MARCH 14, 2014

Integrated Clean Water Plan

DRAFT

CH2MHILL

Message from Mayor Condon

When I was elected Mayor, I didn't realize that so much of my time would be spent talking about stormwater and wastewater. But the magnitude of the work that needed to be done and the expected price tag that came with it underscored its importance.

For me, good government requires delivering excellent services at an affordable price. I constantly consider and pursue new ways of doing business to benefit our citizens and deliver value. So, I challenged our Utility Division to take another look, to reconsider the assumptions, to find a path forward that would be both environmentally and financially responsible.

This Integrated Clean Water Plan is the result of that effort.

We spent a year reevaluating our work to reduce combined sewer overflows and stormwater runoff going to the Spokane River, along with plans to improve treatment at our wastewater facility. We identified a path forward that would reduce the cost by about $150 million and vastly improve the health of the river.

Interestingly, this work is pushing us to be "integrated" in more than just our solutions to stormwater and CSO projects. We already have committed to treat stormwater on site whenever we improve street infrastructure to lessen the impact on our wastewater system. And we are looking for opportunities to integrate other above-ground benefits into our projects, like improved parks, completed sidewalks, multi-modal connections, and projects that encourage private investment, enhance our business districts, and improve neighborhoods.

We've also embarked on a major update to our Comprehensive Plan chapter that deals with transportation and we're expanding it to include utility infrastructure. Streets are three-dimensional, and we must evaluate them and plan that way.

Frankly, it can be difficult to get people excited about utility projects that primarily occur underground, but the benefits of this work combined with the potential for above-ground improvements should help bridge that divide.

Certainly our outdoor beauty and recreational opportunities are some of the primary draws that make people and businesses choose Spokane. Through the heart of our downtown, we have a beautiful, wild river with falls that literally roar during spring runoff. We have to commit to protecting the river for current residents and future generations, if we are truly going to be the City of Choice.

In the end, that's why this is so important. We are steering change that will serve us for generations. I feel a great responsibility to get it right.

ELEMENT #5 – Measuring Success

The City is committed to measuring the success of this plan. The City has documented conditions as they exist today and will assess the effectiveness of the work going forward. The City will continue to monitor CSO frequency and volumes, the quantity and quality of wastewater at the RPWRF, and provide monitoring and modeling of stormwater and green infrastructure projects. This information will help determine regulatory compliance and actions that might be needed in the future.

ELEMENT #6
Adapting for the Future

This Integrated Clean Water Plan allows the City to adapt to changing conditions and changing information. The City has committed to removing stormwater from combined sewers and separated storm sewers when reconstructing streets and other infrastructure. The goal is to reduce the amount of water in our system and lessen overflows to the river. Green infrastructure is a likely method to accomplish this.

This adaptive management approach allowed the City to size facilities based on current information and still accommodate for growth and varying weather patterns as a result of climate change.

The City will codify this integrated approach to infrastructure planning through an update to its Comprehensive Plan, called Link Spokane. Rather than just considering the surface transportation uses for streets, the City is taking a three-dimensional view of its streets that includes connectivity for pipes and conduit and management of stormwater, along with multi-modal connections.

Questions or Comments on this Integrated Plan?

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CITY OF SPOKANE

Integrated Clean Water Plan

DRAFT

The City of Spokane (City) is proud to introduce its Integrated Clean Water Plan—a plan that meets the City's strategic objective of delivering a cleaner Spokane River faster in a financially responsible way.

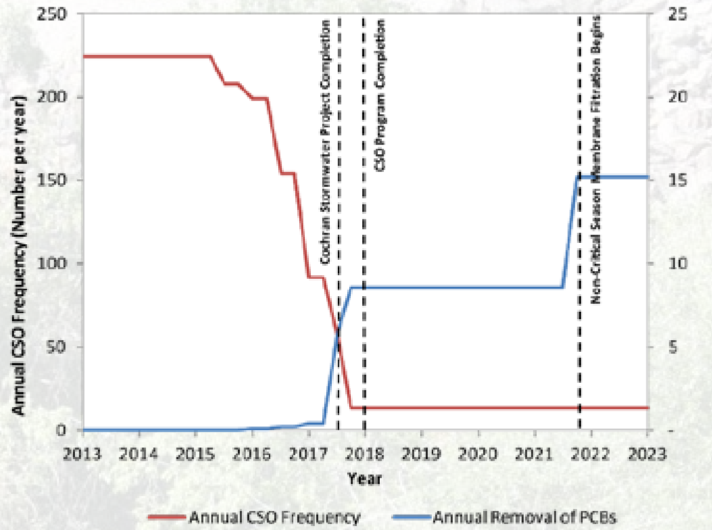
Facing significant costs, an aggressive timeline, and a changing regulatory environment, the City decided to take a new look at its plans to improve water quality in the Spokane River and meet Clean Water Act mandates, adopting an integrated approach to its planning. The City used the U.S. Environmental Protection Agency's Integrated Planning Framework as a guide and collaborated with the Eastern Region of the Washington State Department of Ecology.

An integrated approach requires the City to study all flows that bring pollutants to the river, consider all viable technologies and options to manage those flows, and develop a comprehensive solution that delivers the best value for the investment. Essentially, this approach is designed to get enhanced results more quickly at a more affordable price. The City included flows from its Riverside Park Water Reclamation Facility (RPWRF) along with discharges to the river from combined sanitary and stormwater sewers (CSOs) and separated storm sewers in this integrated approach.

The City established three primary objectives:

- To achieve a cleaner river faster, prioritizing work with the greatest potential to reduce pollution going into the river. The City is working to reduce phosphorus, PCBs, heavy metals, bacteria from sewage, and others.
- To implement cost-effective and innovative approaches. The City will spend dollars wisely and include "green" technologies as they make sense.
- To opportunistically address other critical infrastructure needs with Integrated Clean Water Plan projects.

City staff probed actual rainfall and overflow data, in addition to computer models, and maximized the use of the existing piping system. They considered the result of significant wastewater changes in our community, like the addition of Spokane County's Water Reclamation Facility, which frees up capacity in our main downtown sewer interceptor.



The City has made a commitment to manage stormwater on site when reconstructing streets or making other infrastructure improvements. The more water that is captured before entering City sewer and stormwater pipes, the less there is to flow to the river or to require treatment at the plant.

Overall, the plan will deliver significantly greater pollution reduction benefit to the river on a schedule that meets the City's tight regulatory deadlines. It includes about $310 million in work to be completed over the next four to five years; this collection of work represents the largest infrastructure investment in the City's history. Those savings will allow the City to complete the work while limiting annual utility rate increases to average cost of inflation over the last 25 years—or 2.9 percent.

Before considering this integrated plan, the City had expected to spend more than $450 million on improvements at the City's RPWRF and to reduce CSOs. Other sources of pollution, including stormwater, wouldn't have been addressed. With this integrated plan, the City saves money and prevents more pollution from entering the Spokane River – a win-win.

Ultimately, this Integrated Clean Water Plan will transform how the City manages stormwater and wastewater, while building critical new infrastructure and other above-ground improvements to build stronger neighborhoods and a healthier Spokane.

CH2MHILL

MARCH 14, 2014

Focus on Water Quality

A number of entities and mechanisms regulate water quality in the Spokane River and Long Lake. The overall goal of the regulations is attainment of designated uses, including aquatic life, recreational, and cultural uses. Also, there are less tangible (for example, spiritual) uses of the River and its resources that also depend on the quality of its waters.

The Spokane River and Lake Spokane are on the state's 303(d) list of impaired water bodies for polychlorinated biphenyls (PCBs) and bacteria (Category 5), and total phosphorus, zinc, lead, and dissolved oxygen (Category 4A). A TMDL is in place for dissolved oxygen (related to phosphorus), and additional TMDLs are being developed for dissolved cadmium, dissolved lead, and dissolved zinc. For PCBs, the City is working with Ecology and others on a toxics control task force to establish performance-based PCB limits. The City considered a number of pollutants to evaluate the projects, including fecal coliform bacteria, total suspended solids, total phosphorus, total zinc, dissolved zinc, and PCBs.

The Plan Elements

Following the EPA's integrated planning framework, the City of Spokane's Integrated Clean Water Plan includes six major elements: a discussion of regulatory requirements, a description of the existing system, a public involvement process, a selection of projects with implementation plans, a way to measure success, and a way to adapt the plan for the future. Below is a summary of each of these elements.

Why Integrated Planning?

This Integrated Clean Water Plan seeks to improve water quality of the Spokane River and achieve regulatory compliance. The City is focused both on implementing cost-effective and innovative technologies, and on addressing other critical infrastructure needs while developing Integrated Plan projects. Applying an Integrated Planning Framework to address CSOs, stormwater, and municipal wastewater treatment comprehensively maximizes the benefits provided by the City's clean water investments.

ELEMENT #1 Regulatory Requirements

This Integrated Clean Water Plan allows the City to meet its regulatory requirements related to water quality in the Spokane River and Lake Spokane. The City is subject to regulatory requirements across its range of stormwater, CSO, and municipal wastewater treatment services. All these requirements come from the Clean Water Act and are regulated through a National Pollutant Discharge Elimination System (NPDES) permit for both CSOs and municipal wastewater treatment, existing and potential future total maximum daily load (TMDL) limits, and the Eastern Washington Phase II NPDES Municipal Stormwater Permit. Other regulations also apply.

The regulations specify:

- A performance standard for controlled CSOs as not more than one discharge event per year on a 20-year moving average. The City is required to achieve this standard by the end of 2017.
- The implementation of an additional level of treatment, focused on reducing phosphorus and other pollutants going to the Spokane River and Lake Spokane at the RPWRF, with regulatory compliance by March 2021.

The projects in this Integrated Clean Water Plan also go beyond the City's current regulatory requirements. For example, the City has identified the Cochran stormwater basin as the largest point source contributor of stormwater to the Spokane River and has included a project to treat and infiltrate flows from the Cochran Basin in this plan. Although not specifically required, this project is expected to reduce the total amount of suspended solids by about 500,000 pounds a year.

