration:

City: (1) (2)	1.5*calibrated Volume I/I Projects Complete *(WW Facilities Plan, Table 3-15)*
County: (3)	BWF+10%

(1) 1.5 safety factor on calibrated rates for wet season conditions. Calibration flow monitor period: April 2001 to August 2002.
(2) River influence is not included.
(3) The following ground water infiltration (GWI) conditions apply to the collection system for the various dry weather flow simulations:
  i. Seasonal GWI in areas served by the County that are conveyed to the City's interceptor sewer system is included within a 10% adjustment over BWF for those areas (from System Wide Report 2005).
  ii. GWI in areas served by the Airway Heights is not considered to exist or be significant due to the relatively young age of their collection system.
  iii. GWI in areas served by the Fairchild Air Force Base are expected to be eliminated by the CSO compliance date (2017).

3. Rain Dependent Flow (CSO Design Event and Wet Weather Design Event):

a. A CSO Design Event rainfall is applied to the CSO basins and consists of a system wide synthetic NRCS Type II storm; 1.2-year return frequency of 24 hour duration.

   The unregulated areas tributary to Interceptor Segment I03, Interceptor Segment I04, Interceptor Segment I07 and the Post Street Bypass sewer are to utilize a 1.2-year return frequency of 24 hour duration. The Wet Weather Design Event (5yr 24hr design storm with NRCS Type II distribution including 0.5yr snowmelt) as defined in Unregulated Area Wet Weather Design Event Memo (CTE, 2005) will not be used for this analysis.

   - Depth of rain for each design event is spatially adjusted with predetermined beta factors, applied system-wide, based on City of Spokane rain gauges and is defined in Precipitation and Snowmelt Analysis and Design Event Development for CSO Draft (2009).
   - Snowmelt will not be included in the design events.

b. Safety factors on storage volumes will not be included; to be assigned later.
c. The design storm peak is arbitrarily timed to occur at 12:00 noon, January 1st.
d. Calibration flow monitor period varies (2001 - 2011) from CSO basin models.
e. For runoff areas; infiltration parameter initial moisture content was set at 0.1 wet antecedent moisture conditions
f. For runoff areas; minimal evaporation simulated for January 1st (above freezing temperature conditions).
g. Rain Dependent Inflow & Infiltration (RD I&I) in sanitary basins are to be as calibrated in 2005/2006.
h. County flows include seasonal RD I&I and are incorporated into the flow rates in Table 1. No other areas served by other agencies that are conveyed to City's interceptor sewer system are assumed to have RD I&I.

4. Interceptor system attributes:

a. CSO Regulators and proposed Unregulated Area flow controls are set to 'flat line' performance at existing threshold or at set points determined by the System

C:\WorkSpace\6028xxxx IP & Interc\400 Tech\406 Civil\Analysis_Re-Opt\Interceptor Re-optimization 2013 modeling assumptions memo 051413.doc

2

Wide Report (2005) or the most recent preliminary design. Flat line performance means that flows to the interceptor do not increase above designated maximums with increasing upstream head.

b. Selected pump stations are being simulated dynamically including on/off pumping based on wet well volumes. These are Clark Street, San Souci, Elm Street, Northwest Terrace, Marion Hay (Spokane County), and Francis & Cannon. Other pump stations are located in separated areas or in the upper portions of the collection system and were modeled as part of the flow load based on the overall land area in which the pump station is located.

c. Inverted Siphons (except for CSO 23) are not simulated (to economize computer run time). Velocities in equivalent pipes are checked each simulation to not exceed maximum 10 ft/sec.

d. Full flow pipe conditions are used to determine capacity for simulation results comparisons (100.4% full has been shown to convey flows in model without surcharge). Peak design flow for new interceptor segments are to be limited to 7/10 flow depth divided by pipe diameter.

e. Flow capacities are determined using Manning's roughness factor 'n' set at a constant 0.013 (except for a corrugated section between manhole 2001224CD and the old CSO 2 regulator). Corrugated pipe sections use n = 0.029. A variable n factor is used for partially full pipes.

f. No sedimentation or blockages in any pipes is assumed.

g. No upgrade to Marion Hay pump station is assumed for 2020. Clark Avenue pump station for 2020 is assumed to have 15.5 mgd capacity.

h. The interceptor (I01 and I02) has a peak conveyance capacity at the headworks of the treatment plant of 130 mgd. The treatment plant peak flow rate which can provide full treatment is restricted to 100 mgd. Flow rates in excess of 100 mgd are diverted to detention storage for subsequent full treatment or at least wet weather treatment before discharge to the Spokane River.

5. Assumptions for conducting simulations for all models:

1) One 2020 system wide model is used:
   a. 2020 Model for generating hydrographs for selecting optimized flow control settings.
2) (possibly use later, after this analysis) Sub-storages and storages upstream of regulators which do not have a direct impact on the interceptor are not included. Storages which have direct impact on the interceptor are represented only. This in effect disregards CSO Basins 14, 16, 19, 20, 22, 24-2, 24-3, 24-4, 24-5 , 34-2, 34-3 , and I03-2 storage facilities).
3) Regulator modifications were not directly simulated, however, flow control settings as constructed were used for initial 2020 model simulations.
4) Upriver-Havana growth area flows near CSO Basin 41 are updated per Wastewater Management staff projections for the 2020 model simulations (City Wastewater Management (Yake), April 2010) .
5) Effects of stormwater separations to drywells (6, 7, 12, 14/15 & 23) were not represented in the 2020 models. (to be considered as Integrated Planning alternative)
6) Emphasis is placed on storage facilities to drain within 24 hours after the storm event.

6. Assumptions for conducting simulations for 2020 Model only:

1) I03, I04, and I06 (Post St.) wet weather flow controls were not simulated to initially optimize regulator settings. Due to the influence of local surcharging, I07 Unregulated Area flow control was simulated in this case to more closely represent conditions associated with a storage facility (that would provide hydraulic relief)

2) Because of availability of record drawings during model development, detailed representation of storage facilities for CSO 10, 16, and 42 are not simulated. However, flow control settings as implemented for the facilities are used for initial 2020 Model simulations. CSO Basins 2 & 3c Facilities are simulated based on record drawings.

Attachments: Calibration Tech Memo: Table 2-1, Wastewater Facilities Plan: 3-14, 3-15, and System Wide Report information summary Table 1 & 2.

Interceptor Modeling Assumptions Memorandum Attachments

Combined Sewer System Model Parameters and Calibration (2003)

Table 2 – 1: Population Density and Wastewater Unit Flow Factors

Wastewater Facilities Plan Land Use	GIS Land Use	Population Density (persons/acre)	Wastewater Unit Flow Factor (gpd/acre)	Per Capita Flow (gpd/person)
	Rural, Agricultural	--	0	--
Suburban	Suburban	1.36	100	73
Low Density Residential	Not used	6.43	500	78
Med. Density Residential	Low Density Residential	9.00	690	77
High Density Residential	Higher Density Residential, Schools	22.50	1,750	78
Commercial	Commercial, Public, Semi-Public	--	800	--
Industrial	Industrial	--	400	--

Interceptor Modeling Assumptions Memorandum Attachments

City of Spokane Wastewater Facilities Plan (1999)

Table 3-14 Infiltration & Inflow Summary

Number	Location	MH #	Area (Acre)	Measured Flow (MGD)	Estimated GWI Flow (MGD)	Metered GWI Flow In gpd/acre
1	Geiger Sewer	45078	276	0 07	0 06	217
2	Thorpe/I90	08115	32	0 06	0 05	1,563
	Subtotal		308	0 13	0 11	357
3A	Stevens/Second	54027	199	1 50	1 20	6,030
3B	Stevens/Sprague	54021	266	1.70	1 36	5,113
3C	Stevens/Main/Riverside	N/A	429	2.00	1 60	3,730
3D	Main/Post/Wall	54014	429	2 50	2 00	4,662
	Subtotal		1,323	7 7	6.16	4,656
4	Division/Sprague	54256	163	0 06	0.05	307
5	Browne/4th	54283	68	0 60	0.48	7,059
6	Riverside/Lincoln	54206	59	0 41	0 33	5,593
7	Rockwood/Pittsburg	64321	70	0.13	0 10	1,429
8	Maple/7th	55035	92	0.03	0 02	217
9	Liberty Park	N/A	N/A	0.18	0.18	N/A
10	Spokane Falls/Wall	54227	N/A	0 40	0 40	N/A
	Total		2,083	9 64	7 83	

Notes

1 I&I locations 1 and 2 are located at two separate areas near the airport.

2 I&I locations 3A-D are cumulative.

3 Locations 4-10 are located at isolated areas within the service area.

Interceptor Modeling Assumptions Memorandum Attachments

Table 3-15 1990 Infiltration & Inflow Summary Recommendations

Item	Location	Suspected Deficiency Description (Quantity)	Recommended Remedial Action (and Status)
1	Spokane International Airport Interceptor near I-90 and Thorpe Road	Older pipe along W Thorpe, poor pipe joints, (< 1000 gpd/acre)	Repair as necessary
2	Central Business District, Stevens between Sprague and Main	Unused service connections, basement sumps along Stevens (0 7 mgd)	Locate and block unused service connections, intercept sumps with alternative collector (in progress)
3	Central Business District, Fourth and Brown	Poor service connections and older VC pipe near Sacred Heart (0.48 mgd)	Repair old service connections and replace or inversion line pipe
4	Central Business District, Riverside and Lincoln	Older VC pipe near Deaconess, apartments (3 - 4 mgd)	Repair old service connections and replace or inversion line pipe (has reduced GWI by ~ 1 mgd)
5	Liberty Park	Spring water inflow to collection system (0.2 mgd)	Re-route flow to parallel storm sewer ending at Second & Perry CSO chamber
6	Spokane Falls Boulevard and Wall	River-influenced groundwater in Riverfront Park (0 4mgd)	Block flow from park by sealing pipe at Spokane Falls and Wall manhole (completed)
7	Elm Street lift station	Possible River inflow (up to 0.7 mgd)	Re-arrange pump station's emergency by-pass (completed)
8	Front & Erie	Broken 24-in. RCP allowing river inflow (0 5 to 1 0 mgd)	Remove pipe and block manhole (completed)
9	Cowley Creek	Spring water inflow to collection system (0.2 mgd)	Repair as necessary.

Note. VC is vitrified clay

C:\WorkSpace\6028xxxx IP & Interc\400 Tech\406 Civil\Analysis_Re-Opt\Interceptor Re-optimization 2013 modeling assumptions memo 051413.doc

7

Interceptor Modeling Assumptions Memorandum Attachments

System Wide Report (2005):

Table 1. Interceptor Modeling: Groundwater Infiltration (GWI)

Load Point I.D.	GWI from Figure 3-11, Facilities Plan		GWI from Table 3-14, Facilities Plan		Calibrated GWI x 1.5		2001 Selected GWI (shaded)	GWI Removed (see Table 2)	2020 GWI (Selected-Removed)
	Flow (mgd)	Acres	Flow (mgd)	Acres	Flow (mgd)	Acres	Flow (mgd)	Flow (mgd)	Flow (mgd)
CSO 02	0.007	74			0.016	81	0.016		0.016
CSO 03B	0.004	28			0.000	28	0.000		0.000
CSO 03C	0.003	18			0.000	18	0.000		0.000
CSO 06	0.085	675			0.000	675	0.000		0.000
CSO 07	0.023	218			0.000	218	0.000		0.000
CSO 10	0.007	71			0.000	71	0.000		0.000
CSO 12	0.186	391			0.000	395	0.000		0.000
CSO 14	0.019	103			0.000	122	0.000		0.000
CSO 15	0.027	138			0.000	140	0.000		0.000
CSO 16A	0.039	73	0.06		0.101	162	0.101		0.101
CSO 16B	0.209	417			0.422	768	0.422		0.422
CSO 18	0.042	96			0.000	121	0.000		0.000
CSO 19	0.024	121			0.000	121	0.000		0.000
CSO 20	0.166	178			0.059	182	0.059		0.059
CSO 22B	0.163	90			0.000	25	0.000		0.000
CSO 23	0.088	179			0.000	179	0.000		0.000
CSO 24A	1.993	2240	0.02		2.171	2,393	2.171		2.171
CSO 24B	0.068	58			0.132	132	0.132		0.132
CSO 25	0.020	11			0.000	19	0.000		0.000
CSO 26[(1)]	2.775	616	2.86		4.981	626	4.981	2.380	2.601
CSO 33A	0.022	59			0.048	59	0.048		0.048
CSO 33B	0.424	1226	0.28		2.364	1,227	2.364	0.230	2.134
CSO 33C	0.002	19			0.000	19	0.000		0.000
CSO 33D	0.114	67			0.310	68	0.310		0.310
CSO 34	1.903	4307			1.628	6,061	1.628		1.628
CSO 38	0.027	58			0.000	75	0.000		0.000
CSO 39	0.020	43			0.000	48	0.000		0.000
CSO 40	0.021	47			0.000	55	0.000		0.000
CSO 41	0.051	101			0.000	102	0.000		0.000
CSO 42	0.000	0			0.000	110	0.000		0.000
I01	1.156	2845			0.412	4,202	0.412		0.412
I02	0.054	298			0.000	441	0.000		0.000
I03	2.574	7207			0.260	7,911	0.260		0.260
I04	0.404	870			0.359	869	0.359		0.359
I05 Lower	0.377	364	0.4	completed	0.000	459	0.000		0.000
I05 Upper	0.639	1353			0.042	1,855	0.042		0.042
I07	0.054	108			0.630	108	0.630		0.630
I08	0.030	103	0.05		0.000	752	0.05	0.05	0
Total (MGD)	13.823		3.67		13.932		13.982		11.322

(1) Includes I06 GWI flows.

C:\WorkSpace\6028xxxx IP & Interc\400 Tech\406 Civil\Analysis_Re-Opt\Interceptor Re-optimization 2013 modeling assumptions memo 051413.doc

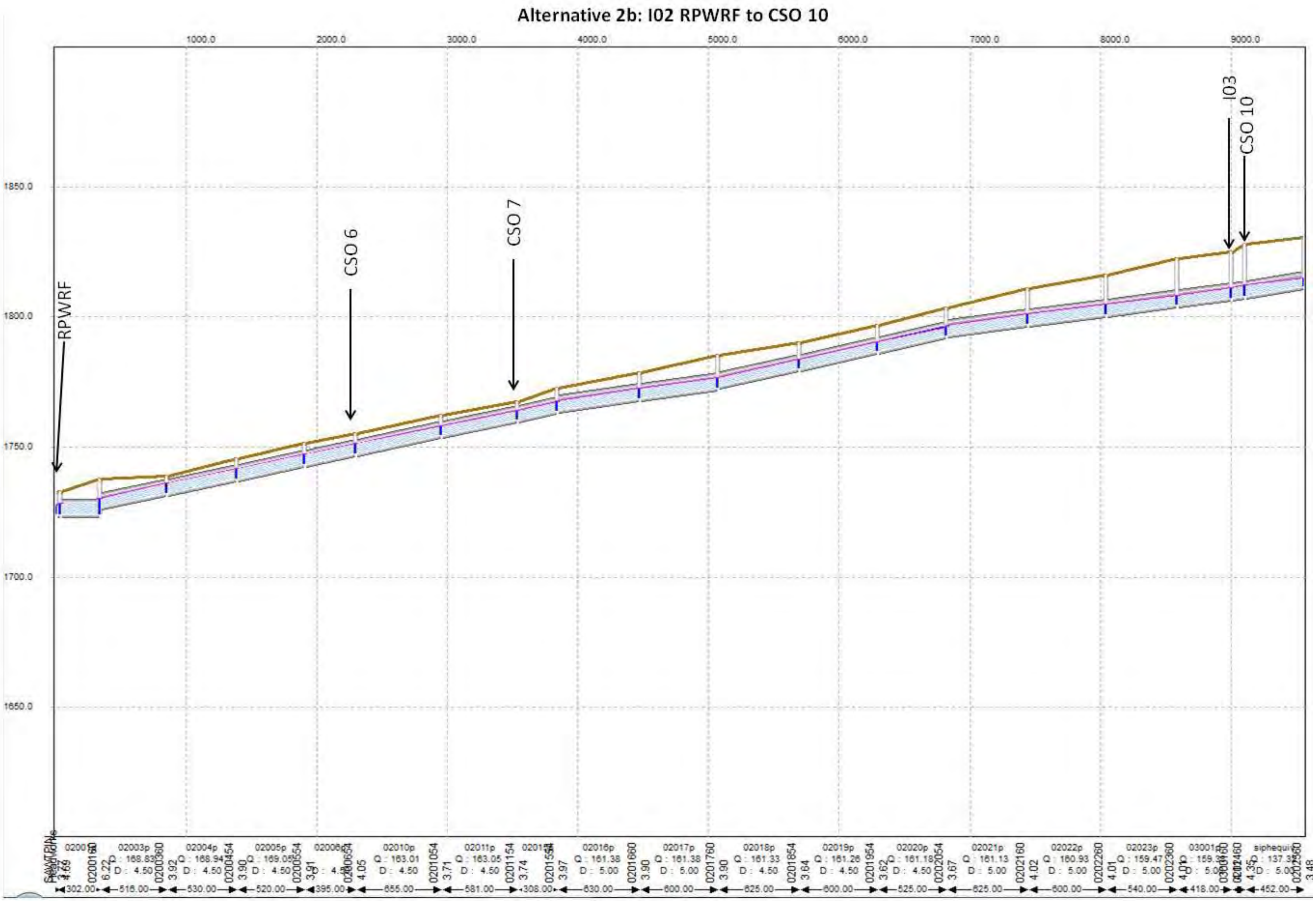
8

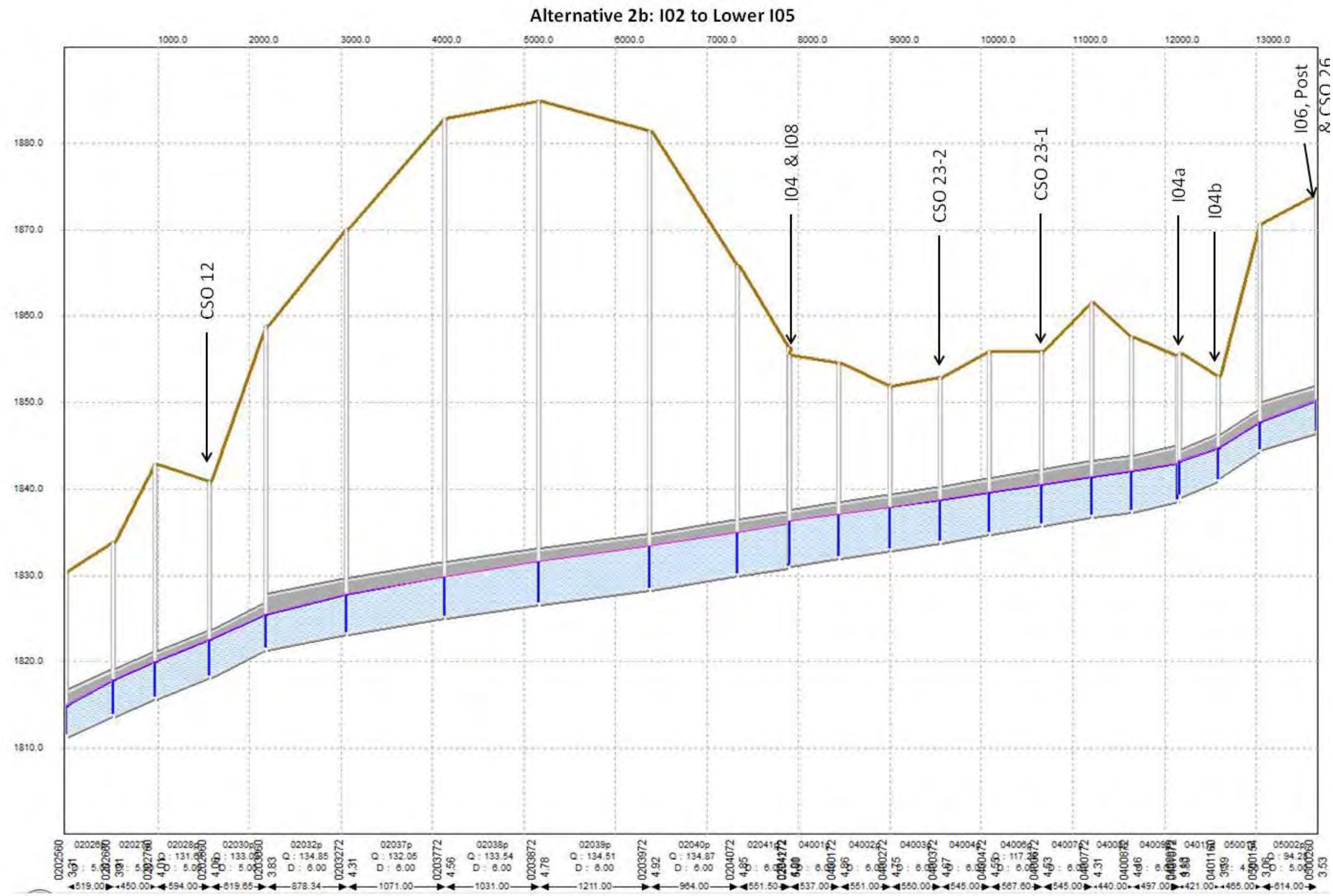
Interceptor Modeling Assumptions Memorandum Attachments