ELEMENT #2 The Existing System

The City operates an extensive wastewater collection and treatment system that serves about 251,000 people in the Spokane metropolitan area. The system includes the RPWRF, which processes about 34 million gallons of wastewater daily, along with nearly 900 miles of sewer pipe, a variety of pumps and pump stations, and 22 combined sewer discharge points to the River.

This Integrated Clean Water Plan includes a comprehensive look at all the City's discharges to the Spokane River, including those from CSOs, separated storm sewers, and the City's RPWRF.

With this plan, the City is building on a long history of stewardship of the River and other surface waters. The City built the community's first sewage collection system and wastewater treatment plant, making significant and ongoing upgrades and improvements over the years. From 2000 through 2012, the City spent $220 million on clean water improvements. Projects to reduce overflows from combined sewers began in the early 1980s, with the City reducing those overflows by 86 percent to date.

ELEMENT #3 Public Involvement Process

Throughout the development of this Integrated Clean Water Plan, the City has worked diligently to open and maintain communication channels with the public, interested stakeholders, and regulatory agencies.

The City developed and implemented a communications action plan that relied on multiple communication approaches—from in-person presentations and meetings, to outreach to local media, to use of internet resources and social media—to reach more people in ways that are convenient for them. The City reached out to specialized interested stakeholders, including environmental advocates, users of the Spokane River, owners of property along the river's shores, and neighborhoods that would experience construction projects.

In all, the City made more than 40 presentations to stakeholder and citizen groups, reaching nearly 1,400 people. The City also partnered with The Lands Council to provide door-to-door outreach and completed dozens of other communications.

In parallel efforts, the City also kept staff from regulatory agencies and the Spokane Tribe engaged and informed. The City held about 30 meetings with regulators, elected officials, and Tribal leaders.

ELEMENT #4 Selecting Projects & Plans for Implementation

This Integrated Clean Water Plan details a significant amount of work to be completed over four to five years, including:

- A series of projects to **control overflows from combined sewers** and meet current regulations.
- Management of **stormwater coming from what's called the Cochran Basin** on Spokane's North Side, where the City separated storm sewers in the 1980s. About half the volume of stormwater runoff that reaches the river comes from this single stormwater outfall.
- Construction of **tertiary treatment at the RPWRF** and plans to operate it year-round to get additional pollution reduction benefits. The City only is required to run tertiary treatment during the "critical" 8-month season.

The projects use different technologies–including storage and/or conveyance of CSOs, treatment and infiltration of stormwater with green infrastructure, and treatment of municipal wastewater at the RPWRF–to reduce pollutant loading to the Spokane River. This combination of projects achieves greater pollution reduction than would have been possible if these clean water investments were implemented just to meet regulatory requirements.

The projects were selected using a set of criteria designed to ensure value for the dollars that will be spent and maximize benefits. The criteria included environmental outcomes, community benefits like improved streets and economic development, operations and maintenance considerations, ability to meet regulatory requirements, and life-cycle costs. The City has:

- **Re-sized tanks** to manage overflows from combined sewers based on actual rainfall and overflow data to meet current regulations.
- **Optimized the use of the overall piping system** for storage during storms and accounted for the addition of a new wastewater treatment plant built by Spokane County that reduces the amount of wastewater in our system.
- **Incorporated stormwater removal** from City piping systems during street construction.

Overall, the projects total about $310 million. Although they represent a significant cost savings from previous plans, these investments still require a significant financial investment by the citizens of the City of Spokane. The EPA's integrated planning framework addresses communities' financial capabilities, and the City of Spokane's median household income is 70 percent of the statewide media household income and about 78 percent of the U.S. median household income.

With that financial consideration, and because improving the health of the Spokane River provides a statewide benefit, a sharing of costs with the state is appropriate. The City is seeking a partnership that would include an investment by the state equal to 20 percent of the overall project cost, or approximately $62 million.

City of Spokane Integrated Clean Water Plan-DRAFT

Prepared by: CH2M HILL

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Amy M. Carlson, P.E.

CH2M HILL, March 2014

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Santtu A. Winter, P.E.

CH2M HILL, March 2014

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Acronyms and Abbreviations

ASA	Aquifer Sensitive Area
BOD	biochemical oxygen demand
C3	Conceptual Cost Calculator
CARA	Critical Aquifer Recharge Areas
CBOD	carbonaceous biochemical oxygen demand
CEPT	chemically enhanced primary treatment
cfs	cubic feet per second
CFU	colony forming unit
CSO	combined sewer overflow
CTE	Consoer Townsend Envirodyne Engineers (now operating as AECOM)
CWA	Clean Water Act
DDT	dichlorodiphenyltrichloroethane
DO	dissolved oxygen
Ecology	Washington State Department of Ecology
GI	Green Infrastructure
IDEQ	Idaho Department of Environmental Quality
I/I	infiltration and inflow
LID	Low Impact Development
MF	membrane filtration
MG	million gallons
mgd	million gallons per day
µg/L	micrograms per liter
mg/L	milligrams per liter
MODA	Multi-Objective Decision Analysis
ng/L	nanograms per liter
NLT	next level of treatment
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
NTR	National Toxics Rule
pg/L	picograms per liter
PCB	polychlorinated biphenyl
RCW	Revised Code of Washington
RM	river mile

RPWRF	Riverside Park Water Reclamation Facility
SAJB	Spokane Aquifer Joint Board
SCADA	supervisory control and data acquisition
SCCD	Spokane County Conservation District
SCRWRF	Spokane County Regional Water Reclamation Facility
SRF	State Revolving Fund
SRRTTF	Spokane River Regional Toxics Task Force
SRSM	Spokane Regional Stormwater Manual
SURGE	Spokane Urban Runoff Greenway Ecosystems
SVRP	Spokane Valley-Rathdrum Prairie
SWA	Systems Wide Alternative
TEQ	toxicity equivalent
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TSS	total suspended solids
UIC	Underground Injection Control
USEPA	United States Environmental Protection Agency
WAC	Washington Administrative Code
WQ	water quality
WRIA	Water Resources Inventory Area
WSDOE	Washington State Department of Ecology

Introduction and Background

The City of Spokane (the City) has developed this Integrated Clean Water Plan following United States Environmental Protection Agency (USEPA) guidance, in cooperation with the Washington State Department of Ecology (Ecology), to achieve a Cleaner River Faster. The City implemented this planning process to integrate the City's clean water investments, including projects for stormwater, combined sewer overflows (CSOs), and the next level of treatment (NLT) of municipal wastewater at the City's Riverside Park Water Reclamation Facility (RPWRF)—all focused on achieving a Cleaner River Faster.

This Integrated Clean Water Plan builds off of the City's CSO Plan Amendment (draft submitted to Ecology December 31, 2013) and Wastewater Facilities Plan Amendment No. 3 (draft submitted to Ecology January 6, 2014), integrating CSO projects, stormwater projects, and municipal wastewater treatment projects into an overall investment focused on water quality.

This Integrated Clean Water Plan is intended to guide the City's clean water investments starting in March 2014. The analyses described in this Integrated Clean Water Plan are based on monitoring data through September 2013 and computer modeling simulations through July 2013. Status of ongoing projects are as of December 31, 2013.

Addressing individual projects and programs as part of an Integrated Clean Water Plan maximizes benefits from each dollar spent. The City evaluated Integrated Clean Water Plan projects based on benefits provided, as defined below. The larger the benefit of any one project, the better the project for the people and aquatic resources of Spokane. Benefit is defined as one or more of:

- **Environmental Outcomes**: Remove pollutants, protect the aquifer, and improve aesthetics.
- **Integrated Benefits**: Minimize construction impacts, increase opportunity for economic development, and create lasting public benefit to other City infrastructure improvements (for example, drinking water distribution and roadway condition).
- **Operations and Maintenance Considerations:** Optimize maintenance and operations, maintain safety and security of City resources and the public.
- **Risks**: Reduce functional risk, reduce regulatory risk, and increase adaptability.
- **Cost**: Reduce life-cycle costs.

USEPA'S INTEGRATED PLANNING FRAMEWORK

USEPA's Integrated Planning Framework allows municipalities to balance Clean Water Act (CWA) requirements in a manner that addresses the most pressing public health and environmental protection issues first. The Integrated Planning Framework encourages the use of innovative technologies, including green infrastructure (GI), and maintains existing regulatory requirements that protect public health and water quality.

Consistent with USEPA's Integrated Planning Approach, and in coordination with Ecology, the City has chosen to implement Integrated Planning, which is documented in this Integrated Clean Water Plan.

RELATIONSHIP TO CITY OF SPOKANE'S CSO PLAN AMENDMENT AND WASTEWATER FACILITIES PLAN AMENDMENT NO. 3

This Integrated Clean Water Plan is consistent with, and encompasses, the City's 2013 CSO Plan Amendment and Wastewater Facilities Plan Amendment No. 3. All of these documents are focused on achieving 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.

The CSO Plan Amendment focuses on control of CSOs using conventional "gray" methods of storage and conveyance improvements, and does not include other technologies such as GI. The Wastewater Facilities Plan Amendment No. 3 analyzed several NLT alternatives to meet the new discharge limits at the RPWRF, focusing on environmental benefit of that investment.

This Integrated Clean Water Plan integrates all of the City's clean water planning efforts, including those for CSOs, stormwater, and for municipal wastewater treatment at the RPWRF. This Integrated Clean Water Plan uses the CSO Plan Amendment as the basis for the CSO investments and then adds stormwater and municipal wastewater treatment including NLT. In addition, this Integrated Clean Water Plan enhances the CSO Plan Amendment by including GI as both a CSO and a stormwater management tool.

This Integrated Clean Water Plan continues the analysis begun in the Wastewater Facilities Plan Amendment No. 3, which selected membrane filtration at a nominal capacity of 50 million gallons per day (mgd) as the alternative to be used to achieve the National Pollutant Discharge Elimination System (NPDES) permit-required NLT. This Integrated Clean Water Plan includes an analysis that justifies the "right-sizing" of membrane filtration at 50 mgd, and compares the cost and pollutant removal that could be achieved by constructing the Membrane Filtration facility at a higher nominal capacity of 85 mgd with other possible clean water investments. See Section 4.3 for details and the results of this analysis.

INTEGRATED CLEAN WATER PLAN DOCUMENT ORGANIZATION

Chapters of this Integrated Clean Water Plan are as follows, consistent with the elements of the USEPA's Integrated Planning Framework:

1. Water Quality, Human Health, and Regulatory Issues
2. Wastewater and Stormwater System Characterization and Performance
3. Public, Stakeholder, and Regulatory Agency Involvement
4. Alternative Development, Evaluation, and Selection
5. Measuring Success
6. Improvements to the Plan

The main chapters of this Integrated Clean Water Plan are followed by technical information in the Appendices.

Chapter 1: Water Quality, Human Health, and Regulatory Issues

This section follows the guidance of the USEPA's Integrated Planning Framework Element 1, and contains a description of the water quality, human health and regulatory issues to be addressed in the plan, including:

- An assessment of existing challenges in meeting CWA requirements and projected future CWA requirements (e.g., water quality-based requirements based on a new total maximum daily limit [TMDL])
- Identification and characterization of human health threats
- Identification and characterization of water quality impairment and threats and, where available, applicable wasteload allocations (WLAs) of an approved TMDL or an equivalent analysis
- Identification of sensitive areas and environmental justice concerns
- Metrics for evaluating and meeting human health and water quality objectives

1.1 RECEIVING WATER BODIES

The following subsections characterize the water bodies receiving flow from the City of Spokane's wastewater and stormwater systems. Water bodies described in this chapter are the Spokane River, Lake Spokane (formerly known as Long Lake), and Latah Creek (also known as Hangman Creek). The Spokane Valley-Rathdrum Prairie (SVRP) aquifer is also described in this section.

Because the majority of discharges from the City's CSO, stormwater, and treated effluent outfalls are discharged directly into the Spokane River and Lake Spokane, this Integrated Clean Water Plan focuses on assessing the water quality benefits to these two water bodies. However, Latah Creek and the SVRP aquifer are also discussed in this chapter. Figure 1-1 is an overview of the water bodies discussed in this Plan.

1.1.1 Spokane River

The Spokane River basin encompasses more than 6,000 square miles in Washington and Idaho, beginning at the outlet of Lake Coeur d'Alene and flowing west 112 miles before discharging in to the Columbia River. The River flows through the cities of Post Falls and Coeur d'Alene in Idaho, and through the large urban areas of the City of Spokane Valley and the City of Spokane in Washington. The Spokane River is the primary receiving water body for discharges from the City of Spokane's separated stormwater system, treated effluent from the RPWRF, untreated CSO discharges from the combined sewer system, and several other point and non-point source discharges. The Spokane River also receives discharges of treated effluent from the Cities of Coeur d' Alene and Post Falls, Idaho; the Hayden Area Regional Sewer Board Wastewater Treatment Plant; the Liberty Lake Water and Sewer District; the Spokane County Regional Water Reclamation Facility (SCRWRF); Inland Empire paper company; and Kaiser Aluminum, all located upstream of the City of Spokane. The City of Spokane is the primary discharger of stormwater to the Spokane River. Relatively smaller stormwater discharges are received from Spokane County, Washington State Department of Transportation, Post Falls Highway District, and the cities of Spokane Valley, Post Falls, and Coeur d'Alene.

There are seven dams on the Spokane River, all of which were built between 1890 and 1922 and are used to generate hydropower. The Upriver Dam is owned and operated by the City of Spokane Water and Hydroelectric Services Department, and the others are owned by the Avista Corporation, an investor-owned electricity and natural gas utility based in Spokane.

1.1.1.1 History and Land Use

Before construction of the hydroelectric dams, members of the Spokane Tribe and other native tribes congregated along the lower Spokane River to fish the spring salmon runs. With the dams and the growing population, land use along many portions of the River evolved through farming to urban development. Land uses within the Spokane River basin are becoming increasingly associated with residential home development, commercial development, and light industry. However, major areas of shoreline within the Riverside State Park system and other portions of the River are still undeveloped.

1.1.1.2 Habitat

Habitat along the Spokane River provides protection and food for many species. Bald eagles, osprey, great blue heron and other raptors and shorebirds currently are present along the shorelines of the River. Numerous waterfowl species, and other species such as beaver and moose, can be found in or along the waters of the River.

Spokane River fish species include many native and non-native species. Redband trout, rainbow trout, brown trout, cutthroat trout, Chinook salmon, kokanee, and others are either naturally reproducing or are stocked in the system. Spawning areas for redband trout and rainbow trout have been identified in the Spokane River.

1.1.1.3 Lake Spokane (Long Lake)

Lake Spokane (formerly called Long Lake) was formed when the Long Lake Dam was built on the Spokane River in 1915 at river mile (RM) 34 to generate hydropower. The resulting 24-mile-long reservoir (from Long Lake Dam to Nine Mile Dam) is used for fishing, boating, and swimming (Avista Corporation, 2014). The reservoir is contained within a long-winding canyon that has eroded into thick glacial-age deposits filling the ancient Spokane River valley. Tributary drainages within the reservoir are short, steep, and consist of small first, second, and third order streams. Adjacent land uses include agriculture, camping grounds, open space, and the towns of Nine Mile Falls and Suncrest.

The reservoir impounds water received from the 6,019-square-mile (mi^2) Spokane River drainage basin (Soltero et al., 1992). The inflow volume varies by year, but the reservoir volume is typically only 4 percent of the average annual flow. Soltero et al. (1992) concluded that 98.5 percent of the inflows to Lake Spokane come from surface waters (i.e., there is very little influence from groundwater in this section of the basin). The Spokane River and the Little Spokane River combined comprise 99.6 percent of the surface water inflow.

As with the other Spokane River dams, Long Lake Dam blocks fish passage. Lake Spokane is now habitat for rainbow trout and other non-anadromous fish species, both native and non-native. Avista Corporation, which currently owns Long Lake Dam, plans to begin stocking rainbow trout annually in Lake Spokane in 2014 as mitigation for fishery impacts from hydropower operation (Washington Department of Fish and Wildlife, 2014). The lake is known for low winter water levels that limit boat access.

1.1.2 Latah Creek (Hangman Creek)

Latah Creek (also known as Hangman Creek) drains approximately 690 mi^2 spanning across eastern Washington and northeastern Idaho and is a major tributary to the Spokane River. Latah Creek's contribution of nutrients and sediment to the Spokane River is important when addressing low oxygen and high nutrients in the River. Efforts to reduce nutrients, especially phosphorus, in the Latah Creek watershed will be necessary to address water quality issues in the Spokane River and Lake Spokane.

Agriculture is the significant land use within the basin, mostly in the upper to middle reaches of the watershed. Most of the cropland is non-irrigated annual small grain production. Livestock regularly have unrestricted access to small tributaries and the main stem of Latah Creek. The lower reaches of the watershed are becoming urbanized, with more urban growth projected.

1.1.2.1 Habitat

Wildlife of the Latah Creek area includes various waterfowl and other migrating birds, pheasant, deer, owls, coyotes, and moose. Great blue heron, river otters, beavers, bald eagles, osprey, white-throated swifts, and peregrine falcons (lower reaches near I-90 bridge) also are observed in and along Latah Creek. The local salmonid fisheries within the Latah Creek system are depressed.

1.1.3 Spokane Valley-Rathdrum Prairie (SVRP) Aquifer

Underneath the Spokane River lies the SVRP aquifer, the sole source of drinking water for more than 500,000 people in the region. The aquifer covers 322 mi^2 in Washington and Idaho and lies beneath the majority of the northern half of the City of Spokane. With a volume of approximately 10 trillion gallons the SVRP aquifer is one of the most productive aquifers in the United States. The SVRP is included in this Plan because water exchanges between the Spokane River and the SVRP aquifer.

The SVRP aquifer is very permeable and consists mainly of coarse sand, gravel, and boulders. Because of the high permeability of the soils in and above the SVRP aquifer, infiltrated stormwater runoff in some areas of the City moves rapidly downward into the aquifer (URS, 2000). Further water quality testing since 1977 has suggested that human activities over the aquifer are having an impact on the water quality in the aquifer (City of Spokane et. al., 2008).

1.2 WATER QUALITY AND HUMAN HEALTH ISSUES

1.2.1 Surface Water Quality Issues

The Spokane River, which flows into Lake Spokane, is the ultimate receiving water body for the majority of CSOs and stormwater that are discharged within the City, as well as the discharge of treated effluent from the RPWRF. Two CSO outfalls and a few stormwater outfalls discharge into Latah Creek, but the relative volume discharged into it is small compared to that discharged into the Spokane River. This Integrated Clean Water Plan focuses on water quality impacts to the Spokane River and Lake Spokane. The water quality issues discussed in the following sections refer only to the Spokane River. However, because Lake Spokane refers to a specific section of the Spokane River located just upstream of the Long Lake Dam, the water quality issues discussed also apply to Lake Spokane.

The CWA is the basis for all water quality regulatory drivers applicable to this Integrated Clean Water Plan and requires states to perform water quality assessments on surface water bodies for specified pollutants of interest, including fecal coliform, biochemical oxygen demand (BOD), total suspended solids (TSS), and total Kjeldahl nitrogen (TKN), among others. These assessments are updated periodically and are based on comparing monitoring data against water quality criteria.

In Washington State, these criteria are the Surface Water Quality Standards for surface water bodies found in Washington Administrative Code (WAC) 173-201A. The 303(d) impaired water body listing and subsequent total maximum daily load (TMDL) development, a result of the water body listing, occurs if the monitoring data show higher levels than applicable criteria.