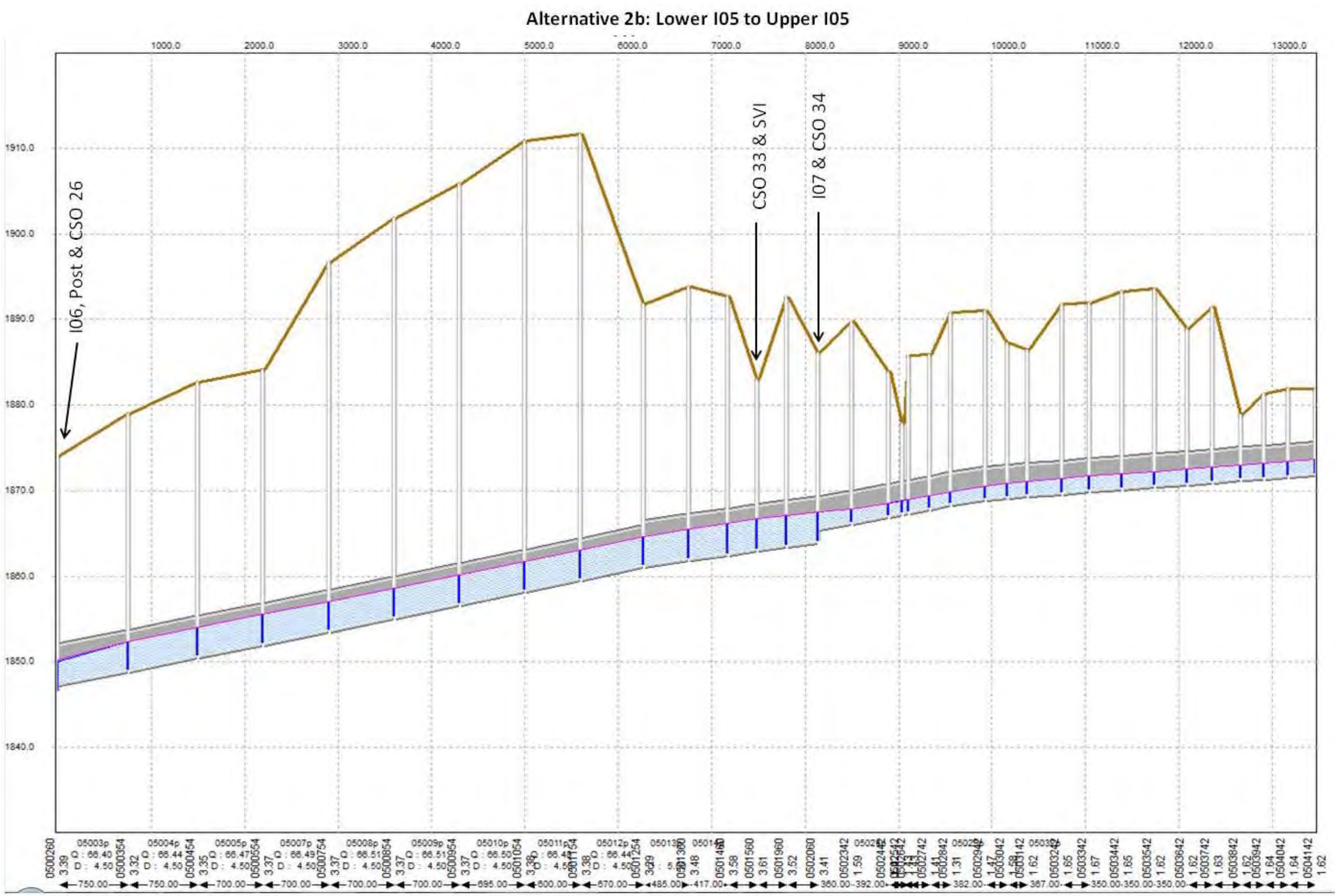
Table 2. Interceptor Modeling: GWI to be removed for 2020 Scenario

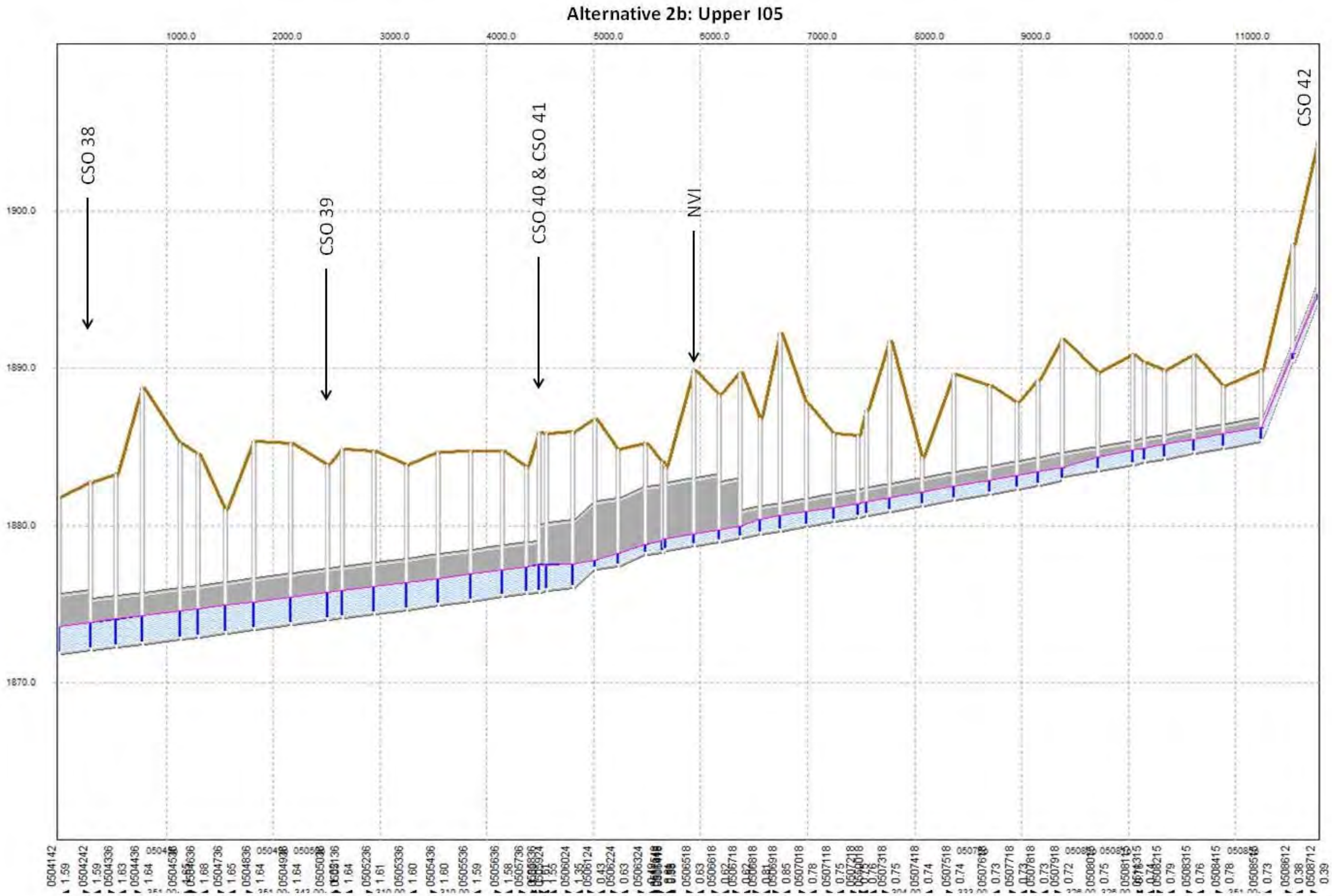
Item	Location (from Table 3-15)	2020 Modeling Assumption Used
1	Spokane International Airport Interceptor near I-90 and Thorpe Road	Removed 0.05 mgd flow from 08087
2	Central Business District, Stevens between Sprague and Main	Removed 0.7 mgd from CSO 26 (as a percent relative to entire basin)
3	Central Business District, Stevens, 4th and Brown	Removed 0.48 mgd from CSO 26 (as a percent relative to entire basin)
4	Central Business District, Riverside and Lincoln	Removed 1 mgd from CSO 26 (as a percent relative to entire basin)
5	Liberty Park	Removed Liberty Park constant inflow values (0.23 mgd)
6	Spokane Falls Boulevard and Wall	This has been completed prior to calibration. No action taken in model.
7	Elm Street Lift Station	This has been completed prior to calibration. No action taken in model.
8	Front and Erie	This has been completed prior to calibration. No action taken in model.
9	Cowley Creek	Removed 0.2 mgd from CSO 26 (as a percent relative to entire basin, Total removed 2.38 mgd)

Appendix: Alternative 2b Profiles



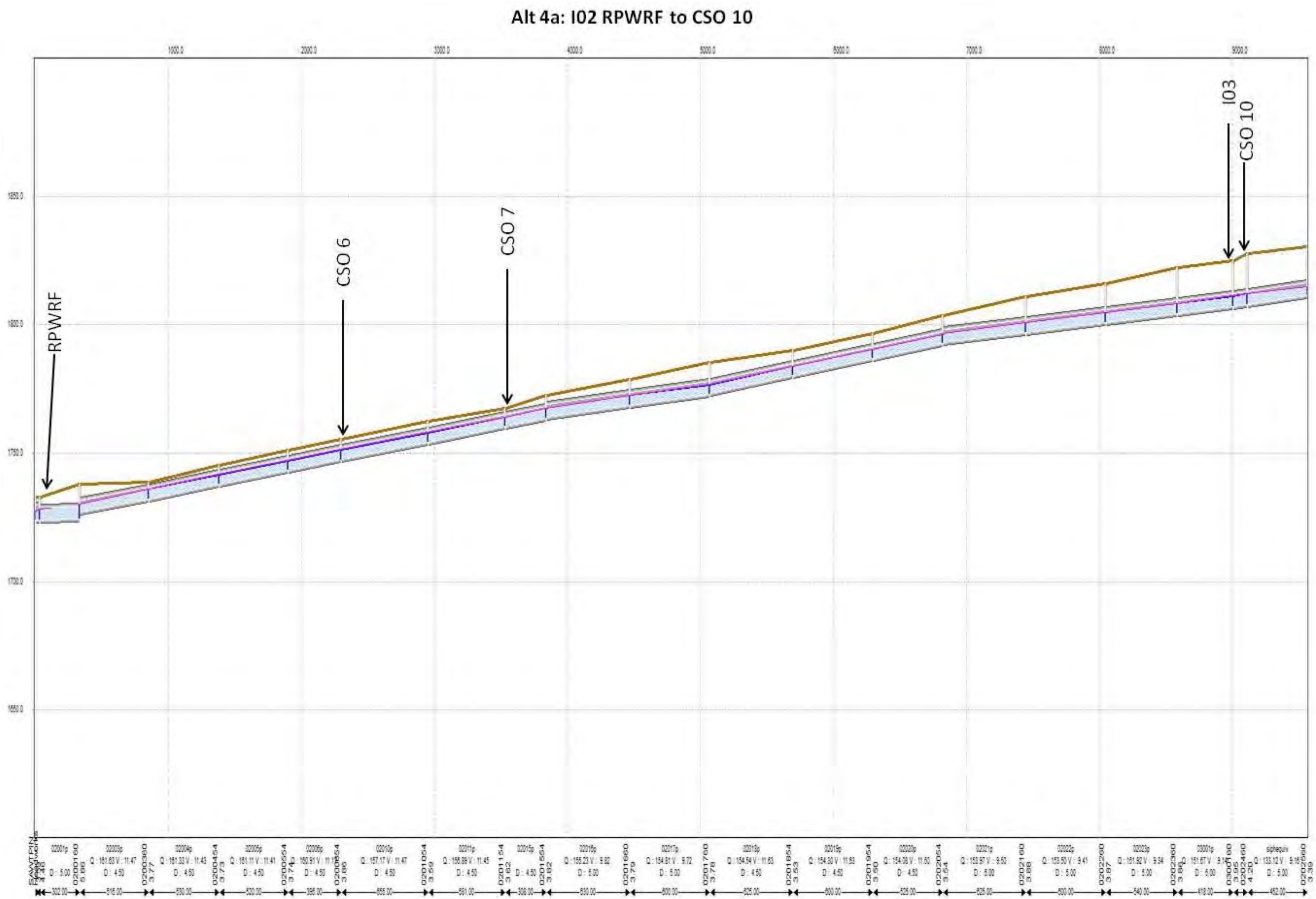

Alternative 2b: I02 to Lower I05
CSO 12
I04 & I08
CSO 23-2
CSO 23-1
I04a
I04b
I06, Post & CSO 26

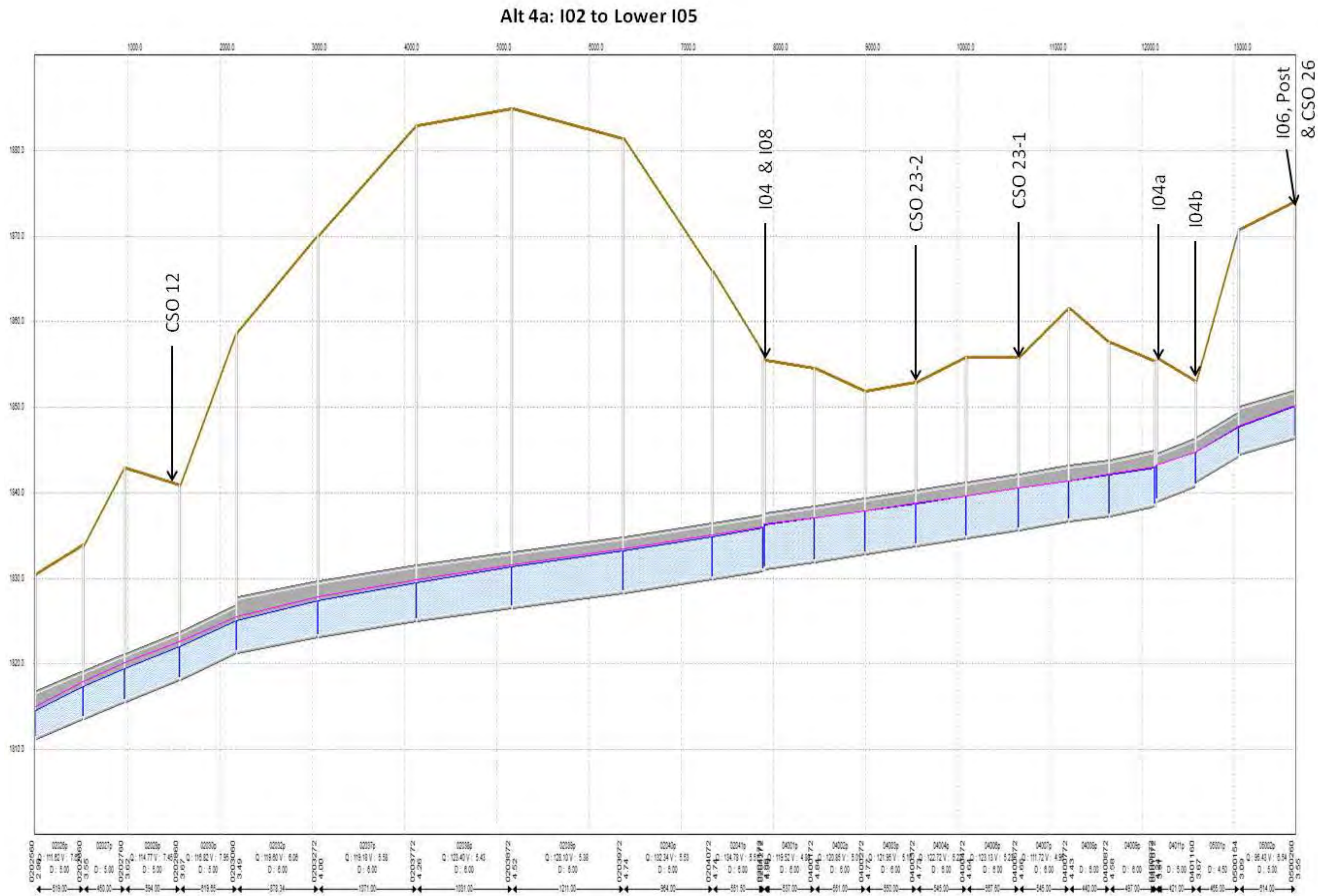

Alternative 2b: Lower I05 to Upper I05
I06, Post & CSO 26
CSO 33 & SVI
I07 & CSO 34

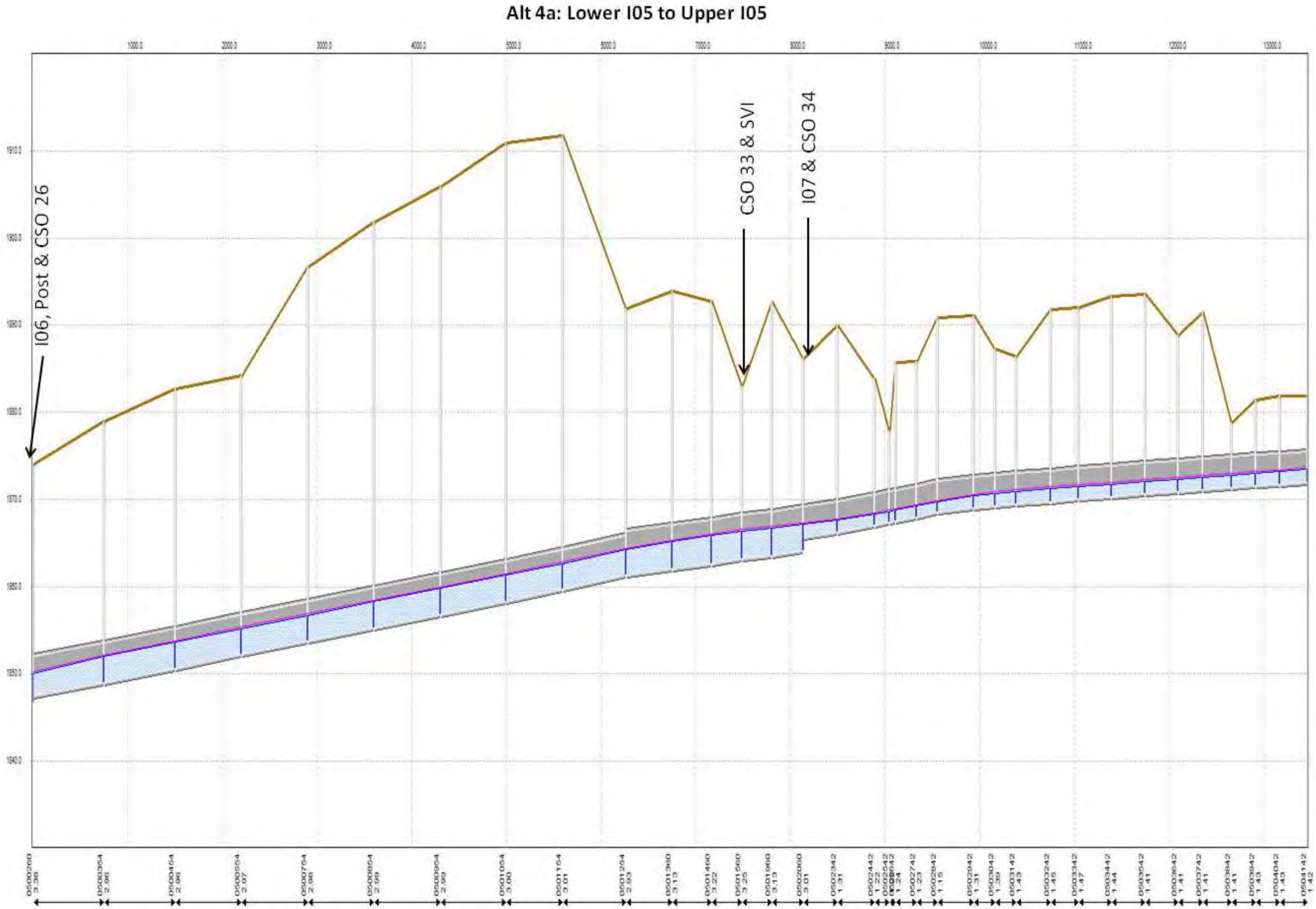

Alternative 2b: Upper I05
CSO 38
CSO 39
CSO 40 & CSO 41
NVI
CSO 42

Appendix: Alternative 4A Additional Information & Alternative 4A Profiles

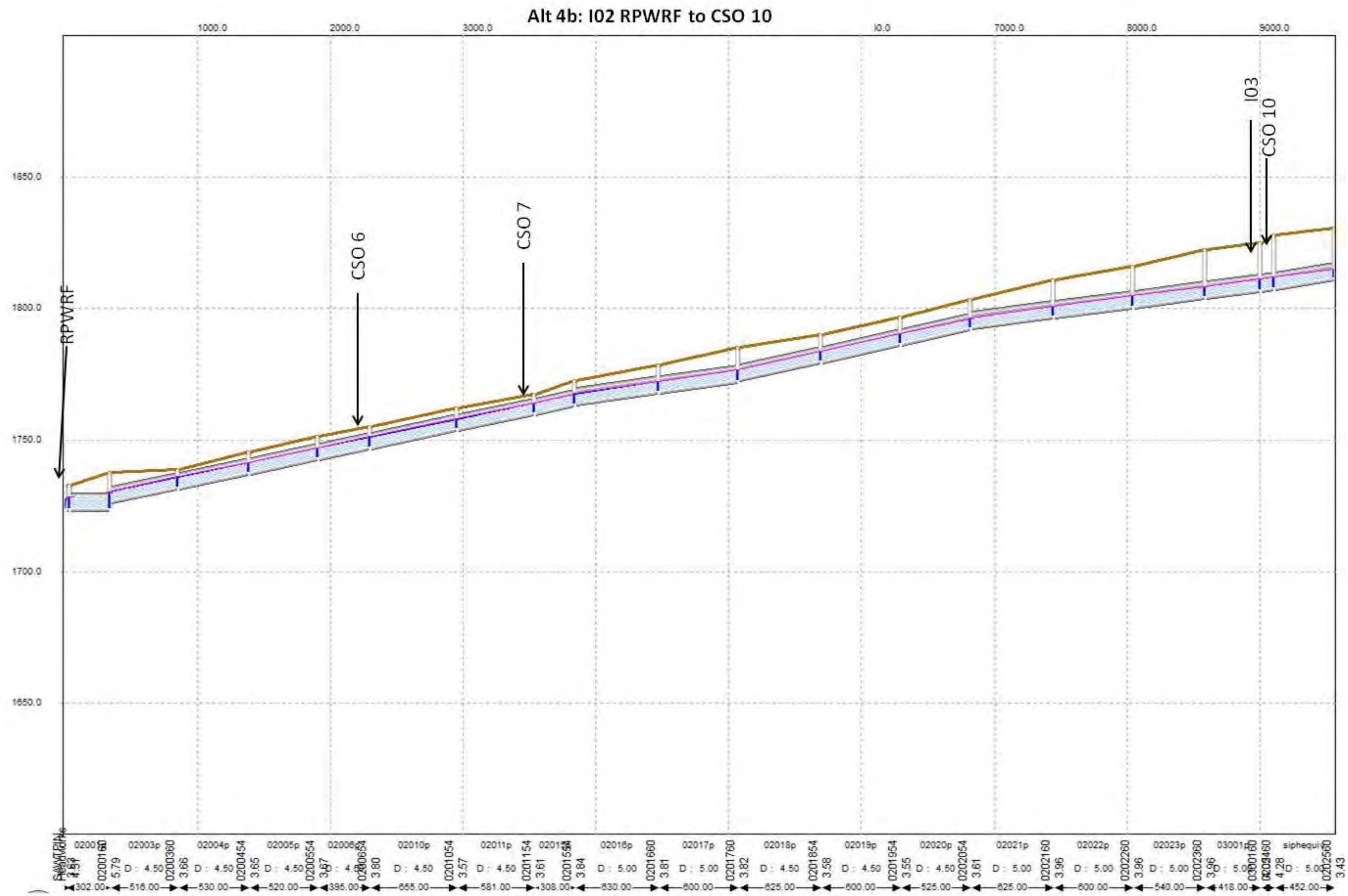
Basin or Segment I.D.	2011 Regulator Setting (mgd)	2020 Peak Dry Weather Flow + 10% (mgd)	Re-Eval Scen.3 Regulator Setting (mgd)	**Proposed** Optimized Regulator Setting (mgd)	Hydrograph Based Control Volume (gallons)[4]	Interceptor Inlet Capacity (mgd)	Storage Approx. Drain time (hrs)	Interceptor Description	Capacity Needed (mgd)	Max % Full (within segment)	Approx. $/gal Storage (2012$)	Approx. Storage Cost (2011$)	If Needed, Conveyance Upgrade to Interc. Inlet Rough Cost (W.A.G.)	DW Separ. Constr. Cost (approx.) (2009$)	**Partial Constr. Cost (approx.)**
CSO 42	1.39	0.63	0.75	**0.71**	**82,000**	1.70	23.7	**I05 Upper[2]**	0.00	24.5%	$ 10.57		$ 50,000		$ -
CSO 41	0.70	0.23	0.70	**5.80**	**400**	**2.00**	0.0	**I05 Upper[2]**	0.00	67.0%	$ 36.93	$ 15,000	1,000,000	409,000	$ 1,424,000
CSO 40	0.35	0.29	0.35	**0.35**	**50,000**	1.10	21.2				$ 11.87		$ 50,000		$ -
CSO 39	0.35	0.20	0.35	**0.35**	**48,000**	2.26	7.6	**I05 Upper[2]**	0.00	68.4%	$ 11.99		$ 50,000		$ -
CSO 38	0.39	0.33	1.20	**0.45**	**120,000**	2.71	24.0	**I05 Upper[2]**	0.00	75.7%	$ 9.67		$ 50,000		$ -
									0.00	**53.1%**		$ -			$ -
CSO 34	10.50	16.39	24.83	**19.80**	**4,156,000**	**18.00**	29.3	**I05 Lower**	0.00	51.4%	$ 4.20	$ 17,463,000	3,000,000		$ 20,463,000
CSO 33-1	11.97	4.21	11.30	**6.30**	**2,522,000**	8.50	29.0	**I05 Lower**	0.00	62.6%	$ 4.73	$ 11,917,000	1,000,000		$ 11,917,000
CSO 33-2	0.71	0.64	1.20	**0.90**	**305,000**	8.50	27.9	**I05 Lower**	0.00	80.8%	$ 7.76	$ 2,368,000	800,000		$ 2,368,000
									0.00	**73.3%**		$ -			$ -
CSO 26	18.15	12.33	27.40	**31.53**	**1,804,000**	40.90	2.3	**I06**	0.00	95.7%	$ 5.11	$ 9,223,000	350,000		$ 9,223,000
CSO 24/25	9.85	7.92	9.53	**9.53**	**2,269,600**	9.53	25.7	**I06**	0.00	95.7%	$ 4.84	$ 10,993,000	800,000		$ 10,993,000
								I06	0.26	**100.4%**					$ -
CSO 23-2	0.48	0.11	0.83	**5.60**	**400**	**1.40**	0.0	**I04**	0.00	84.4%	$ 36.93	$ 15,000	120,000	850,000	$ 985,000
CSO 23-1	0.48	0.40	0.65	**5.40**	**0**	**0.62**	0.0	**I04**	0.00	80.2%	$ -	$ -	90,000		$ 90,000
CSO 16			4.67			3.62			**0.00**	**80.6%**		$ -			$ -
CSO 14	0.90	0.24	0.90	**0.90**	**3,400**		0.1	**I08**	0.00	53.4%	$ 22.33	$ 76,000	810,000	1,250,000	$ 1,326,000
CSO 15	1.16	0.47	1.20	**2.45**	**9,500**	5.50	0.1		**0.00**	**53.6%**	$ 17.54	$ 167,000	100,000	1,600,000	$ 1,767,000
								I02	0.00	92.5%		$ -			$ -
CSO 12	1.07	1.99	5.57	**2.7**	**310,900**	3.50	10.5	**I02**	0.00	97.5%	$ 7.73	$ 2,403,000	200,000	4,350,000	$ 6,753,000
CSO 10	0.39	0.10	0.39	**0.39**	**55,000**	0.75	4.5	**I02**	0.00	94.6%	$ 11.61		100,000		$ -
								I02	0.00	85.1%		$ -			$ -
CSO 7	1.03	0.43	1.10	**6.00**	**0**	**1.70**	0.0	**I02**	0.00	92.3%	$ -	$ -	100,000	2,550,000	$ 2,650,000
CSO 6	1.81	1.22	4.50	**2.26**	**614,500**	23.30	14.2	**I02**	0.00	94.0%	$ 6.58	$ 4,046,000	1,000,000	3,400,000	$ 7,446,000
					12,350,700		**CSO Basin Subtotal**						**CSO Basin Subtotal**		**$ 77,405,000**
I04-1 (monroe)		0.21	0.97	**3.20**	**136,000**		1.1				$ 9.39	$ 1,276,000	0		$ 1,276,000
I04-2 (Wash.)		2.88	5.49	**5.49**	**1,090,000**		10.0				$ 5.75	$ 6,273,000	0		$ 6,273,000
I03		10.79	13.70	**11.40**	**1,631,000**		64.3				$ 5.23	$ 8,538,000	0		$ 8,538,000
I07		0.34	1.94	**3.00**	**765,000**		6.9				$ 6.25	$ 4,784,000	0		$ 4,784,000
					3,622,000	**Unregulated Basin Subtotal**							**Unregulated Basin Subtotal**		**$ 20,871,000**
					15,972,700			**TOTAL**					**TOTAL**		**$ 98,276,000**

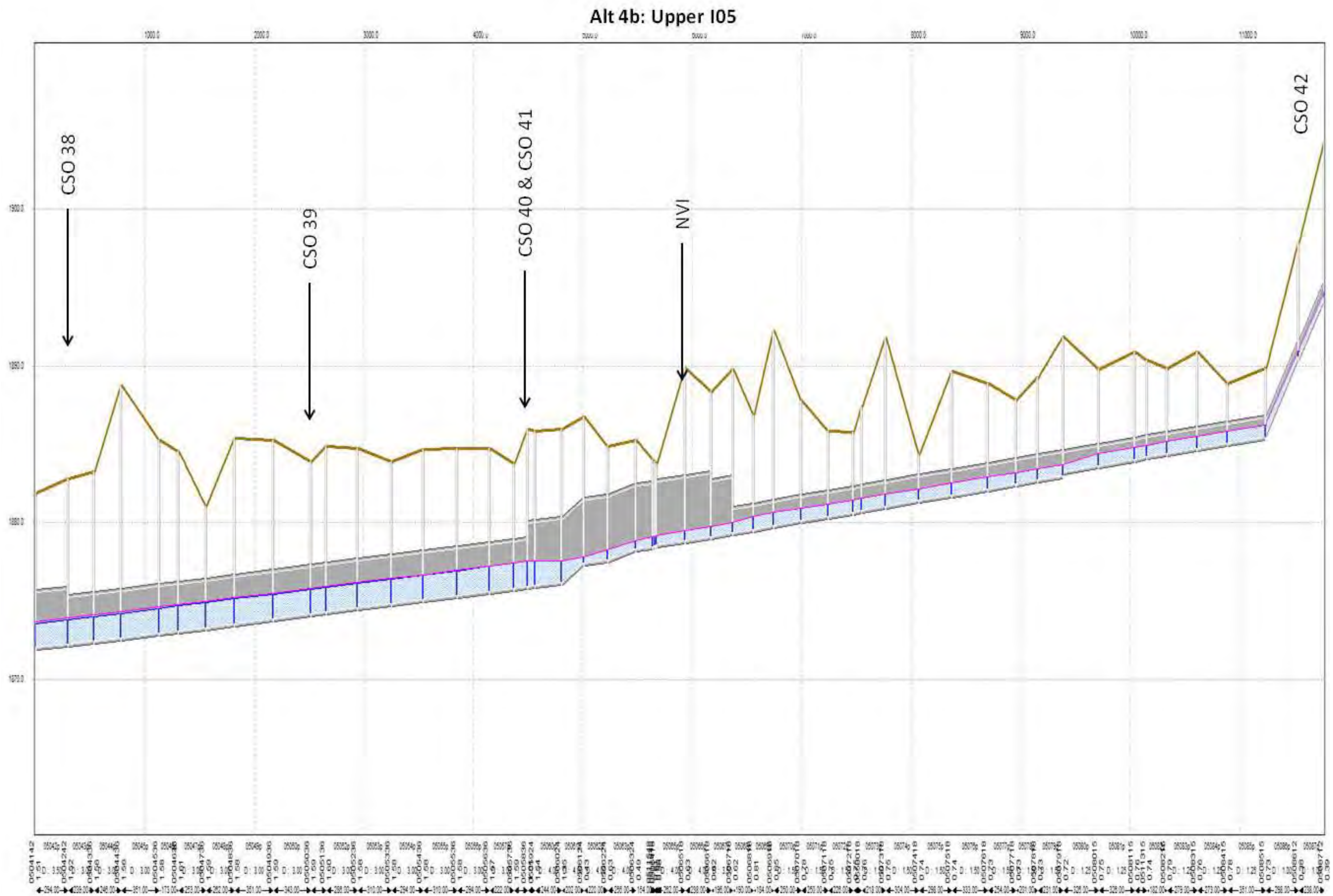

Alt 4a: I02 RPWRF to CSO 10
RPWRF
CSO 6
CSO 7
I03
CSO 10

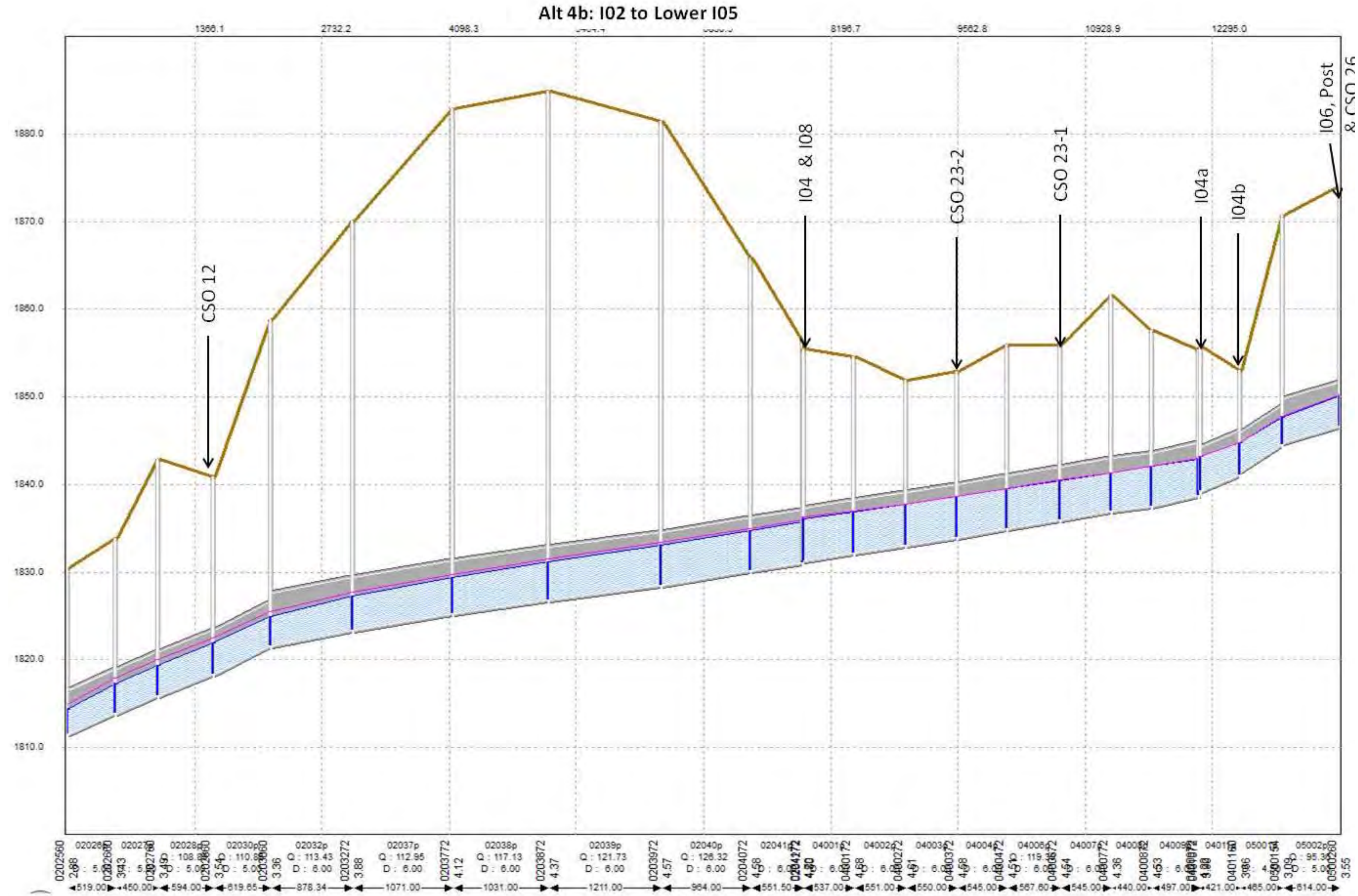

Alt 4a: I02 to Lower I05
CSO 12
I04 & I08
CSO 23-2
CSO 23-1
I04a
I04b
I06, Post & CSO 26