Water quality criteria for a particular water body are dictated by designated uses of that water body. Table 602 in WAC 173-201A-600 specifies the designated uses for each freshwater surface water body in Washington State, which can include aquatic life uses, recreation uses, water supply uses, and miscellaneous uses. Each of these designated uses has specific pollutants of interest. For instance, primary contact recreation use criteria are met by limiting the amount of fecal coliform, while aquatic life uses are met by maintaining minimum dissolved oxygen (DO) levels.

Figure 1-1 presents an overview of the Spokane region and summarizes the designated uses for the Spokane River. Per WAC 173-201A-600 Table 602, the Spokane River between Nine Mile Bridge (RM 58.0) and the Idaho border (RM 96.5) through the City is designated for Salmonid Spawning/Rearing/Migration aquatic life uses, primary contact recreation uses, all water supply uses (domestic water, industrial water, agricultural water, stock water), and all miscellaneous uses (wildlife habitat, harvesting, commerce/navigation, boating, aesthetics). The Spokane River between Long Lake Dam (RM 33.9) and Nine Mile Bridge (RM 58.0) has a designated aquatic life use of Core Summer Salmonid Habitat and a recreation use of Extraordinary Primary Contact, both of which are more stringent use designations than for the section upstream between Nine Mile Bridge and the Idaho border. Because the Nine Mile Bridge separating these two river sections is proximate to Spokane, both are considered here. The sections share the same water supply use and miscellaneous use designations.

Aquatic life uses and recreational uses have related numeric water quality criteria and narrative water quality criteria. Water supply and miscellaneous uses have only narrative criteria. Washington State adopted narrative criteria to supplement numeric criteria. The narrative criteria are statements that describe a specific water quality goal, such as waters being "free from" pollutants such as color, odor, oil, scum, and other substances that can harm people and aquatic life. These criteria are used for pollutants for which numeric criteria are difficult to specify, such as those that offend the senses (e.g., color and odor).

Water quality standards for toxics (including PCBs and metals such as zinc) can be found both in the State of Washington water quality standards related to Aquatic Life Protection (WAC 173-201A-240) and at the federal level in the National Toxics Rule (NTR; USEPA, 1992). The NTR specifies Human Health Criteria for water consumption and for organism (e.g., fish) consumption. These criteria apply to the water and organisms being consumed, rather than the surface water body.

Ecology compares water quality monitoring data to applicable uses and pollutants to determine 303(d) listings of impaired water bodies. The Spokane River's Category 5 and 4a listings are summarized as follows:

- **Category 5 Listings:** These listings require a TMDL, and for the Spokane River include polychlorinated biphenyls (PCBs), total dissolved gas, bacteria, and 2,3,7,8-TCDD (an abbreviation for 2,3,7,8-Tetrachlorodibenzo-p-dioxin, a polychlorinated dibenzo-p-dioxin, which is a byproduct in organic synthesis and burning).
- **Category 4a Listings:** These listings already have an approved TMDL and are actively being implemented. For the Spokane River this includes total phosphorus, zinc, lead and dissolved oxygen.

Applicable Surface Water Quality Standards, the 303(d) listings for the Spokane River, and the subsequent TMDLs have resulted in specific monitoring requirements and/or effluent limits within the City's NPDES Permit for the RPWRF and CSOs, and contains specific interim monitoring requirements and/or effluent requirements for BOD, TSS, fecal coliform, pH, total PCBs, total residual chlorine, total ammonia (as NH_3-N), phosphorus (total as P), and total recoverable cadmium, lead, and zinc, with carbonaceous biochemical oxygen demand (CBOD) added, effective as of March 1, 2018.

See Chapter 2 for additional characterization of the receiving water bodies in the City of Spokane.

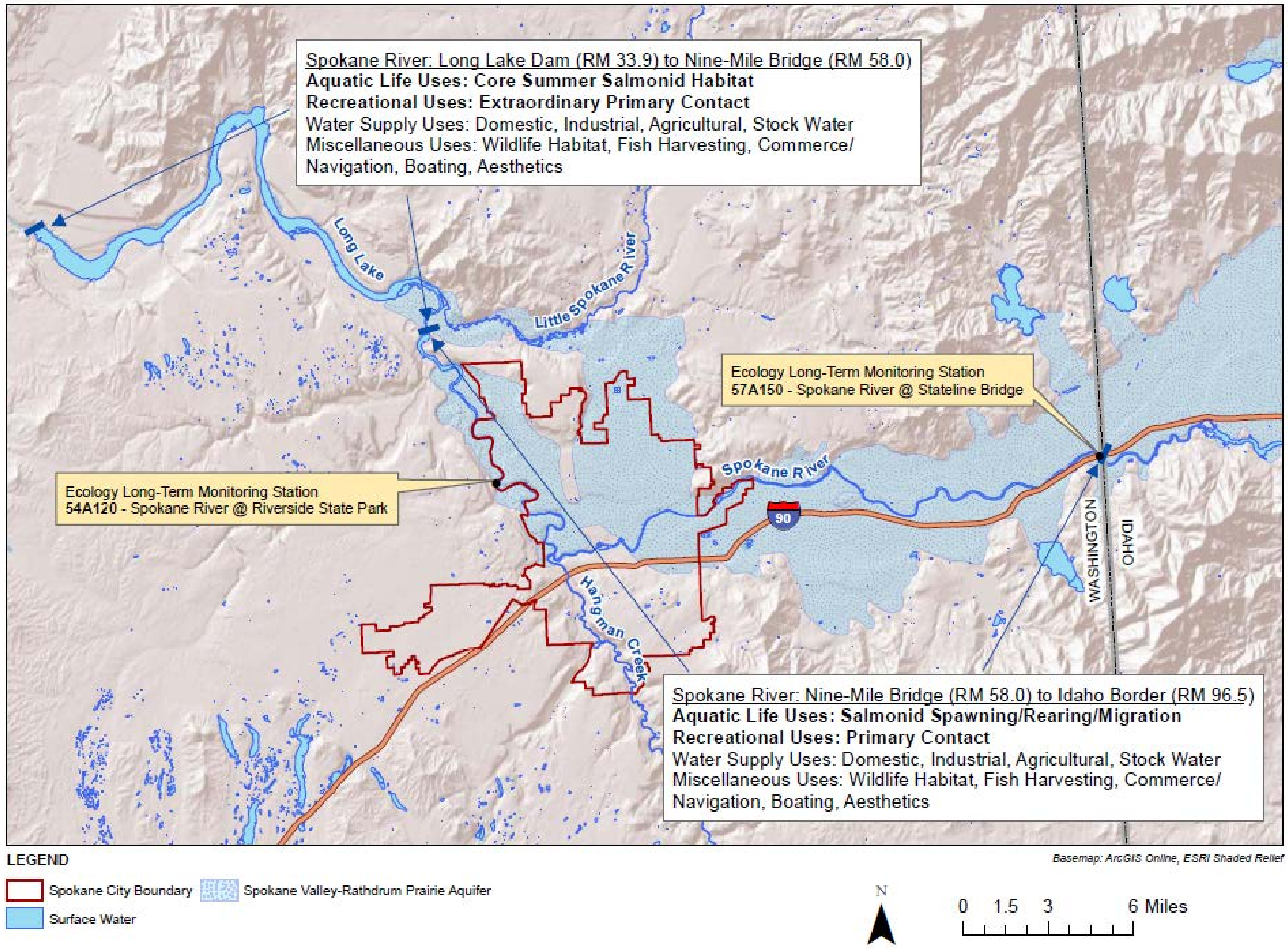

FIGURE 1-1
Use Designations for the Spokane River (per WAC 173-201A-600)

1.2.2 Groundwater Quality Issues

Protection of the SVRP aquifer as a drinking water supply is the priority of the City of Spokane, the Spokane Aquifer Joint Board (SAJB), and the Spokane County Water Resources Department which administers aquifer protection. The list of monitored pollutants is a result of Washington State Department of Health drinking water criteria, and includes total arsenic, cadmium, chromium, copper, lead, mercury, orthophosphate-phosphorus, total phosphorus, total nitrate + nitrite, total dissolved solids, zinc, and alkalinity, among others.

Because of the importance of the SVRP aquifer as a drinking water source, several regulatory steps have been taken to protect the aquifer, including:

- **Sole-Source Aquifer Designation**: The SVRP aquifer was designated a Sole Source Aquifer by USEPA in 1978. This Safe Drinking Water Act designation recognizes the importance of the aquifer as the only viable source of drinking water in the area.
- **Aquifer Sensitive Area (ASA)**: Provides protection to the aquifer by regulating groundwater recharges by requiring treatment for all stormwater runoff from pollution-generating, impervious surfaces in the City of Spokane.
- **Critical Aquifer Recharge Areas (CARA)**: These areas have high infiltration rates that create a high potential for contamination of groundwater, and also contribute significantly to groundwater recharge. As described in the Spokane Regional Stormwater Manual, "The CARA resolution adopted by Spokane County requires that special consideration be given to stormwater runoff from areas with commercial and industrial development where chemical spills are more likely to occur" (City of Spokane, et. al., 2008).
- **City of Spokane Comprehensive Plan Goals:** The Natural Environmental Chapter of the City of Spokane Comprehensive Plan identifies protecting the SVRP aquifer as a goal.

See Chapter 2 for additional characterization of the SVRP aquifer.

1.2.3 Human, Aquatic Life, and Wildlife Health Issues

The discharge of pollutants from the City's CSO, stormwater, and treated effluent outfalls to the Spokane River can impact humans, aquatic life, and wildlife in the Spokane region. These discharges contain a number of different types of pollutants, each presenting different issues. To address these issues, and to evaluate how well different projects improve the water quality of the Spokane River, a narrower list of pollutants was used in this Integrated Clean Water Plan to represent the different types of pollutants discharged and their impacts. Table 1-1 presents the selected representative pollutants for this Integrated Clean Water Plan (CH2M HILL, 2013a). These representative pollutants have different effects, depending on who or what is being exposed to the pollutants, as shown in Table 1-2.