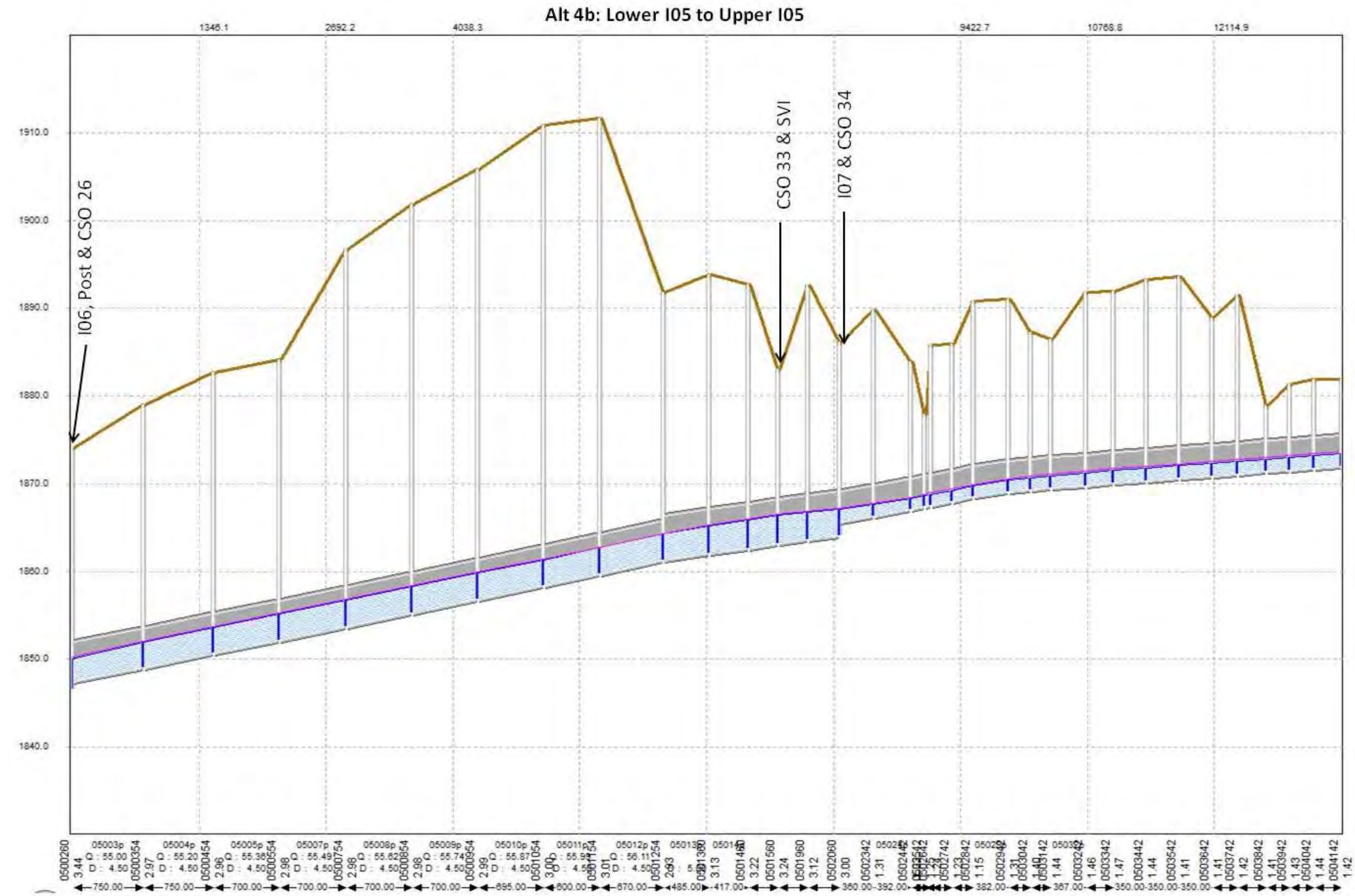

Alt 4a: Lower I05 to Upper I05
I06, Post & CSO 26
CSO 33 & SVI
I07 & CSO 34

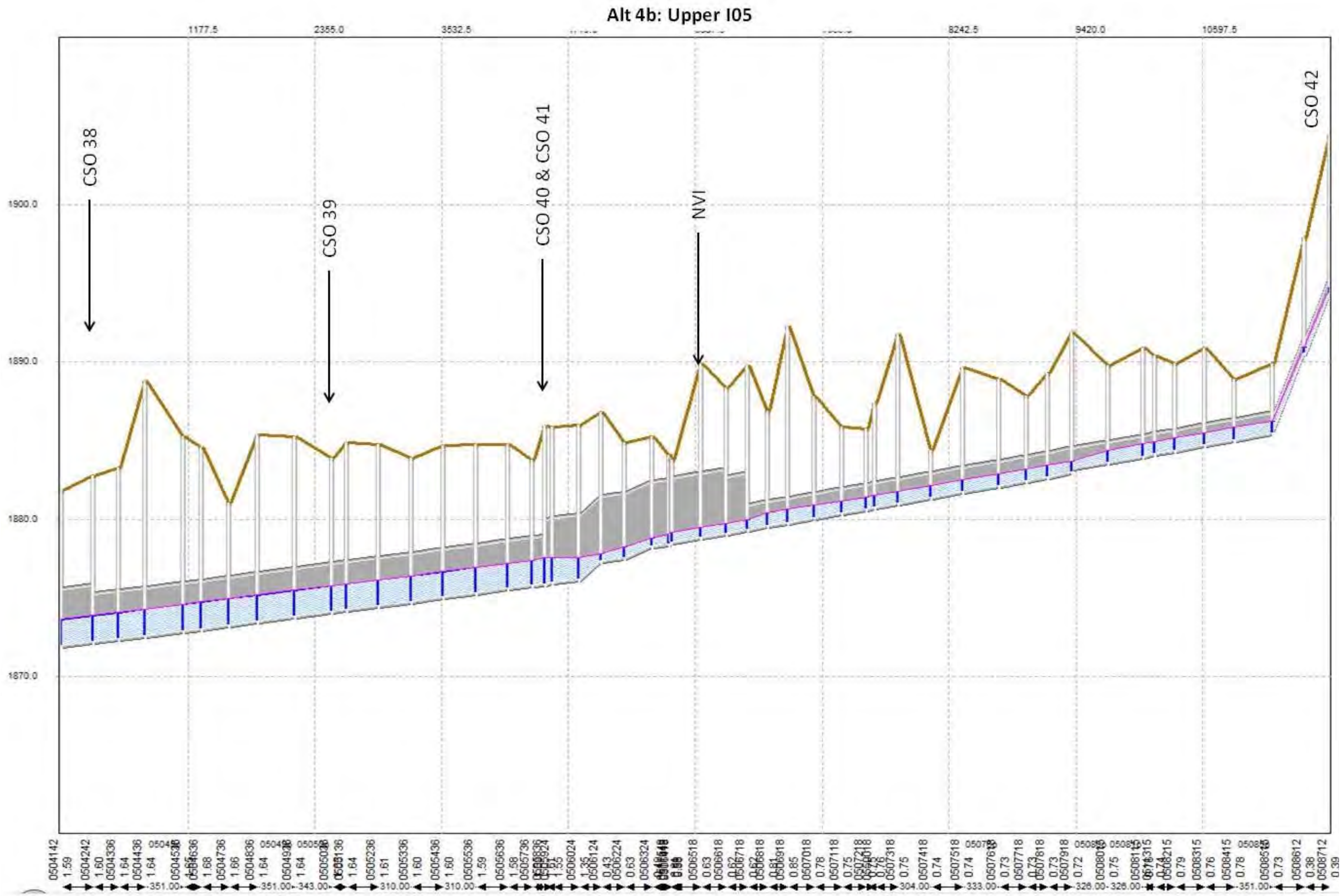
Appendix: Alternative 4b Profiles




Alt 4b: Upper I05
CSO 38
CSO 39
CSO 40 & CSO 41
NVI
CSO 42


Alt 4b: I02 to Lower I05
CSO 12
I04 & I08
CSO 23-2
CSO 23-1
I04a
I04b
I06, Post & CSO 26


Alt 4b: Lower I05 to Upper I05
I06, Post & CSO 26
CSO 33 & SVI
I07 & CSO 34
1910.0
1900.0
1890.0
1880.0
1870.0
1860.0
1850.0
1840.0
1346.1
2692.2
4038.3
9422.7
10768.8
12114.9


Alt 4b: Upper I05
CSO 38
CSO 39
CSO 40 & CSO 41
NVI
CSO 42
1900.0
1890.0
1880.0
1870.0
1177.5
2355.0
3532.5
8242.5
9420.0
10597.5

APPENDIX C

Confirmation of Conceptual Control Volumes (1.2-year event model)

CH2MHILL TRANSMITTAL

To: City of Spokane
808 W. Spokane Falls Blvd
Spokane, WA 99201

From: Jennifer Price
Program Management
4401 N Aubrey L White Parkway
Spokane, WA 99205

Attn: Rick Romero

Date: September 26, 2013

Re: Integrated Clean Water Plan - Historical CSO Volume Analysis Final Draft TM

We Are Sending You: Method of delivery: **Electronic ONLY**

- ☐ Attached
- ☐ Under separate cover via
- ☐ Shop Drawings
- ☒ Documents
- ☐ Tracings
- ☐ Prints
- ☐ Specifications
- ☐ Catalogs
- ☐ Copy of letter
- ☐ ***Non-Contracted Deliverable***
- ☒ ***Contracted Deliverable***

Quantity	Description
1	Integrated Clean Water Plan - Historical CSO Volume Analysis Final Draft TM (Work Modification Pending)

☒ **Confirmed QC Review is complete**

[signature]
Signature

Kelly Irving
Printed Name

If the material received is not as listed, please notify us at once.

Remarks:

Copy To: Mike Taylor, City of Spokane
Marcia Davis, City of Spokane
Lars Hendron, City of Spokane
Contracted Deliverables File

Analysis of Historical CSO Volumes for Modeled Control Volume Validation

PREPARED FOR:	City of Spokane
COPY TO:	Jennifer Price/SEA File
PREPARED BY:	Santtu Winter, PE/SEA
REVIEWED BY	Amy Carlson, PE/SEA
DATE:	September 18, 2013
PROJECT NAME:	Riverside Park Water Reclamation Facility Integrated Plan/CSO Plan Amendment
PROJECT NUMBER:	382918.T7.02.05

Purpose

The purpose of this technical memorandum is to document the methodology and results of the analysis of historical combined sewer overflow (CSO) volumes for validating the modeled control volumes based on the 1.2-year/24-hour design storm. The final version of this technical memorandum will be incorporated into the City of Spokane's CSO Plan Amendment.

Summary

The modeled control volumes were validated by comparing the control volumes with two other sizing methods, both of which are based on historical data. The City of Spokane completed one of the validations, which consisted of analyzing historical flow monitoring data at each CSO regulator. CH2M HILL completed the other validation, which consisted of analyzing historical CSO volumes. This memorandum focuses on describing the methodology and results of the second validation method: the analysis of historical CSO volumes. The modeled control volumes being validated do not include CSO Basin 20 or any of the unregulated areas.

The results indicate that most of the total control volume comes from five CSO basins: CSO Basins 24, 25, 26, 33 (A, B, and C), and 34. These five basins account for more than 80 percent of the total control volume. Overall, the analysis of historical CSO volumes supports the modeled control volumes. Most of the differences between the analysis of historical CSO volumes and the modeled 1.2-year/24-hour storm are due to differences in regulator settings, which the analysis of historical CSO volumes did not take into consideration.

Introduction

The City of Spokane is in the process of resizing needed CSO storage facilities, and to stay on schedule has elected to size facilities in three phases:

- **Phase I**: Develop conceptual sizing of CSO storage facilities using the City's existing event model with a revised synthetic precipitation event. The results are validated by estimating control volumes based on historical flow monitoring data and CSO volumes. Use these conceptual facility sizes and the event model to perform screening of basin alternatives.

- **Phase II**: Revise/update/verify conceptual sizing of CSO storage facilities and preferred basin alternatives using continuous model simulations based on a long-term record of precipitation. Use long-term (>20 years) continuous model simulation to verify that the preferred CSO alternative meets the goal of one overflow per year per outfall on a 20-year moving averaging period at each outfall in the system. Document in CSO Plan Amendment.
- **Phase III**: During individual facility preliminary design and final design, revise facility sizing to account for changed conditions, uncertainty, and risk not previously considered.

As described above for Phase I, the modeled control volumes were validated by comparing the control volumes with two other sizing methods, both of which are based on historical data. These two methods are summarized below:

- **Analysis of historical flow monitoring data at each CSO regulator**: This analysis consisted of taking the historical measured flow monitoring data at each CSO regulator and manipulating it to simulate what could have happened during the 20 largest CSO events if a CSO storage facility had been in place (along with the associated adjustments to the regulator flow settings). This work was completed by the City of Spokane (City of Spokane, 2013a, b, and c).
- **Analysis of historical CSO volumes:** This analysis consisted of reviewing the measured CSO volumes of historical events from 2001 through 2012, as reported in the City of Spokane's monthly CSO reports, and estimating what volume of storage facility would have been required to bring each of the uncontrolled CSO basins into control.

This memorandum focuses on describing the methodology and results of the second validation method described above, the analysis of historical CSO volumes.

Methodology

The first step in the analysis was to compile the dates and volumes of all measured CSO events from 2001 through 2012 from the City of Spokane's monthly CSO reports. These CSO events were then listed by CSO basin and sorted according to the measured CSO volume.

To review cost-effectiveness of control volumes and their associated level of risk, control volumes were estimated based on the lists of sorted CSO volumes. To fully use the available data, two levels of control were chosen for initial screening: 6 CSO events in 12 years (0.5 CSOs/yr), and 11 CSO events in 12 years (0.92 CSOs/yr). Comparing these two levels of control allowed the CSO team to do a simple knee-of-curve analysis to determine the cost-effectiveness of increased control. The number of CSO events over a 12-year period was used because there was 12 years of CSO volume data available for most basins.

The rationale for selecting these event levels included consideration that in many basins, multiple opportunities of "green solutions" and further storage exist to enhance storage and attenuation if the initial design does not meet all compliance criteria. The policy decision is that the benchmark of 0.92 CSOs/yr on a rolling 20-year average provides a very high probability of compliance. The 0.5 CSOs/yr was identified as a relatively conservative benchmark. Together, these two develop a clearer picture of capital investment versus performance expectations.

The control volumes for the two levels of control were estimated by selecting the $(N+1)^{th}$ largest measured CSO event volume, where N equals the allowable number of CSO events during the 12-year period from 2001-2012. For the 0.5 CSOs/yr risk level, the 7th largest CSO event volume was selected as the control volume. For the 0.92 CSOs/yr risk level, the 12th largest CSO event volume was selected as the control volume. CSO events with volumes smaller than the selected control volume would have been contained and treated. CSO events with volumes larger than the selected control volume would have overflowed. However, because of storage, any overflow events would have discharged a smaller volume than comparable events prior to control.

Figure 1 presents an example of the process of selecting the control volumes for the various risk levels for CSO Basin 26.

Control volumes were not estimated for CSO Basin 20, which is currently undergoing preliminary design, nor for any unregulated areas. Unregulated areas are portions of the combined sewer system that do not have a CSO outfall as a relief point, but still have a significant stormwater flow component. These areas do not have control volumes, because they do not have any CSOs. However, storage facilities are being planned in these areas to control the amount of flow in the interceptor, to alleviate surface flooding issues, and to create room in the interceptor system.

Results

Table 1 presents a summary of the resulting control volumes for the two risk levels based on the analysis of historical CSO volumes. Several basins have been grouped together based on the anticipated combining of storage tanks. For example, CSO Basins 24 and 25 are expected to be controlled with one tank, so the control volume was calculated for the two basins combined.

TABLE 1
Summary of Estimated Control Volumes

CSO Basin	0.5 CSOs/yr Control Volume (gallons)	0.92 CSOs/yr Control Volume (gallons)
6	1,016,000	813,000
7	113,000	79,000
12	767,000	654,000
14/15	121,000	88,000
23	339,000	285,000
24/25	2,506,000	1,898,000
26	3,645,000	2,795,000
33A-C	2,656,000	1,861,000
33D	135,000	135,000
34	4,528,000	2,830,000
41	110,000	76,000
Total[a]	15,937,000	11,514,000

[a]Total does not include storage requirements for unregulated areas, substorage being constructed in CSO Basin 34, or storage facilities being constructed in CSO Basin 20.

Figure 2 presents pie charts for the control volumes of the two risk levels. The results of both indicate that the majority of the total control volume comes from five CSO basins: CSO Basins 24, 25, 26, 33 (A, B, and C), and 34. These five basins account for more than 80 percent of the total control volume for both risk levels.

The analysis of historical CSO volumes did not take into account changes in dry weather wastewater flows due to future population increases, changes to existing regulator flow rates, or errors in flow monitoring data. It also does not account for the effects of climate change, nor does it consider other ways in which an uncontrolled CSO basin might be brought into control. The control volumes estimated from this analysis are approximate and should only be used to confirm that the historical data support the modeled control volumes.

Conclusions

Table 2 and Figure 3 present a comparison of the control volumes estimated using the various methods, and also include the control volumes used in the 2005 CSO Plan (CTE, 2005). Overall, the validation approaches support the modeled control volumes. The 0.5 CSOs/yr control volumes tend to correlate very closely with the modeled volumes, except for basins where the CSO storage facilities were being modeled as eliminated (CSO Basins 7, 23, and 41). The 0.92 CSOs/yr and historical flow monitoring validation approaches tend to predict slightly smaller control volumes with the exception of CSO Basin 26. Most of the differences between the validation methods and the modeled 1.2-year/24-hour storm are due to differences in regulator settings.[1] The historical CSO volumes approach described in this memorandum could not practically take into account any future changes to regulator flow settings, whereas the modeled results and the historical flow monitoring methods did in order to optimize storage volumes (although they occasionally had different future regulator settings).

TABLE 2
Comparison of Control Volumes Using Various Approaches

CSO Basin	2005 CSO Plan (CTE, 2005)	For Use in 2013 CSO Plan Amendment	Validation Methods		
		Modeled 1.2-yr/24-hr Design Storm[a] (MG)	Historical CSO Volumes[b] 0.5 CSOs/yr (MG)	Historical CSO Volumes[b] 0.92 CSOs/yr (MG)	Historical Flow Monitoring[c] (MG)
6	2.0	1.0	1.02	0.81	0.41
7	0.14	0.005	0.11	0.08	-
12	1.0	0.7	0.77	0.65	0.37
14 & 15	0.8	0.2	0.12	0.09	-
23	1.2	0.01	0.34	0.28	-
24 & 25	6.0	2.3	2.51	1.90	2.48
26	5.6	1.8	3.65	2.79	3.37
33	4.7	2.8	2.79	1.96	1.86
34	6.7	4.2	4.53	2.83	2.82
41	0.45	0.005	0.11	0.08	-
Total[d]	28.6	13.0	15.9	11.5	11.3

[a]Results developed by AECOM (AECOM, 2013).
[b]Results from Table 1 of this memorandum.
[c]Results developed by the City of Spokane.
[d]Total does not include storage requirements for unregulated areas, substorage being constructed in CSO Basin 34, or storage facilities being constructed in CSO Basin 20.
MG = million gallons

[1] Regulator setting changes are being implemented as a part of the overall strategy to reduce CSOs by maximizing the use of the interceptor system and sending as much flow as possible to the wastewater treatment plant.

Recommendations

No specific recommendations are presented in this technical memorandum. This technical memorandum was prepared to support the recommendations made in the CSO Plan Amendment, and will be included in the appendix of the CSO Plan Amendment.

References

AECOM. 2013. *Draft Interceptor Re-optimization Analysis Memorandum*. Prepared for the City of Spokane, Spokane, WA. June 28, 2013.

City of Spokane. 2012. *Monthly CSO Reports, January 2001 through December 2012*. Spokane, WA.

City of Spokane. 2013a. *CSO 24/25/26 Tank Sizing Analysis*. PowerPoint presentation prepared by Chris Kuperstein. Spokane, WA. April 22, 2013.

City of Spokane. 2013b. *CSO Tank Sizing Model – Revised*. PowerPoint presentation prepared by Chris Kuperstein. Spokane, WA. May 15, 2013.

City of Spokane. 2013c. *CSO 26 and 33 Monitoring Profiles*. PowerPoint presentation prepared by Chris Kuperstein. Spokane, WA. May 29, 2013.

CTE. 2005. *Combined Sewer Overflow Reduction System Wide Alternative Report*. Prepared for the City of Spokane, Spokane, WA. December 2005.

Figures

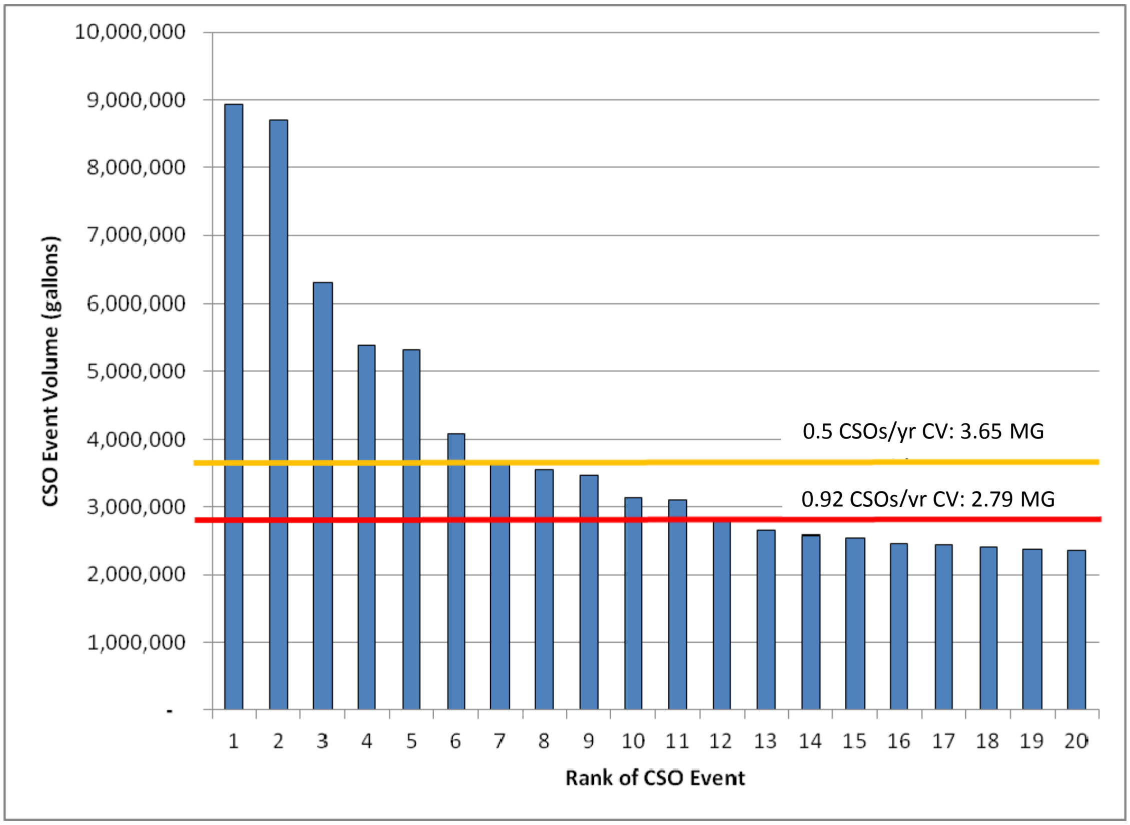


FIGURE 1
Top 20 CSO Events Ranked by Volume for CSO Basin 26

Note: The basin had approximately 280 CSO events from 2001-2012, and only the top 20 events are shown. All CSO events below the red or orange line would not have occurred had a control volume-sized storage facility been in place.

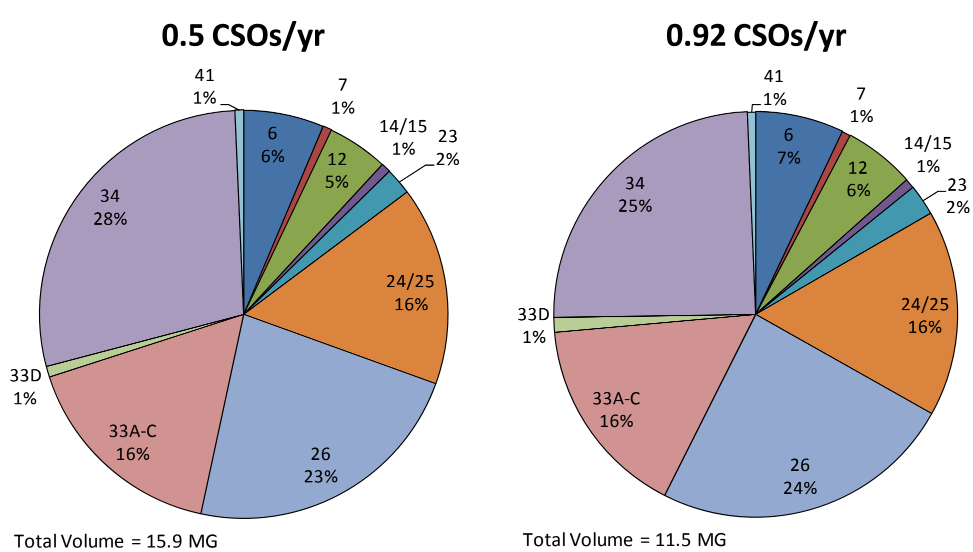


FIGURE 2
Pie Chart Presenting Breakdown of Control Volumes for the Two Risk Levels

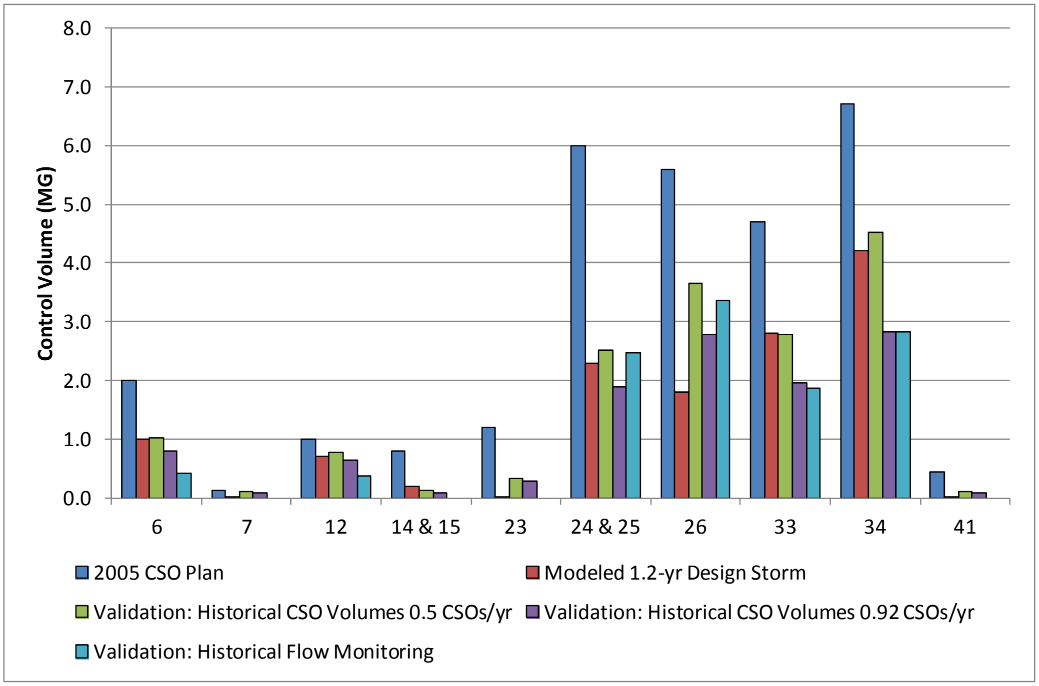


FIGURE 3
Comparison of Control Volumes Using Various Approaches

APPENDIX D

Background on 20-year Precipitation Record

CITY OF SPOKANE

WASTEWATER MANAGEMENT DEPARTMENT
909 E. SPRAGUE AVE.
SPOKANE, WA 99202

Draft Technical Memorandum

DATE: August 9, 2013

TO: Duane Studer, P.E. (AECOM),

DISTRIBUTION: Amy Carlson, P.E. (CH2M HILL), Mike Taylor, P.E., Lars Hendron, P.E., Marcia Davis, P.E.

PREPARED BY: Chris Kuperstein

Subject: 20-year rainfall dataset summary and assumptions

Background

In order to facilitate modeling efforts for the CSO Plan Amendment, the City of Spokane was requested to provide a scrubbed rain dataset for 20 years. This set of rainfall data will be used to verify CSO facility sizing and interceptor flows in a model run developed by AECOM.

Summary of data set and data quality.

The city has maintained 5 rain gauges consistently in the same location since 1995. Other gauges were added in 2002-2004 time frame to augment these gauges, but they are not used in this data set, other than for substitution.

The collection of rain data and quality of data has varied over the 20-year period. For the most part, the data quality has gotten better.

The data is roughly in two parts: 1995-1999 contains 15-minute data, and at 2000-2013 contains 1 minute data. The total number of data points in this data set is roughly:

876,000 from 1995-1999
38,132,000 from 2000-2013(July).

Total: 39,008,100 data points.

The number of data points with errors or data missing in the data set are as follows:

343 – 129,174, or 1.66%
344 – 192,173, or 2.46%
345 – 574,049, or 7.36%
346 – 117,968, or 1.51%
347 – 353,345, or 4.53%

Average: 3.50% missing or erroneous data points.

Method of data QC and substitution

Three passes through the data were conducted to perform quality control. The first pass was to find and remove duplicate timestamps introduced because of Daylight Savings time and other monitor clock errors.

The second pass was to remove obvious over-reporting errors. For example, 7.5 inches in 15 minutes is clearly an impossible reading. The threshold set for review of data was 0.10 inches in 15 minute data and 0.04 inches in one minute data. Data that was a single point with no neighboring data and no rain reported on other gauges was removed.

The third pass was to substitute missing data Due to the nature of the analysis AECOM is trying to perform, substitution of data allows a consistent triangulation methodology in the model. Data that was missing and did not have rainfall on any other gauge for the period was marked as missing. Data that was missing during periods of rainfall was substituted for by a schedule of replacement gauges. The nearest gauge may not be the preferred gauge because of the rainfall variance due to the geography.

When this gauge has missing data:	Next Preference Replacement gauge:	
	1st Choice	2nd Choice
343	344	349
344	343	349
345	350	348
346	343	349
347	349	352

A summary file is included in this dataset that includes the data points that were erroneous and the time periods of data substitution.

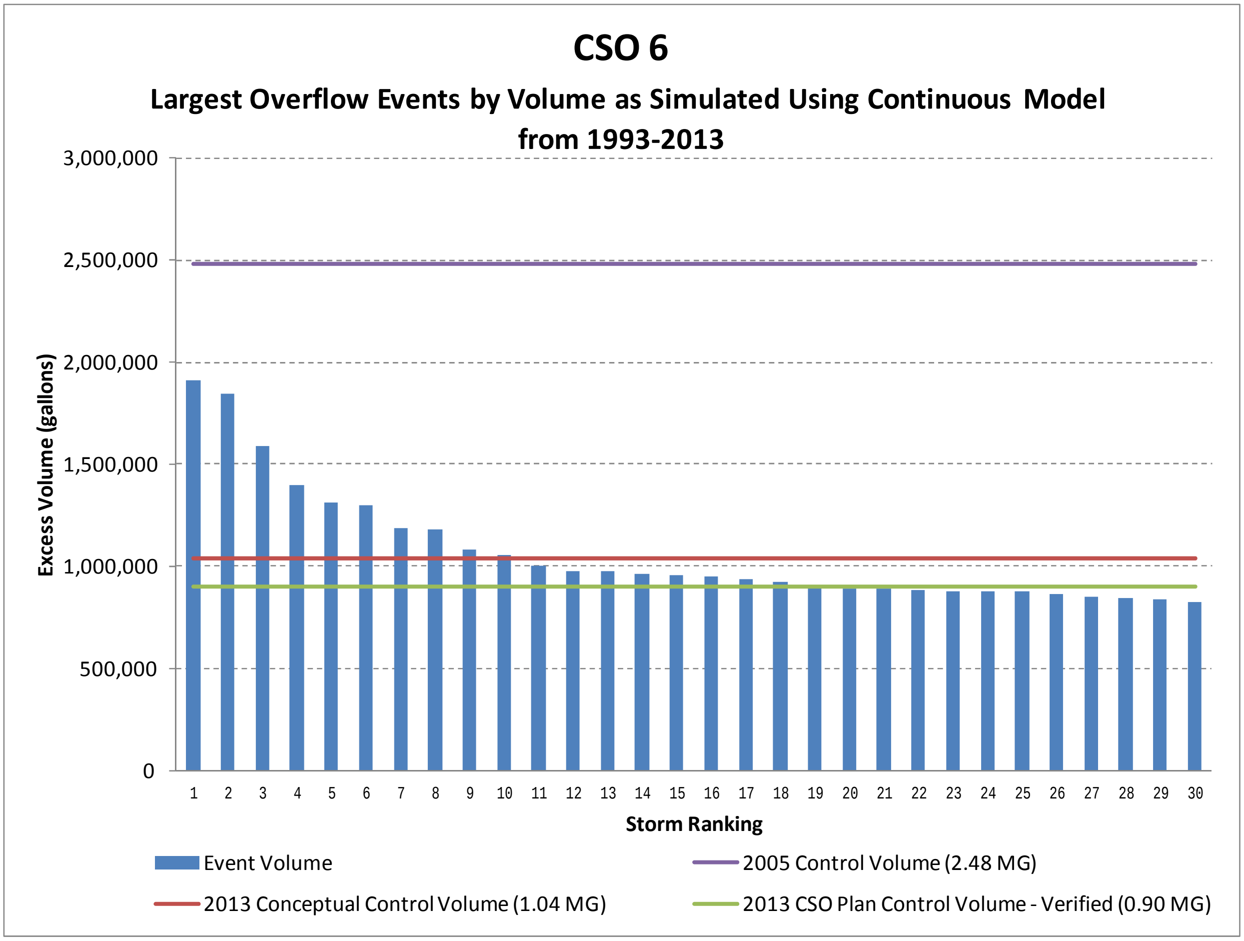
The end result of the Quality Control passes is a consistent dataset, with no over-reporting errors; and also with the leas possibility of under-reporting errors due to missing data. Though not perfect, this represents the best representation of the dataset that works for AECOM's model needs.