It is important to note that from a human health protection perspective, Ecology is continuing to evaluate fish consumption rates used to support some of the state's water quality standards. The outcomes of this evaluation are unknown, but are likely to result in more-stringent standards related to human health risks for many pollutants. This uncertainty is another reason that the City is electing to focus on an integrated suite of potential water quality improvement projects from multiple types of discharges.

TABLE 1-1
Representative Pollutants for Integrated Planning

Pollutant	Pollutant Category	Regulatory Driver	Applicable Spokane River Designated Use or Driver
Total Phosphorus	Nutrients	TMDL for DO (related to phosphorus inputs); Category 4a 303(d) listing; effluent limitation in City's NPDES permit; numeric criteria in surface water standards (dependent on water body trophic state)	Aquatic Life Use (phosphorus affects DO) Water Supply and Miscellaneous Uses Wellhead Protection
Fecal Coliform	Bacteria	Category 5 303(d) listing; effluent limitation in City's NPDES permit; numeric criteria in surface water standards	Recreational Use Miscellaneous Uses Wellhead Protection
Total Suspended Solids (TSS)	Conventionals	Surrogate for turbidity, which has a numeric criteria; effluent limitation in City's NPDES permit	Aquatic Life Use (surrogate for turbidity) Miscellaneous Uses
Total Zinc	Metals	Category 4a 303(d) listing, also effluent limitations in City's NPDES permit	Aquatic Life Use, Water Supply Use Human Health Protection (toxics consumption, wellhead protection)
Dissolved Zinc	Metals	TMDL was developed for dissolved zinc (and lead and cadmium); numeric criteria in surface water standards (dependent on water body hardness)	Aquatic Life Use Water Supply Use
Polychlorinated biphenyls (PCBs)	Organics	Direct-to-implementation strategy for PCBs developed in lieu of TMDL; Category 5 303(d) listing; monitoring requirements in City's NPDES permit; numeric criteria in surface water standards	Aquatic Life Use Recreational Use Water Supply and Miscellaneous Uses Human Health Protection (toxics consumption, wellhead protection)

TABLE 1-2
Summary of Receptors and Effects of the Representative Pollutants

Pollutant	Receptor	Effect of Pollutant on Receptor
Fecal Coliform	Human	Gastroenteritis
PCBs	Human Wildlife	Cancer risk (from consumption of fish that have accumulated PCBs) Non-cancer effects (typically reproductive impairment)
TSS	Human Aquatic Life	Aesthetics (discolored water) High TSS blocks photosynthesis, which lowers DO levels, which affects aquatic life. Increased temperature lowers DO levels, which affects aquatic life. Impedes ability of fish to see and catch food, clogs gills, reduces growth rates, and decreases resistance to disease. Prevents egg and larval development. Smothers and suffocates newly hatched invertebrate larvae, base of fish food chain. Pollutants attach to suspended solids, TSS can be pollutant 'storage' sites
Total Phosphorous	Human Aquatic Life	Aesthetics (growth of unsightly or nuisance aquatic plants) Not directly toxic to aquatic organisms at levels and forms present in the environment. Effects on aquatic life are from increased eutrophication (e.g., enhanced growth of aquatic plants) and subsequent DO depletion. Presence of toxic blue-green algae.
Total Zinc and Dissolved Zinc[a]	Aquatic Life	Chronic toxicity to benthic invertebrates (organisms most sensitive to zinc toxicity)

[a]Total Zinc will over-represent biologically available (dissolved) zinc. Aquatic toxicity of zinc is hardness dependent.

1.2.4 Metrics for Evaluating Human Health and Water Quality Benefits

The overarching goal of this Integrated Clean Water Plan is to recommend a suite of projects that result in a Cleaner River Faster. It is important to be able to quantify what "cleaner" means. There are a number of different ways to quantify the water quality benefits from these projects, including one or a combination of the following:

1. Take a presumptive approach, where any reduction in pollutant loading will produce immediate and/or cumulative benefit to water and sediment quality.
2. A reduction in exposure of humans and aquatic organisms to representative pollutants resulting from control measures will be beneficial, regardless of the change in water quality measures.
3. Use measured or modeled (predicted) improved water quality compared to water quality standards, with water quality standards being set to provide a measure of protection to the most sensitive organisms.
4. Use risk assessment: A reduction in significant adverse effects on aquatic organisms and humans resulting from the combination of reduced exposure and/or reduced ingestion and habitat improvement resulting from pollutant load reduction.

The City has elected to quantify water quality benefits using the first method, which relies on a presumptive approach, for several reasons:

- This is the simplest method to measure water quality benefits, makes comparing the water quality benefits of various projects straightforward, and lends itself to an understandable cost per unit of pollutants removed.
- Water quality modeling would significantly lengthen the process of selecting a recommended Systems Wide Alternative, and would not be anticipated to substantially change the suite of recommended projects.
- A preliminary risk assessment indicated that a measurable reduction in the risk of an adverse effect would not be a distinguishing feature among the alternatives. This method would also be complicated by the fact that the risk of an adverse effect varied depending on the time of year. Similar to water quality modeling, this method would significantly lengthen the process of selecting a recommended Systems Wide Alternative.

The presumptive method described above does have limitations. For example, the value of removing pollutants from effluent during different times of the year is not captured in this method. The value of removing a large amount of pollutants during the winter may not be as beneficial as removing a large amount of pollutants during the summer, when recreation activities are more prevalent. The presumptive method also does not take into account the existing prevalence of a given pollutant. For example, if the receiving water body already has a very low concentration of a given pollutant, removing a large amount of that pollutant may not result in as significant a water quality benefit.

Although the presumptive approach does have limitations, it is a simple and effective way to compare the water quality benefits of various projects.

1.3 REGULATORY REQUIREMENTS

1.3.1 Water Quality Regulations

The Spokane River is the ultimate receiving water body for the majority of CSOs, stormwater, and treated effluent that is discharged within the City. Water quality in the Spokane River is regulated by a number of entities and mechanisms. In response to Surface Water Quality Standards, the 303(d) listings for the Spokane River, and the subsequent TMDLs, the City's NPDES permit contains the specific effluent requirements shown in Table 1-3.

TABLE 1-3

Regulatory and Other Drivers for Spokane River and Related Pollutants

Regulatory or Other Driver	Applicable Pollutants
Surface Water Quality Standards for Washington State (WAC 173-201A – Section 200 Freshwater Criteria)	Numeric criteria: DO, temperature, total dissolved gas, pH, turbidity, bacteria, nutrients, toxics (including metals and PCBs), and radioactive substances Narrative criteria: water supply uses: domestic, industrial, agricultural, stock; misc. uses: wildlife habitat, harvesting, commerce/navigation, boating, aesthetics
303(d) Listings (listing of impaired water bodies) (Washington State's Water Quality Assessment and 303(d) listings conducted in conformance with the requirements of the CWA)	303(d) listings for Water Resources Inventory Area (WRIA) 54 (Spokane River from Idaho border to mouth) by category: Category 5 (requires a TMDL), by sample media: PCBs (tissue), total dissolved gas (water), bacteria (water), and 2,3,7,8-TCDD (tissue) Category 4A (has a TMDL): Total phosphorus, zinc, cadmium, lead, and DO Category 2 (waters of concern – evidence of water quality problem): mercury, dichlorodiphenyltrichloroethane (DDT), pH, temperature, 2,3,7,8-TCDD toxicity equivalent (TEQ) Category 1 (meets tested standards for clean waters) : ammonia-N, pH, temperature, aldrin, mercury
TMDL	TMDL in place for DO (related to phosphorus) TMDL under development for: dissolved cadmium, dissolved lead, and dissolved zinc Direct-to-implementation strategy for PCBs developed in lieu of TMDL
City of Spokane NPDES Permit for Riverside Park Water Reclamation Facility and Combined Sewer Overflows (CSOs) (Ecology, 2011a)	Specifies interim effluent limitations for specific pollutants: BOD, TSS, fecal coliform bacteria, pH, PCBs, total residual chlorine, total ammonia (as NH3-N), phosphorus (total as P), cadmium (total recoverable), lead (total recoverable), and zinc (total recoverable); specifies effluent limitations for compliance with Spokane River TMDL (effective March 1, 2018) for all the above, plus CBOD; monitoring required for PCBs
Wellhead Protection (Spokane Aquifer Joint Board [SAJB])	List of monitored parameters (from SAJB): total arsenic, cadmium, chromium, copper, lead, and mercury, ortho-phosphate-phosphorus, total phosphorus, total nitrate + nitrite, total dissolved solids, zinc, and alkalinity, among others

1.3.2 CSO Regulations

The City operates its CSO control program within the NPDES permit program as authorized by the 1972 amendments to the Federal Water Pollution Control Act (CWA). Ecology has authority to administer the NPDES program on behalf of the 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 (WAC 173-201A).

The City's current NPDES permit (Permit No. WA-002447-3, effective July 1, 2011, expiration date June 30, 2016) (Ecology, 2011a) 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 to 2005, which specified a performance standard of not more than one discharge event per year based on a 5-year moving averaging period. The WAC specifies the performance standards, which are then carried out in the NPDES permits.

The City's combined sewer system is characterized in Section 2.1.

1.3.3 Stormwater Regulations

The Spokane Regional Stormwater Manual (SRSM) (Spokane County, City of Spokane, and City of Spokane Valley, 2008) is the primary regulatory document that guides the collection, treatment, and disposal of stormwater in the City of Spokane. It has been approved as equivalent to the Stormwater Management Manual for Eastern Washington by Ecology (Ecology, 2004). The SRSM stipulates that stormwater treatment facilities must be sized to treat either the water quality (WQ) storm volume or the WQ peak flow rate, depending on whether the treatment facility employs a volume-based or a flow-based process.