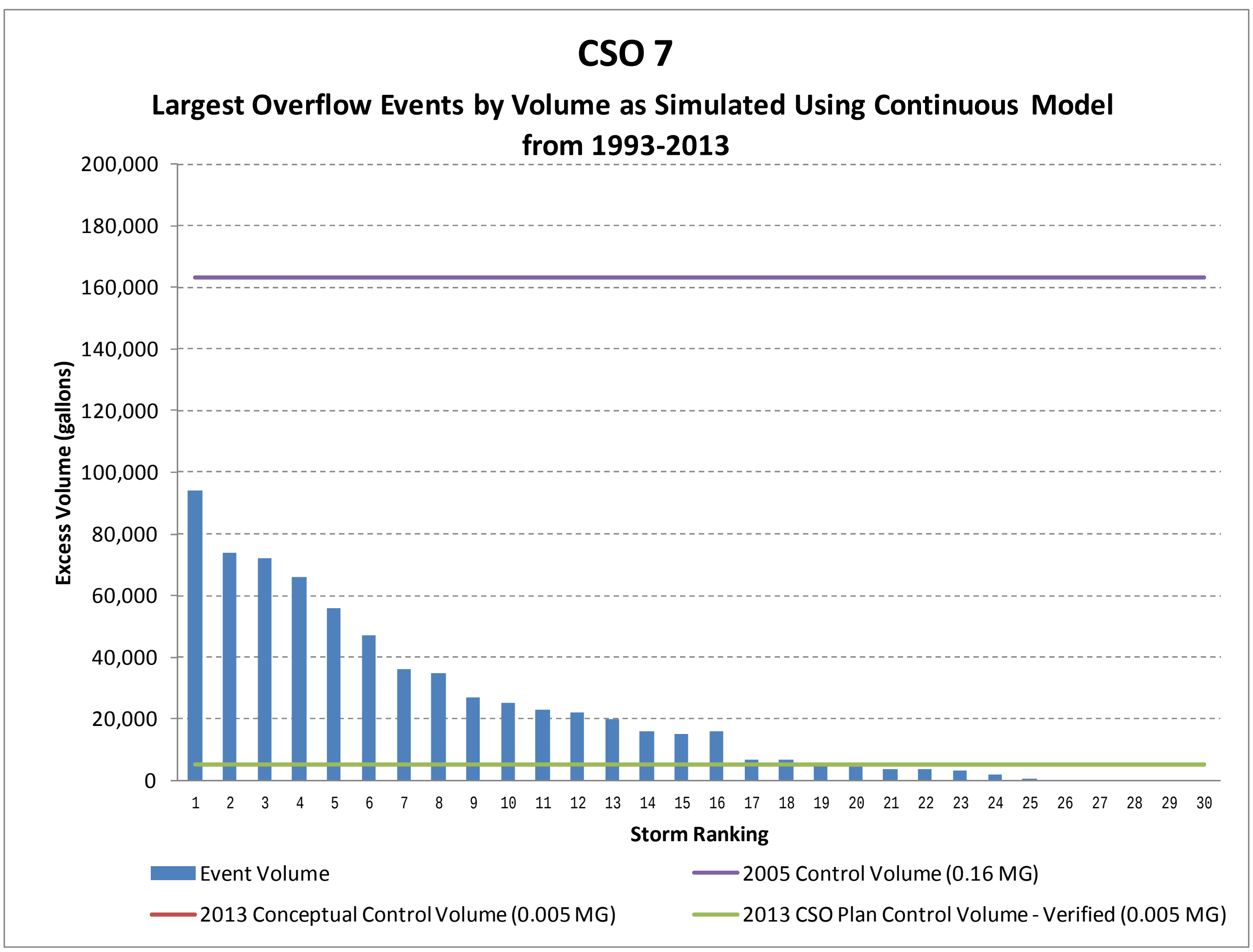
Model Run

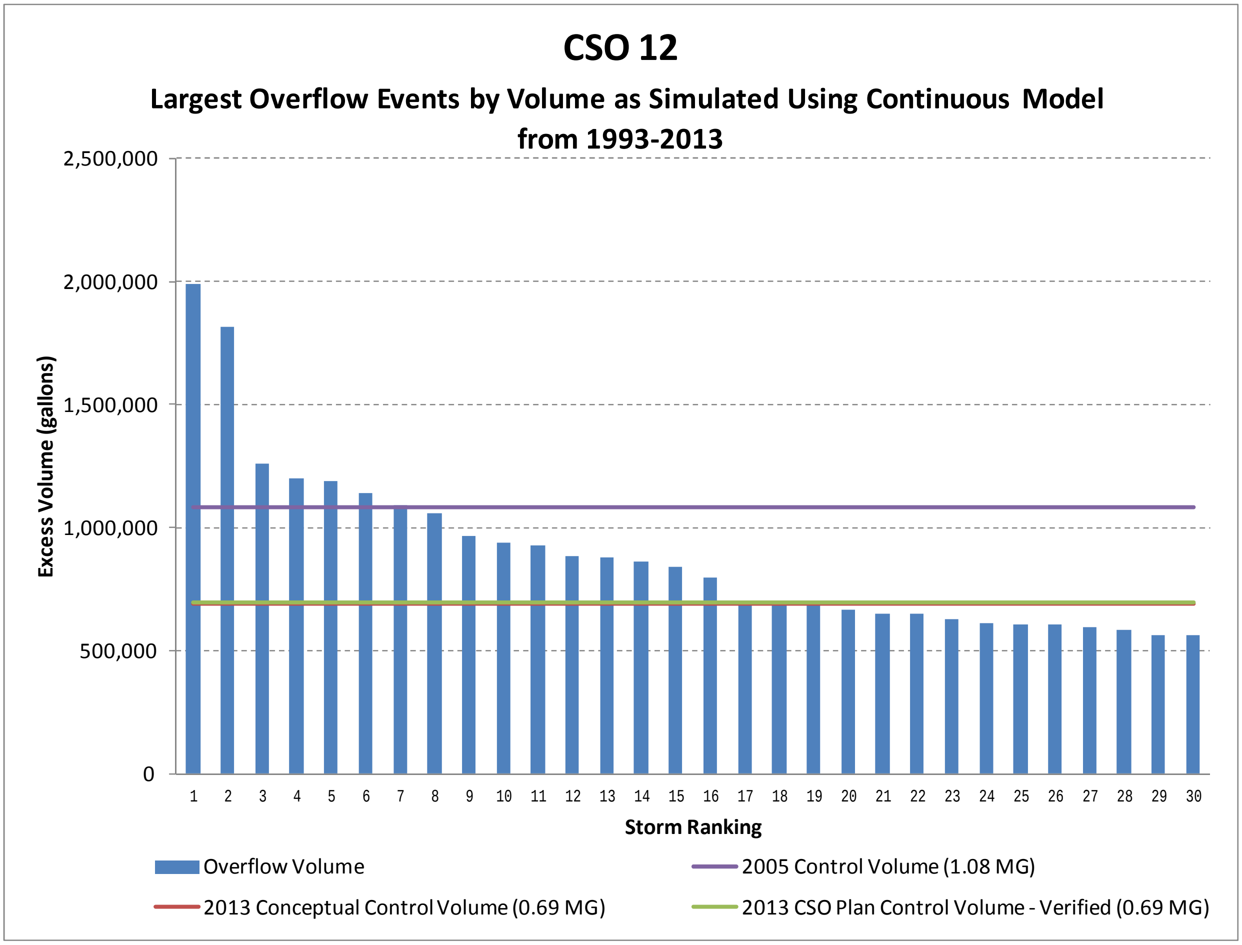
AECOM will use this data to run a full simulation of historical rainfall on each basin by using a distance-weighted triangulation with each basin. This simulation will result in an estimation of volume and frequency of CSO overflows for each basin at the selected regulator settings, as well as a summary of the effect on the interceptor flows to the RPWRF to verify modifications to the collection system do not exceed 120mgd of flows in I02.

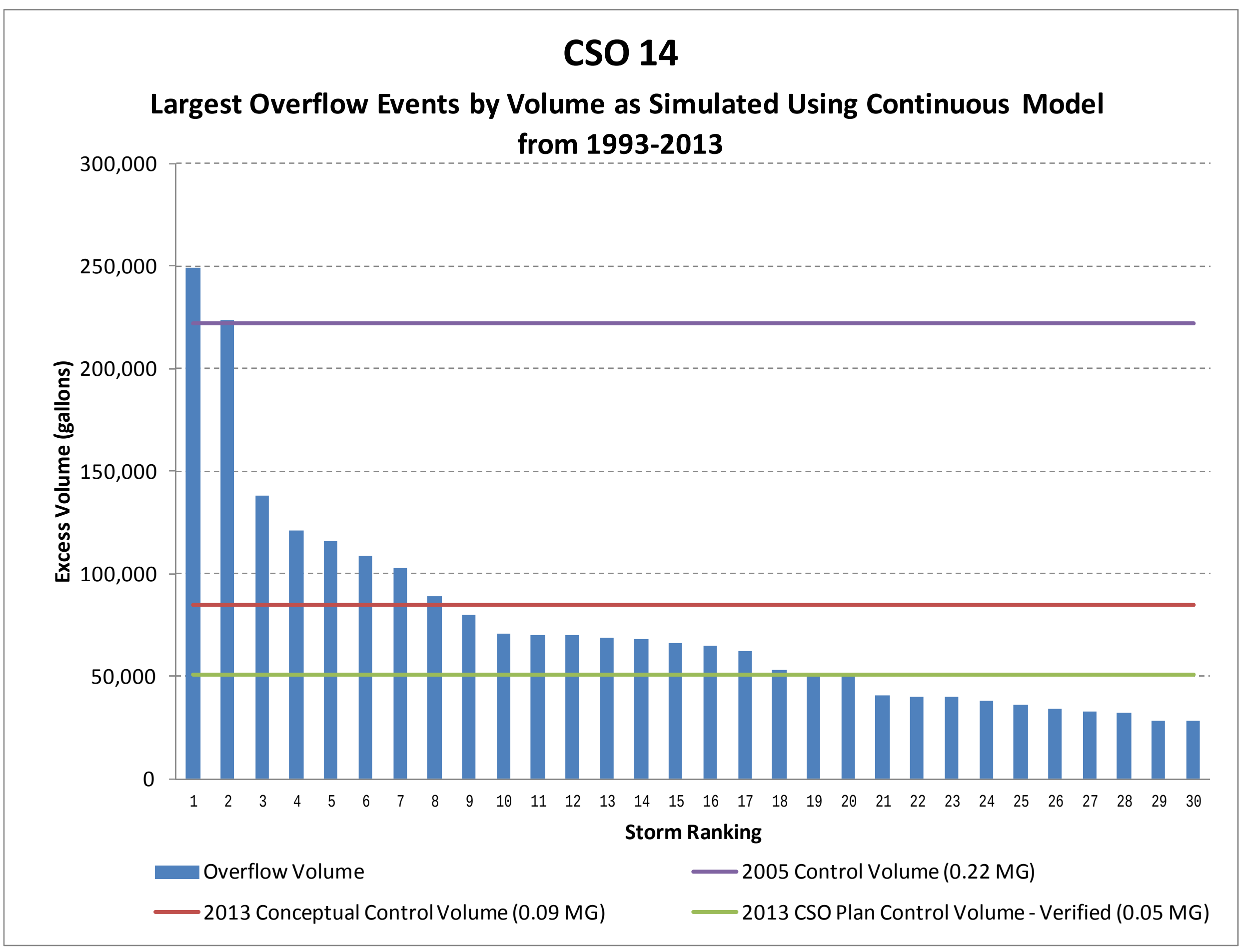
APPENDIX E

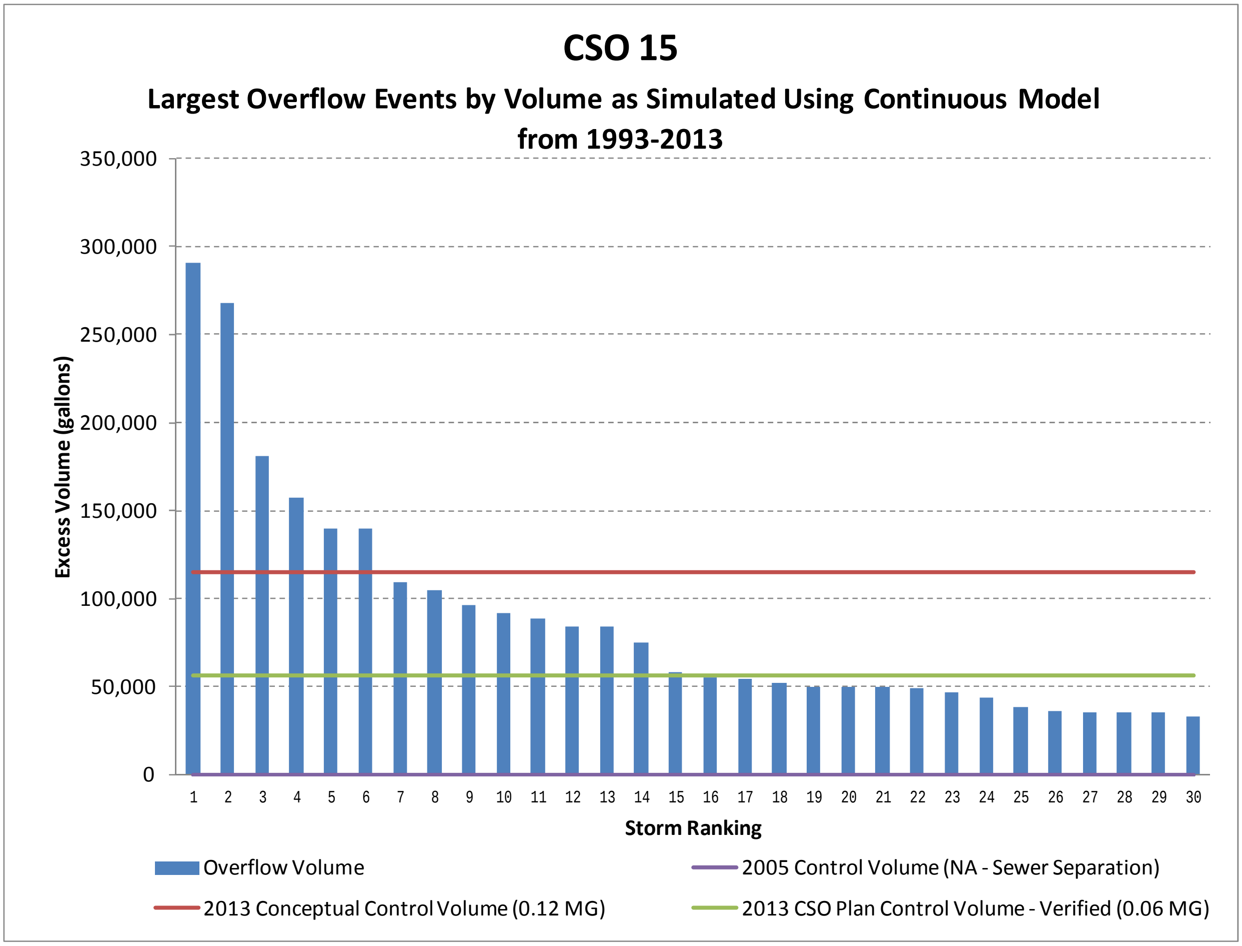
Basis of Control Volumes

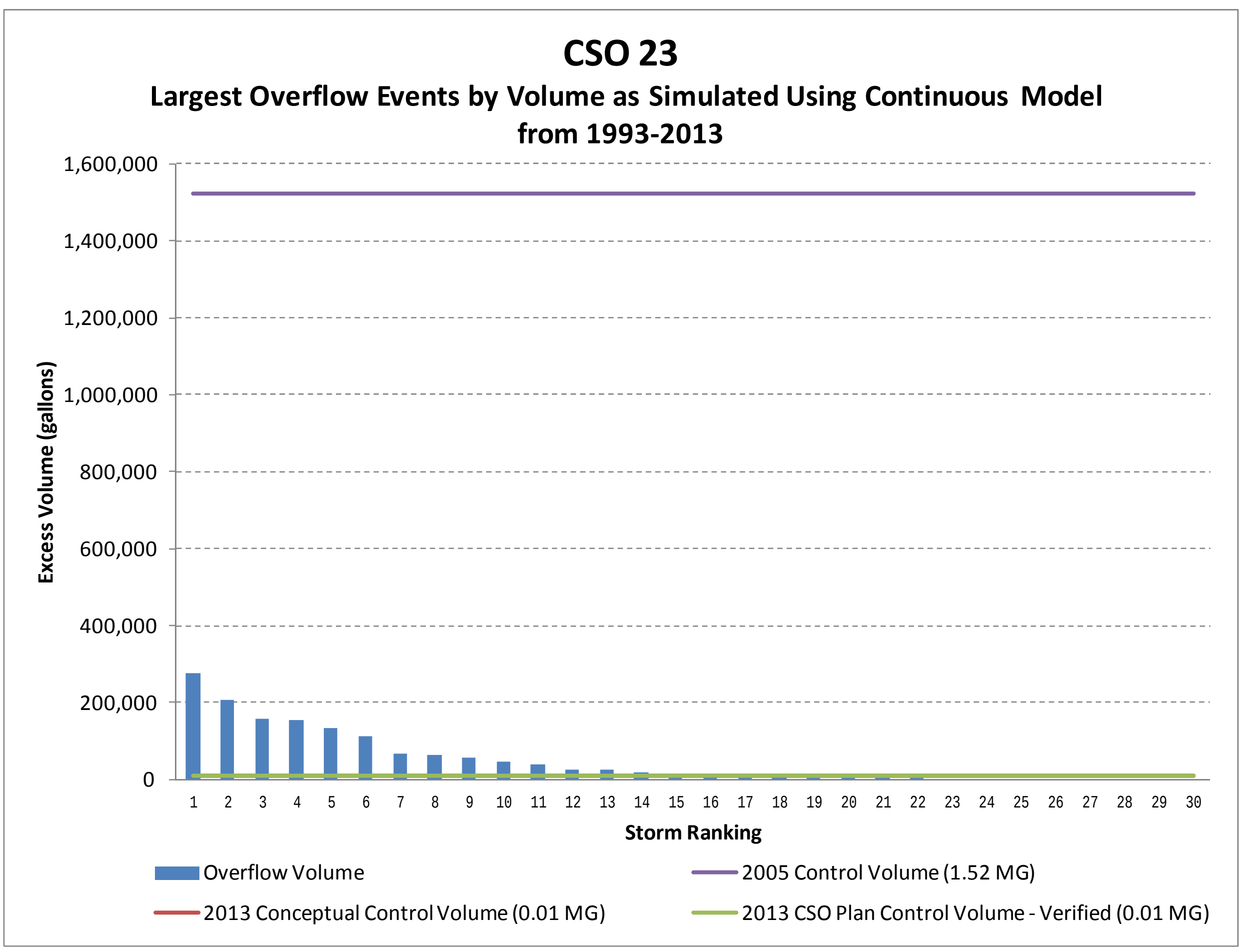

CSO 6
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Excess Volume (gallons)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Event Volume
2005 Control Volume (2.48 MG)
2013 Conceptual Control Volume (1.04 MG)
2013 CSO Plan Control Volume - Verified (0.90 MG)

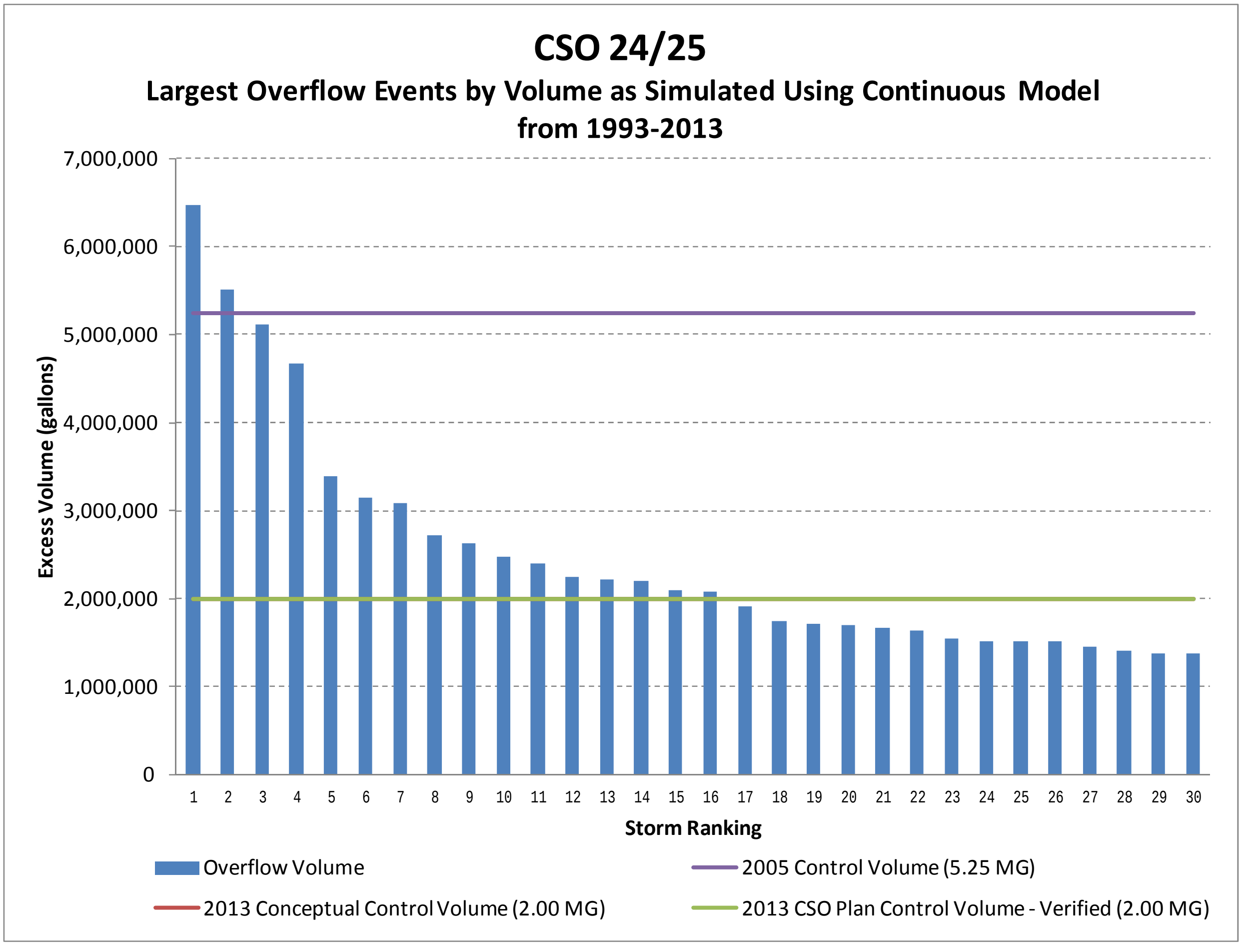

CSO 7
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Excess Volume (gallons)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Event Volume
2005 Control Volume (0.16 MG)
2013 Conceptual Control Volume (0.005 MG)
2013 CSO Plan Control Volume - Verified (0.005 MG)

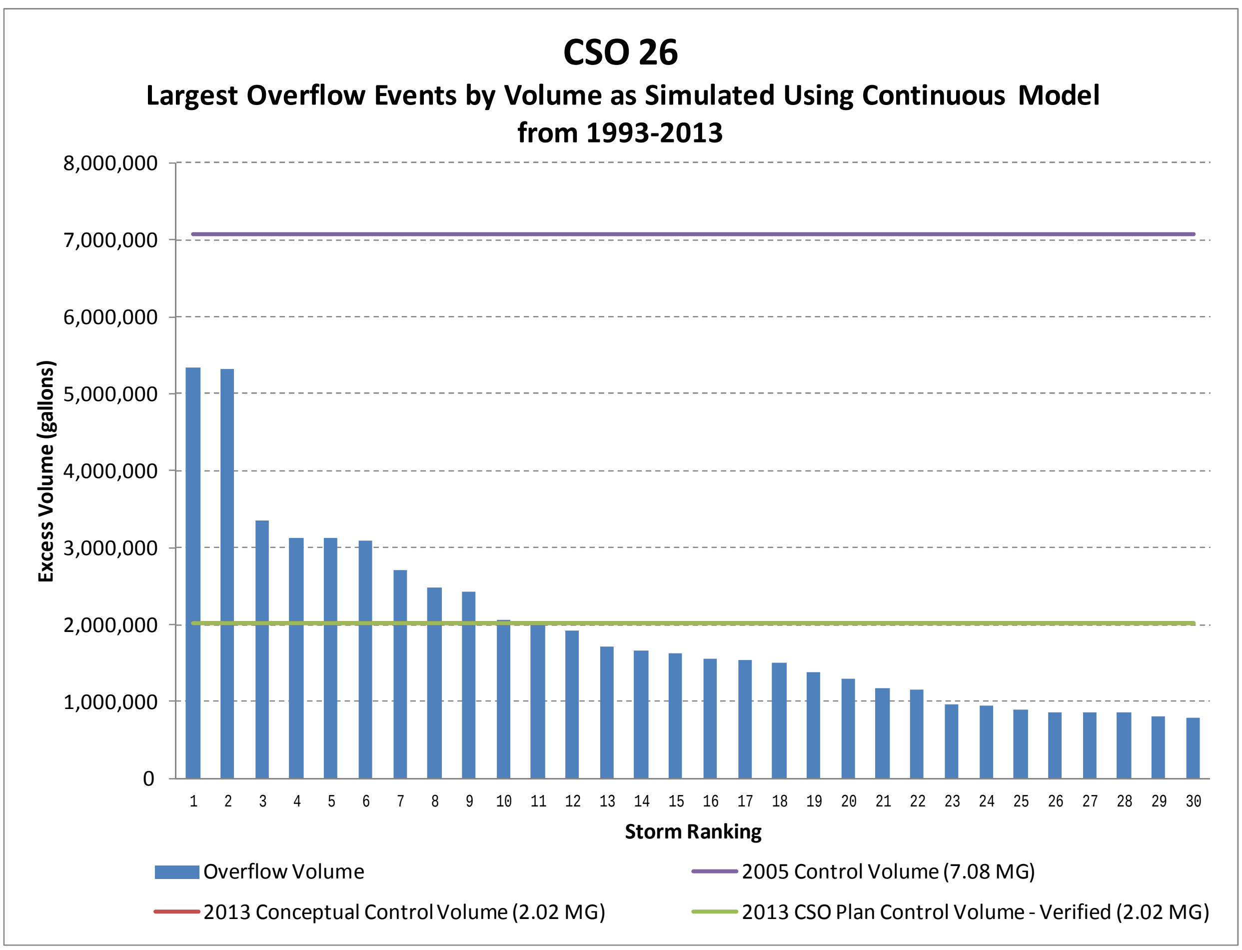

CSO 12
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
Storm Ranking
Overflow Volume
2005 Control Volume (1.08 MG)
2013 Conceptual Control Volume (0.69 MG)
2013 CSO Plan Control Volume - Verified (0.69 MG)

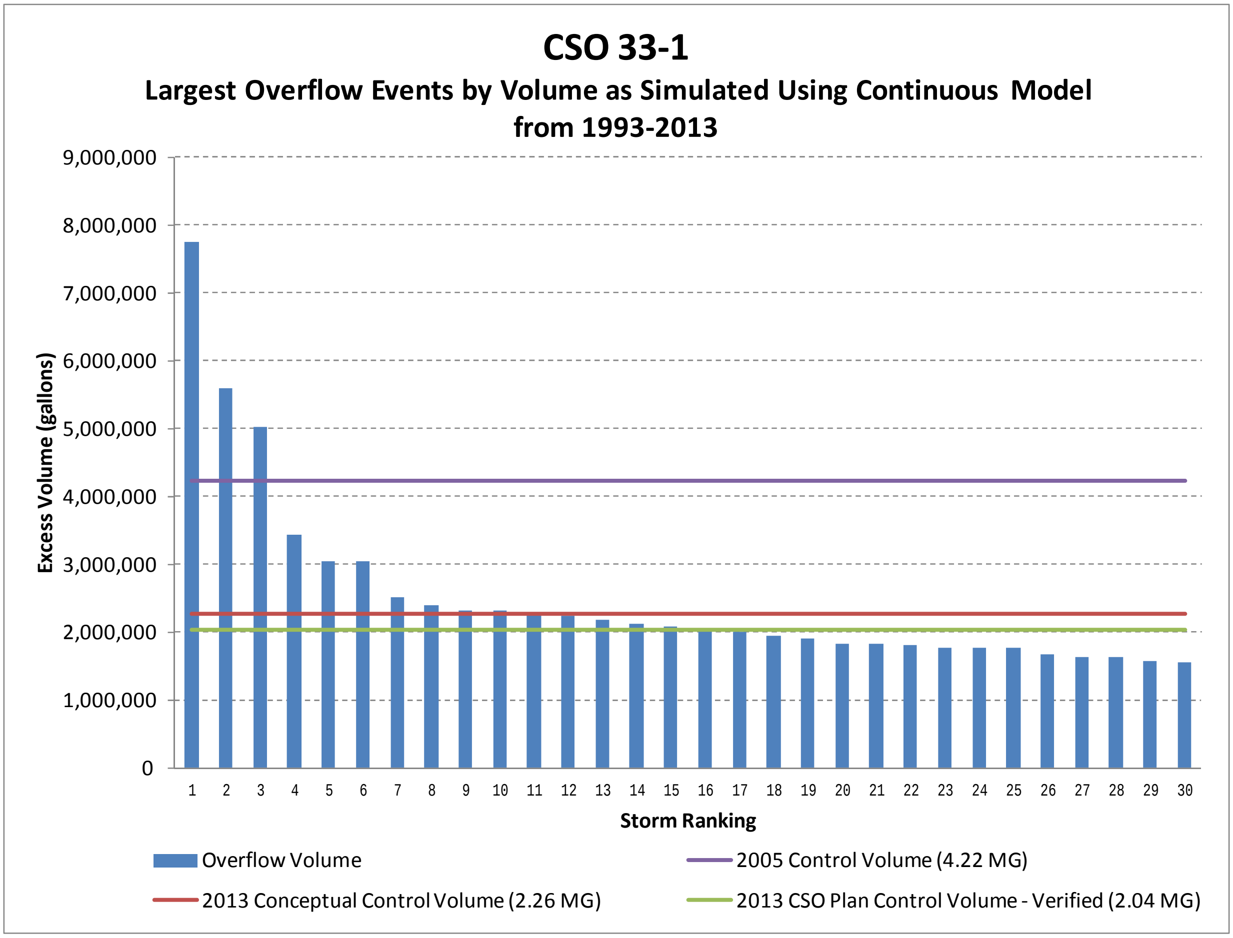

CSO 14
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
Storm Ranking
Overflow Volume
2005 Control Volume (0.22 MG)
2013 Conceptual Control Volume (0.09 MG)
2013 CSO Plan Control Volume - Verified (0.05 MG)

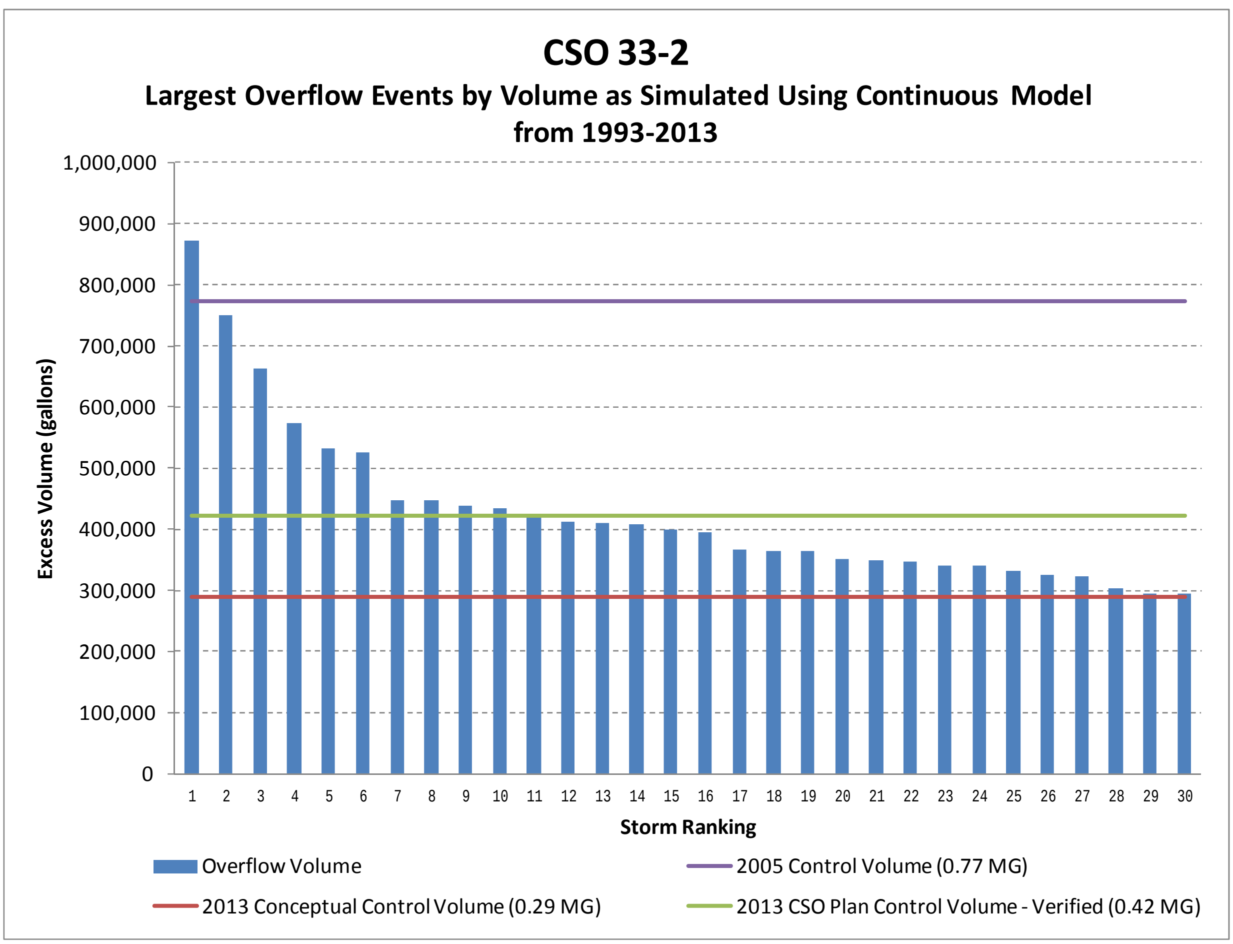

CSO 15
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (NA - Sewer Separation)
2013 Conceptual Control Volume (0.12 MG)
2013 CSO Plan Control Volume - Verified (0.06 MG)

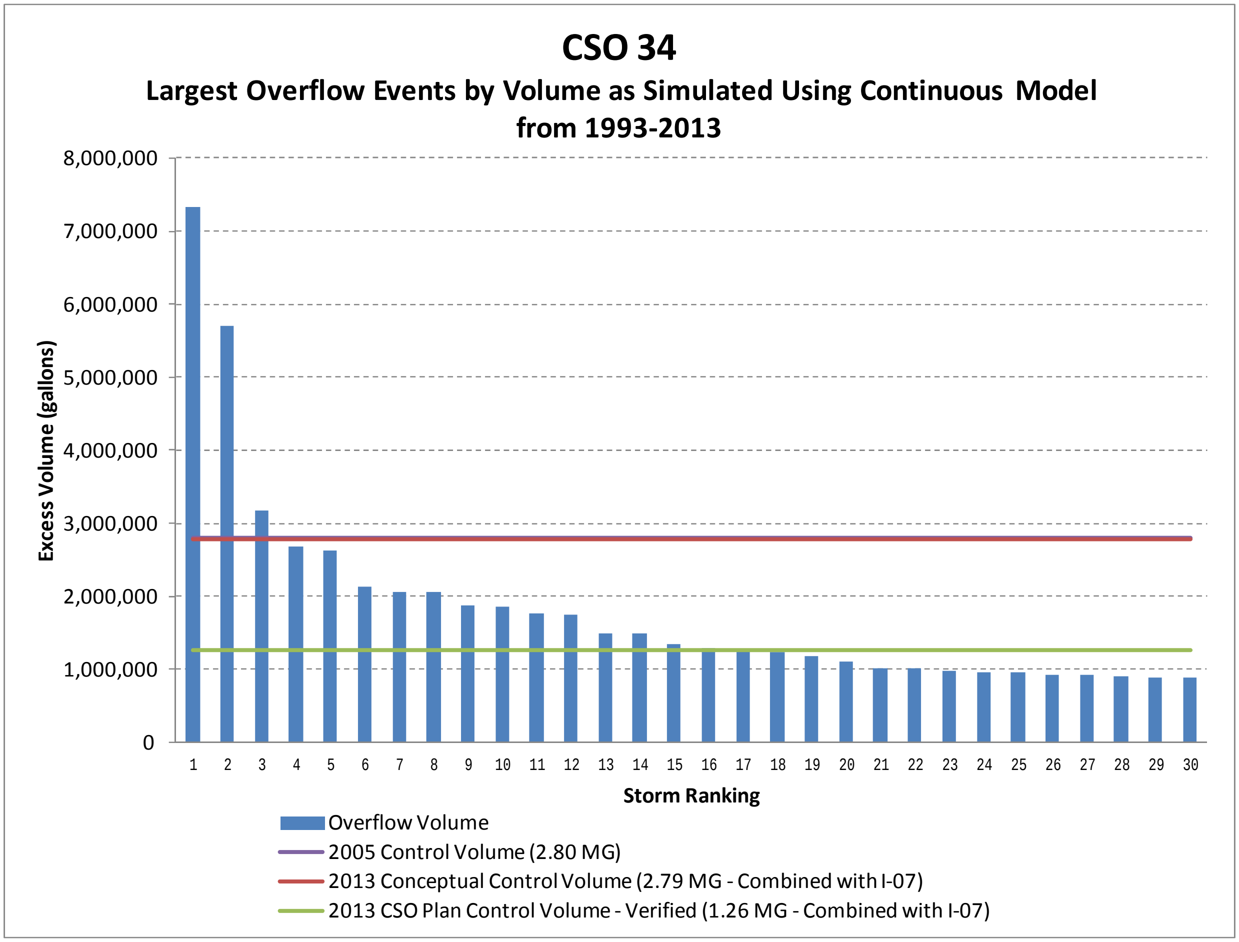

CSO 23
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (1.52 MG)
2013 Conceptual Control Volume (0.01 MG)
2013 CSO Plan Control Volume - Verified (0.01 MG)