The City of Spokane received a Phase II Eastern Washington Municipal NPDES and State Waste Discharge General Permit from Ecology in 2007, which allows it to discharge stormwater into surface waters or ground waters of Washington State. The permit was modified in 2009 by Ecology, and reissued in unmodified form in 2012; it expires on July 31, 2014. The updated 2014-2019 permit will become effective on August 1, 2014. This updated permit includes two significant changes. First, the permit requires permittees to allow Low Impact Development (LID) stormwater management techniques in new development and redevelopment projects, where feasible. Second, the permit features new requirements for permittees to cooperatively develop and conduct Ecology-approved studies to assess effectiveness of permit-required stormwater management program activities and best management practices.

Additionally, the updated 2014-2019 permit requires the City to monitor the Cochran basin for pollutants associated with the DO TMDL, including phosphorus, ammonia, CBOD, and flow rates. No later than August 31, 2017 the City of Spokane must begin to evaluate the monitoring results with respect to the city's share of the stormwater waste load allocations.

Currently, there are no regulations in place that require the City to collect and treat the runoff from Cochran basin; however, stormwater regulations continue to evolve and are likely becoming more stringent in the future. This alternatives analysis is part of an initial effort to anticipate these changes and take preparatory steps to address them in order to achieve the Integrated Clean Water Plan's objective of a Cleaner River Faster.

The City's stormwater collection and conveyance system is characterized in Section 2.3.

1.3.3.1 Low Impact Development/Green Infrastructure

Low impact development (LID) is a form of green infrastructure (GI), and the two terms are used synonymously throughout this document. The Eastern Washington Low Impact Development Guidance Manual was published in June 2013. It was developed by Eastern Washington Phase II permittees and professional volunteers in coordination with the Department of Ecology. The manual provides guidance on these optional stormwater management tools to use for development and redevelopment projects. The City of Spokane adopted this manual in its stormwater ordinances in August 2013, citing it as an optional but preferred reference for use in LID projects. With the adoption of the LID manual, several of the City's ordinances were revised to allow and encourage the use of LID.

1.3.4 Underground Injection Control Regulations

Drywells and other underground injection facilities are regulated under Washington State's Underground Injection Control (UIC) Program, which protects underground sources of drinking water from discharges of fluids to the ground. As described in the "Guidance for UIC Wells that Manage Stormwater" (Ecology, 2006), the two basic requirements of the UIC Program are to: 1) register UIC wells with Ecology, and 2) make sure that current and future underground sources of groundwater are not endangered by pollutants in the discharge.

The City's drywells are characterized in Section 2.3.1.2.

1.4 OPPORTUNITIES FOR ENVIRONMENTAL JUSTICE AND SOCIAL EQUITY

USEPA defines Environmental Justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." As part of the Integrated Clean Water Plan, the City will strive to ensure balanced environmental justice and social equity through the implementation of the plan. This will be done through alternative development, evaluation, selection, siting of facilities, and maximizing additional benefits to the surrounding community. However, many of the clean water investments that are being considered in this Integrated Clean Water Plan need to be located close to already existing pieces of infrastructure, such as outfalls. As such, although the City will consider environmental justice and social equity in siting facilities, there are technical constraints on where the facilities can be sited. The City has already recognized the following opportunities for environmental justice from siting the following projects:

- CSO Basin 20 Improvements will provide a cleaner river for all users. With the completion of this project, less untreated sewage will be discharged to the Spokane River, creating a cleaner environment for everyone downstream. The attached maps in Appendix A show the ethnic population and low-income distribution for CSO Basin 20.
- West Broadway SURGE (Spokane Urban Runoff Greenway Ecosystems) is located in the West Central Neighborhood, which has a low-income population. The SURGE project will benefit this neighborhood by providing education, low impact development stormwater facilities, and enhancements of trees and plants in storm gardens.
- CSO Basins 38, 39, or 40 Improvements will provide a cleaner river and equal access to the river bank. With the completion of this project, less untreated sewage will be discharged to the Spokane River, creating a cleaner environment for everyone downstream. The site also includes reconstructing the existing trail, providing river views and equal access for everyone.

The City also considered environmental justice and social equity in the alternative evaluation process, by using a multi-objective decision analysis (MODA) process. This process, described in detail in Section 4.2.4, considers various factors in evaluating alternatives, including:

- System benefits and risks
- Environmental outcomes
- Integrated benefits, like minimizing construction impacts and increasing economic opportunities
- Operations and maintenance considerations
- Cost

The MODA process is a useful tool to help capture the environmental and social justice impacts of projects, because projects that provide higher benefits in these and other areas score higher. The MODA process is described in detail in Section 4.2.4.

The City also will consider environmental justice and social equity by incorporating community benefits into facilities that are built as part of this Integrated Clean Water Plan. For example, the top of a CSO storage facility provides an opportunity to create space for recreation or economic development. The City also will minimize the impacts during construction by following best management practices and working cooperatively with the neighbors who are affected by these projects.

Chapter 2: Wastewater and Stormwater System Characterization and Performance

This chapter follows the guidance of the USEPA Framework Element 2, and includes a description of existing wastewater and stormwater systems under consideration, and summary information describing the systems' current performance, including:

- Identification of municipalities and utilities that are participating in the planning effort and a characterization of their wastewater and stormwater systems
- Characterization of flows in and from the wastewater and stormwater systems under consideration

The primary objective of system characterization is to present a detailed description of the current conditions of the wastewater and stormwater systems and receiving waters. This assessment, a crucial component of the planning process, establishes the existing baseline conditions and provides the basis for determining receiving water goals and priorities and identifying specific projects for the Integrated Clean Water Plan.

The following sections characterize the City's wastewater collection system, wastewater treatment system, stormwater collection system, and receiving water bodies.

2.1 WASTEWATER COLLECTION SYSTEM

2.1.1 Wastewater Collection System Components

The City's wastewater collection system serves an estimated population of 251,000 people in the Spokane metropolitan area (Ecology, 2011b). Table 2-1 summarizes the key components of the City's wastewater collection system, with data contained in the City's NPDES Permit Fact Sheet (Ecology, 2011b).

TABLE 2-1
Sewer Collection System Components

Component	Value
Total length of sewer pipe (combined + separated sewer)	871 miles
Length of combined sewer pipe	400 miles
Length of separated sewer pipe	471 miles
Sewer lift stations	27
Inverted siphons (sag pipe facilities)[a]	18
CSO Outfalls	20[b]
Wastewater Treatment Plan Outfalls (includes treated CSO discharge)	1

[a] Two inverted siphons are inactive.

[b] The City has 20 permitted CSO outfalls, now that CSO outfalls 39 and 40 have been eliminated (in January 2013)

Based on the miles of pipe, approximately 54 percent of the City is serviced by a separated sanitary sewer system that is not intended to receive any direct stormwater inflow from roof drains and/or catch basins. Many of the currently separated areas are former CSO basins that underwent storm sewer separation during the 1980s and early 1990s. These separated areas of the City are located primarily north of the Spokane River, although there are some areas to the south of the River that also have separated sanitary sewer systems. Some of these areas continue to see a significant wet weather response despite the sewer separation projects, and thus are referred to as incomplete separation areas. The most significant incomplete separation areas are associated with the IO3, IO4, and IO7 interceptor segments. These incomplete separation areas do not have any flow control devices associated with them, and can take up valuable capacity in the interceptor system during storm events.

The portion of the City's main interceptor running along Aubrey L. White Parkway (referred to as IO2) 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 repaired. Protection of this critical infrastructure is paramount for the City. Although complete failure has not occurred, there were two near-misses in 1996 and 2006 when washouts occurred that threatened to undermine the interceptor to the extent that the interceptor itself was at risk, as shown in Figure 2-1. The City is undertaking actions to limit the flow in IO2 to no more than 120 mgd, which is 10 mgd less than the rated capacity of the pipe, as described in Section 4.1.1.2.

FIGURE 2-1
1996 Image of a Near-Failure of the Interceptor along Aubrey L. White Parkway

While 54 percent of the City is serviced by separated sanitary sewer system, the remaining 46 percent of the City is serviced by a combined sewer system, about 3/4ths of which is intended to convey both sanitary sewer flows and stormwater runoff. The remaining 1/4th of the area that is serviced by a combined sewer system contains dedicated sanitary sewers in newer areas that were built without storm connections, but see a wet weather response because they are located downstream from areas that do contain storm connections. Rainfall events that cause excessive amounts of stormwater runoff to enter the combined sewer system may result in CSOs. These overflows are discharged to the Spokane River through pipes called CSO outfalls, and consist of a mixture of partially treated stormwater runoff and raw sewage. The City currently has 20 permitted CSO outfalls. Section 1.3.2 describes the regulations governing the discharge of CSOs.

Each of the City's separated and combined sewer basins flow into the interceptor system, which is made up of larger-diameter pipes designed to convey flow to the RPWRF, as shown in Figure 2-2. The City's interceptor segments are labeled numerically, from IO1 through IO8.

Figure 2-3 presents the CSO runoff areas of the City's CSO basins. These areas have storm connections to the combined sewer system. Note that the runoff boundaries in Figure 2-3 and the sewerage boundaries in Figure 2-2 overlap, but are not the same. As an example, the southerly parts of CSO Basin 34 are dedicated sanitary only, but further downstream they discharge into trunks in the older CSO runoff area of CSO Basin 34 where inlets are connected to the wastewater collection system. So, sewage from this southerly dedicated sanitary area could overflow at the CSO regulator for CSO Basin 34.

2.1.2 History of CSO Control

The City's first piped sewage system was built initially as a combined sewer system. As described in the Final System Characterization Report (URS, 2000), the City has been aware of the problems associated with discharging sewage to the river since the 1890s, and was eventually warned by Washington State of potential water quality problems during the 1930s. In response to these concerns, the City constructed the interceptor sewer system and a wastewater treatment plant in 1950. These steps were the beginning of the City's efforts to reduce the frequency and volume of sewage discharges to local waterways.