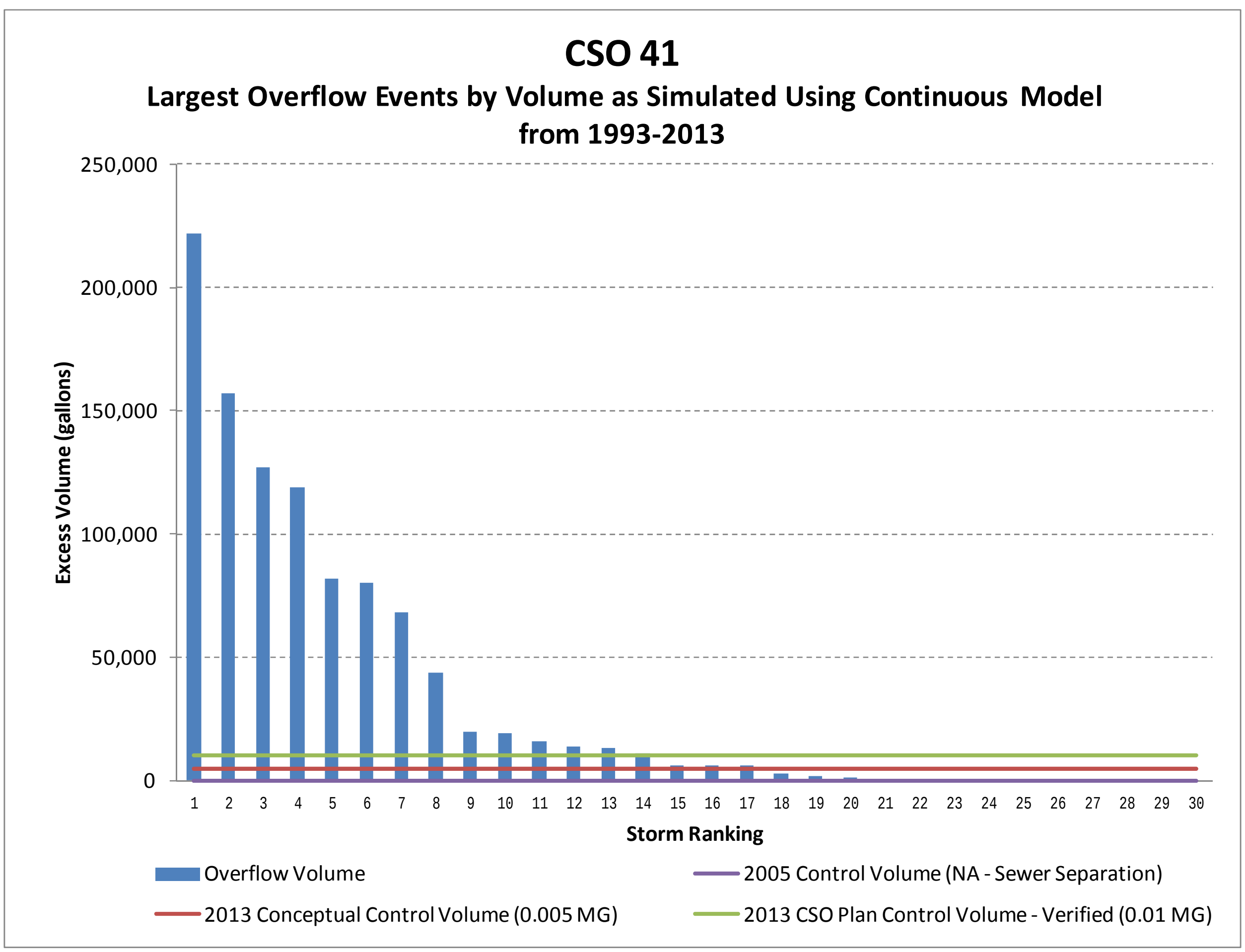

CSO 24/25
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (5.25 MG)
2013 Conceptual Control Volume (2.00 MG)
2013 CSO Plan Control Volume - Verified (2.00 MG)

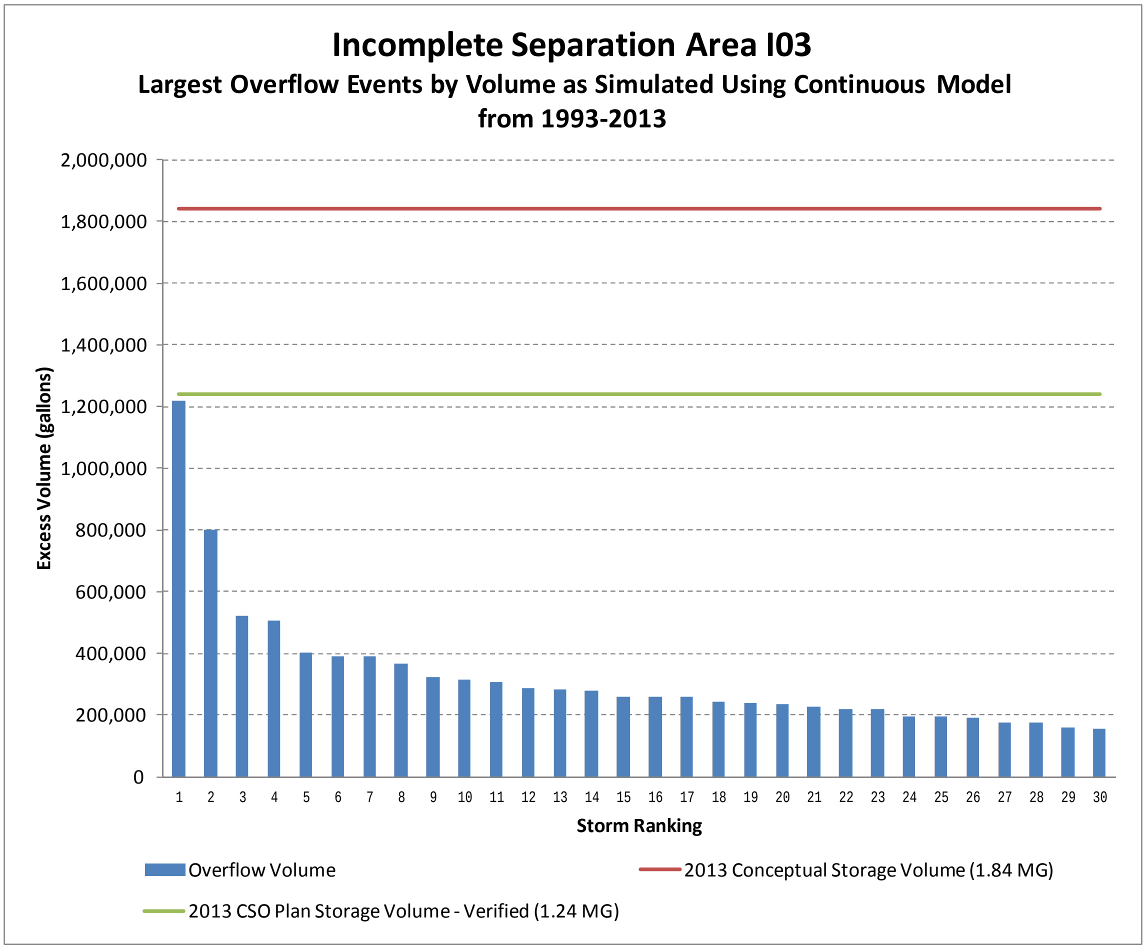

CSO 26
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (7.08 MG)
2013 Conceptual Control Volume (2.02 MG)
2013 CSO Plan Control Volume - Verified (2.02 MG)


CSO 33-1
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Excess Volume (gallons)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (4.22 MG)
2013 Conceptual Control Volume (2.26 MG)
2013 CSO Plan Control Volume - Verified (2.04 MG)

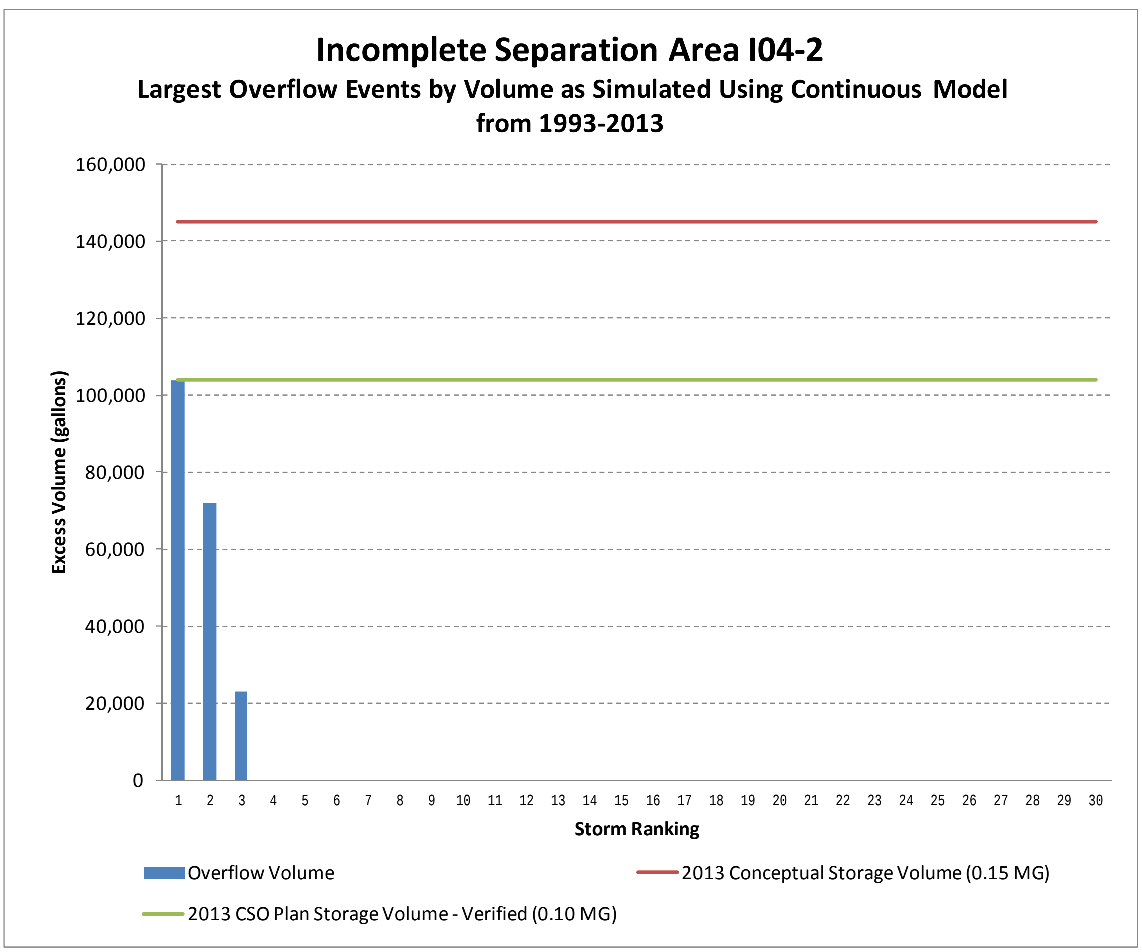

CSO 33-2
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Excess Volume (gallons)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (0.77 MG)
2013 Conceptual Control Volume (0.29 MG)
2013 CSO Plan Control Volume - Verified (0.42 MG)


CSO 34
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (2.80 MG)
2013 Conceptual Control Volume (2.79 MG - Combined with I-07)
2013 CSO Plan Control Volume - Verified (1.26 MG - Combined with I-07)

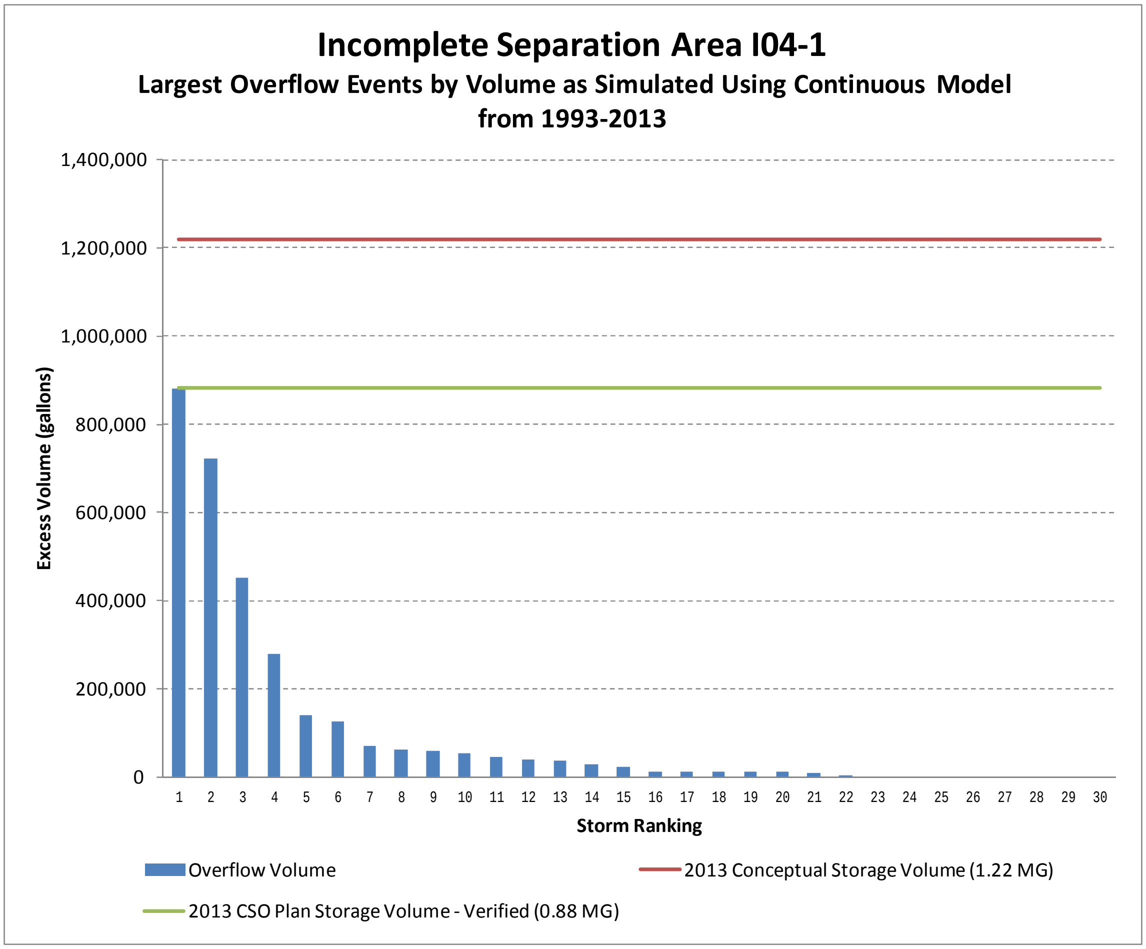

CSO 41
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
Excess Volume (gallons)
250,000
200,000
150,000
100,000
50,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2005 Control Volume (NA - Sewer Separation)
2013 Conceptual Control Volume (0.005 MG)
2013 CSO Plan Control Volume - Verified (0.01 MG)

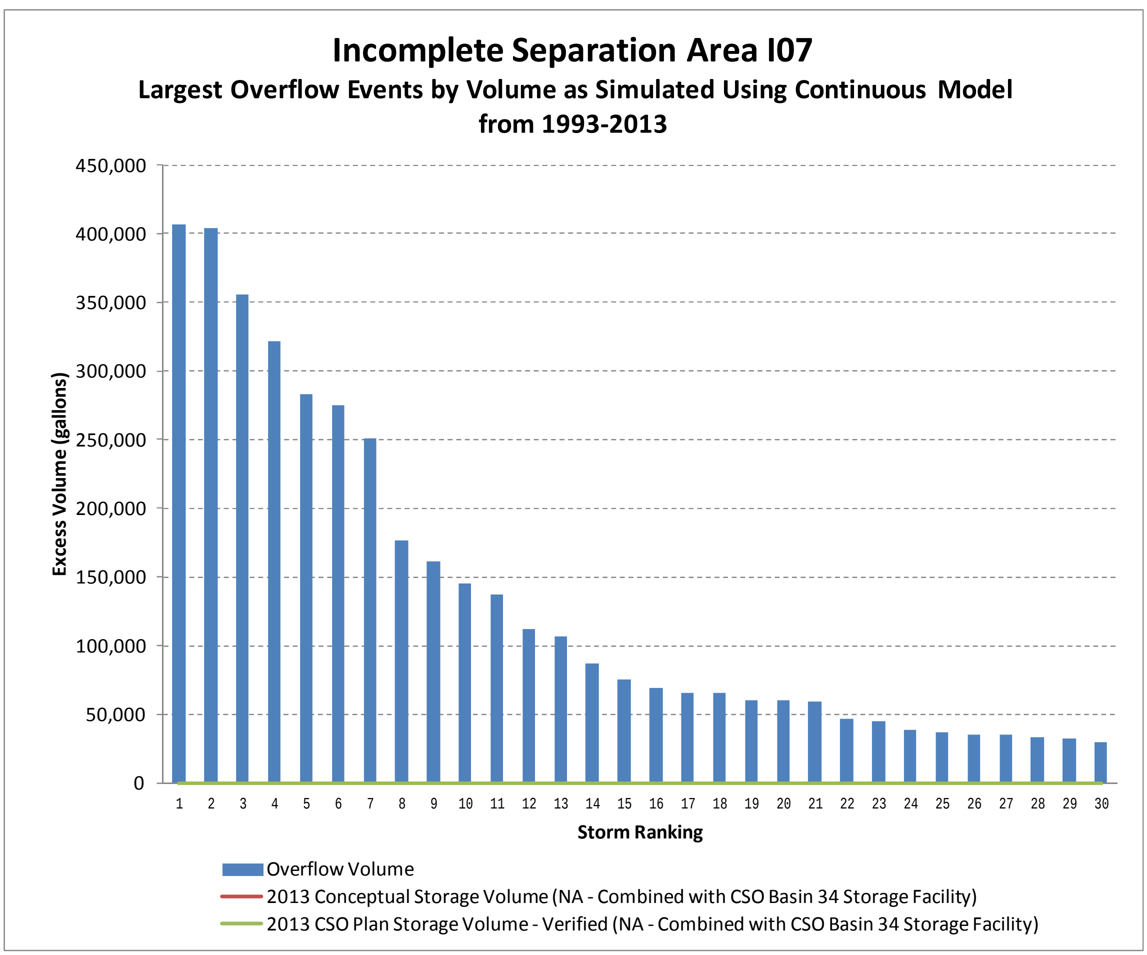


Incomplete Separation Area I03
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
2,000,000
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Excess Volume (gallons)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2013 Conceptual Storage Volume (1.84 MG)
2013 CSO Plan Storage Volume - Verified (1.24 MG)



Incomplete Separation Area I04-2
Largest Overflow Events by Volume as Simulated Using Continuous Model from 1993-2013
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Excess Volume (gallons)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2013 Conceptual Storage Volume (0.15 MG)
2013 CSO Plan Storage Volume - Verified (0.10 MG)


Incomplete Separation Area I04-1
Largest Overflow Events by Volume as Simulated Using Continuous Model
from 1993-2013
Excess Volume (gallons)
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2013 Conceptual Storage Volume (1.22 MG)
2013 CSO Plan Storage Volume - Verified (0.88 MG)


Incomplete Separation Area I07
Largest Overflow Events by Volume as Simulated Using Continuous Model
from 1993-2013
Excess Volume (gallons)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Storm Ranking
Overflow Volume
2013 Conceptual Storage Volume (NA - Combined with CSO Basin 34 Storage Facility)
2013 CSO Plan Storage Volume - Verified (NA - Combined with CSO Basin 34 Storage Facility)