CSO reduction planning began in 1972 with the Combined Sewer Action Plan (Esvelt and Saxon, 1972), and continued with the Facilities Planning Report for Sewer Overflow Abatement in 1979 (City of Spokane, 1979). Following the completion of these reports, the City completed nearly $50 million (in the year of expenditure dollars) in capital improvements from 1980 to 1992 to reduce CSOs to the Spokane River through separation with new storm sewers, mostly on the north side of town. Those projects reduced annual CSOs from an average of 570 million gallons (MG) to an average of 79 MG, representing an 86 percent reduction in annual CSO volume (City of Spokane, 2013a).

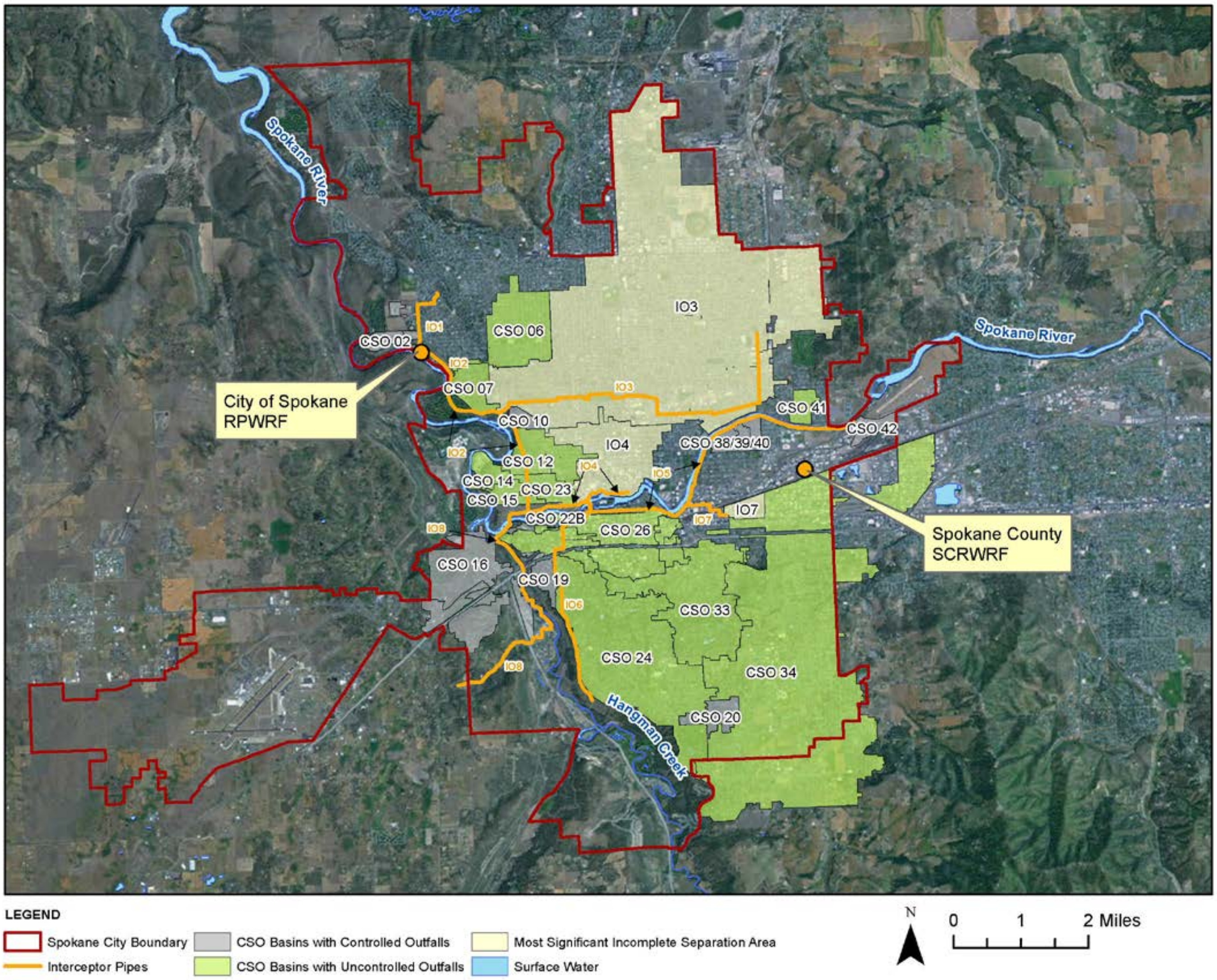

FIGURE 2-2
Sewerage Boundaries for CSO Basins and Incomplete Separation Areas, Interceptor System, and Water Reclamation Facilities

The 1994 Combined Sewer Overflow Reduction Plan (Bovay, 1994) recommended a combination of storage facilities, sewer separation, and conveyance improvements to control the City's remaining uncontrolled CSO outfalls. In 1999, the City began implementing its 1994 CSO Reduction Plan to control all remaining CSO outfalls by December 31, 2017. CSO reduction projects constructed following the completion of the 1994 CSO Reduction Plan through 2005 include multiple flow control and infiltration and inflow (I/I) projects, along with the 367,000-gallon pumped storage facility. The outfall at CSO 3 was functionally eliminated following this project, and reported as such to Ecology.

In 2005 the City completed the Combined Sewer Overflow Reduction System Wide Alternative Report (CTE, 2005), also referred to as the 2005 Plan, which included a comprehensive review of the City's combined sewer system. The objective of this report was to identify a set of CSO reduction projects that optimized the use of the interceptor sewer system and the RPWRF. Based on the recommendations in the 2005 Plan, the City constructed a total of six CSO control facilities associated with CSO Outfalls 10, 16, 19, 38 (two facilities), and 42. In addition to building CSO control facilities, the City has made weir modifications to regulators for CSO Outfalls 6, 7, 12, 14, 15, 25, and 26. The City has physically eliminated CSO Outfalls 3b, 16a and 16c, 18, 39, and 40, with CSO Outfalls 39 and 40 eliminated most recently in December 2012 (CH2M HILL, 2013b).

In addition to the storage facilities, weir modifications, and outfall eliminations, the City performs CSO reduction activities specified in the Nine Minimum Controls in the USEPA's CSO Policy. These activities include operations and maintenance, collection system I/I reduction, and optimization of wet weather treatment at the City's RPWRF. The City summarizes its activities and efforts related to the Nine Minimum Controls through required annual reporting to Ecology, most recently in its 2012 CSO Annual Report (City of Spokane, 2013a).

In December 2013 the City completed the Draft 2013 CSO Plan Amendment (CH2M HILL, 2013b), which recommended the construction of new storage facilities and conveyance improvements with an estimated total capital cost of approximately $183 million (in April, 2013 dollars). The recommended set of projects from the Draft 2013 CSO Plan Amendment are re-evaluated with other clean water investments in this Integrated Clean Water Plan, as described in Chapter 4. The City expects to finalize the 2013 CSO Reduction Plan Amendment in spring of 2014.

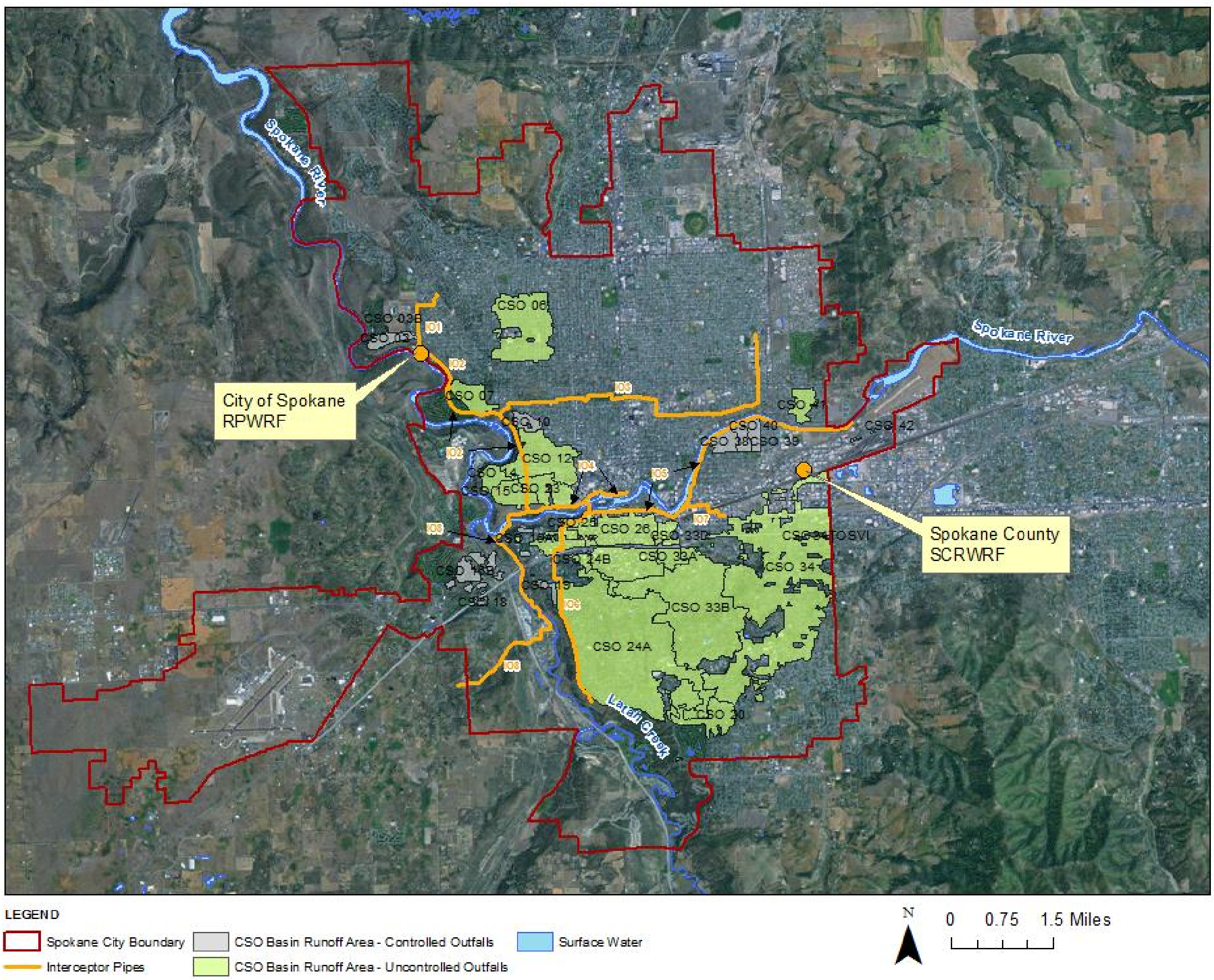

FIGURE 2-3
Runoff Areas for CSO Basins

2.1.3 CSO Monitoring (Flow, Precipitation, Effluent Quality) and Modeling

The City has been monitoring CSO event duration, frequency, and volume since 2000. Additional flow monitoring was conducted during the early to mid-2000s to be used to calibrate the City's hydraulic and hydrologic models. The City also collects flow monitoring data from various locations in the interceptor system, and has several flow meters that can be deployed as needed into the wastewater or stormwater collection systems.

As described in the "Combined Sewer System Model Inputs and Calibration Technical Memorandum" (CTE, 2010), precipitation measurements within the City have been underway since mid-1996. The City currently collects rainfall data from 13 rain gauges located throughout the City.

Over the last 20 years, the City has undertaken several efforts to conduct CSO effluent quality monitoring while CSOs were being discharged to the Spokane River, as shown in Tables 2-2 and 2-3. To provide some regional context for PCB concentrations, the average measured PCB concentration in an industrial area in King County, Washington, was 65,200 picograms per liter (pg/L), with a range of 8,000 to 455,000 pg/L (King County, 2011).

TABLE 2-2

City of Spokane CSO Effluent Quality Data

Pollutant	1994 CSO Reduction Plan[a]	Spokane River Dissolved Oxygen TMDL[b]	2013 Water Quality Monitoring by the City[c]	USEPA Report to Congress Typical Concentrations[d]
Total Phosphorus (mg/L)	>2	0.95	1.92	0.7
Fecal Coliform (CFU/100 mL)	2,000,000	NA	NA	215,000
TSS (mg/L)			203	127
Total Zinc (µg/L)	NA	NA	131	156
Dissolved Zinc (µg/L)	NA	NA	19	NA

[a] Bovay, 1994.

[b] Ecology, 2010.

[c] Collected in 2013 from May through September at CSO Basin 34. Concentrations presented are median values, collected during five overflow events.

[d] Median values, USEPA, 2004.

mg/L = milligrams per liter
CFU = colony forming unit
µg/L = micrograms per liter

TABLE 2-3

City of Spokane CSO Effluent Quality Data for PCBs[a]

CSO Outfall	2003-2007 Ecology Sampling[b]	2009-2011 Ecology Sampling[c]	2013 Water Quality Monitoring by the City[d]
6			12,700
7	2,490		
10		6,330	
24A	2,560		
26	3,380		
33		5,850	
34	14,800	177,000	12,300

[a] All concentrations in picograms per liter (pg/L)

[b] Ecology, 2011c.

[c] Ecology, 2012a.

[d] Collected in 2013 from May through September at CSO Basin 34. Concentrations presented are median values, collected during five overflow events. One event was sampled in November 2013 at CSO Basin 6.

The City has calibrated hydraulic and hydrologic models of most of the CSO basins in the City, built using the XP-SWMM modeling platform. These models were initially constructed in the early 2000s and have been updated as needed. The City has two types of models:

- **Basin Models**: These models simulate the combined sewer system in an individual CSO basin, and are used to establish control volumes and evaluate alternatives for CSO control. Each CSO basin that is modeled has its own Basin Model.
- **Interceptor Model**: This model simulates flows in the City's interceptor system, and is used to evaluate conditions in the interceptor system.

2.1.4 Current CSO Control Status and Pollutant Loads

The City has 20 NPDES-permitted outfalls. Of those, six have been addressed through implementation of CSO storage 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 current NPDES permit. In addition to the six outfalls addressed with storage facilities, CSO Outfall 22 appears to meet with the performance standard, but will also be addressed in an on-going CSO control project. Including CSO outfall 22, 14 uncontrolled outfalls remain. Figure 2-4 shows the outfalls that are controlled and those that remain uncontrolled based on monitoring data through December 2012. This information is also summarized in Table 2-4.

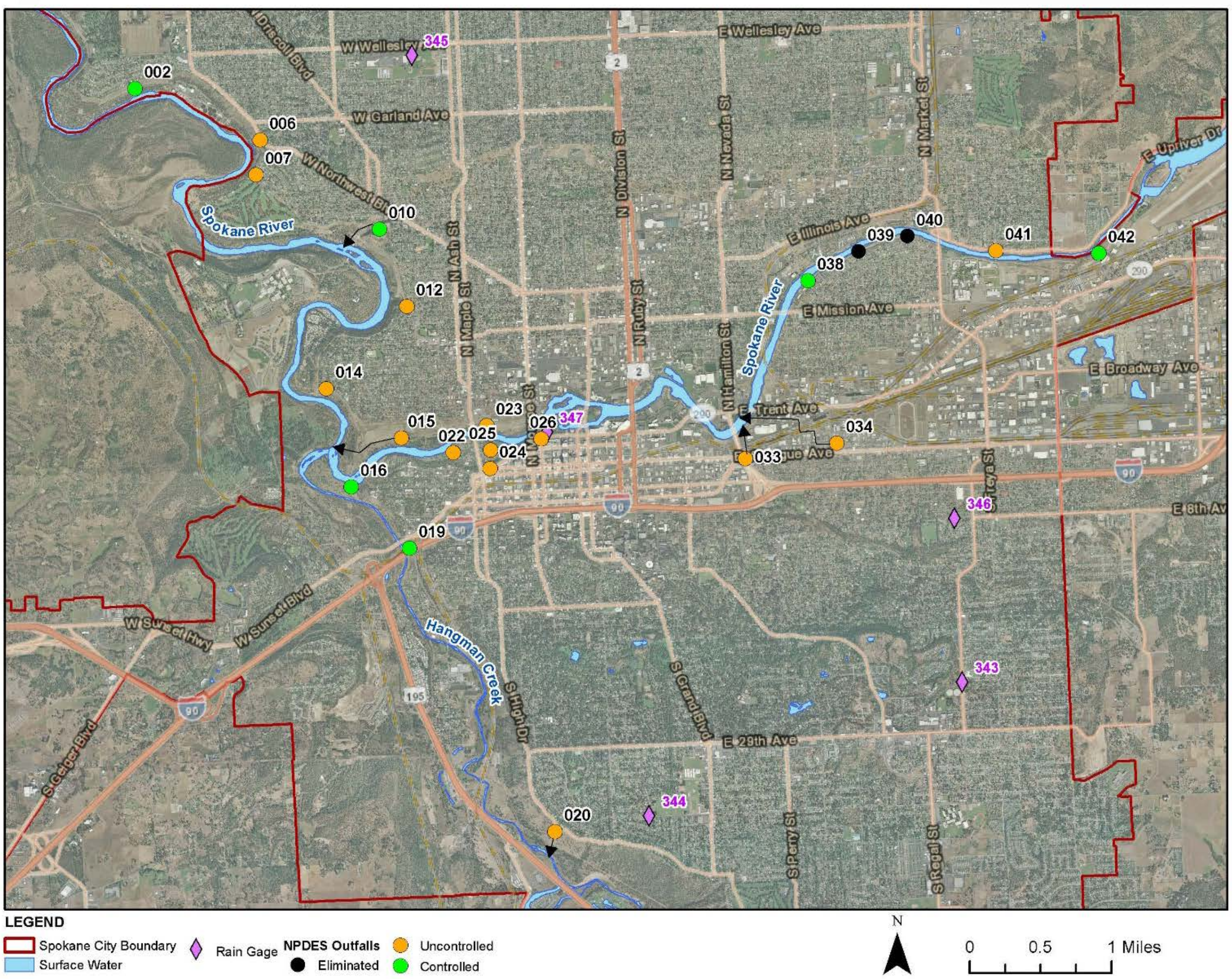

FIGURE 2-4
NPDES-Permitted CSO Outfalls in the City

TABLE 2-4
Summary of CSO Control Status through December 2012

CSO Outfall Number [a]	Average Annual CSO Frequency (Number per year)	Meets Performance Standard (average of 1 per year)	Built Facilities (year came online)
2	0.0 [b]	Yes [b]	2003
6	25.8	No	
7	10.6	No	
10	1.0 [b]	Yes [b]	2012
12	27.7	No	
14	14.0	No	
15	8.3	No	
16	0.0 [b]	Yes [b]	2007
19	0.0 [b]	Yes [b]	2010
20	0.4	Yes	
22	1.3	No	
23	16.5	No	
24	24.0	No	
25	18.9	No	
26	23.3	No	
33	27.8	No	
34	18.3	No	
38	0.0 [b]	Yes [b]	2012
39 [c]	NA	Yes [d]	
40 [c]	NA	Yes [d]	
41	11.1	No	
42	0.0 [b]	Yes [b]	2009

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

[b] Monitored CSOs per year with facility in place. Outfall has met performance standard since facility was built (year built specified).

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

[d] Considered to meet performance standard now that outfall is eliminated.

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

Figures 2-5 and 2-6 present the annual CSO frequencies and volumes discharged from the City's CSO outfalls, along with three-year running averages that show the overall trend in CSO frequency and volume. Note that the volume and frequency of CSO events is highly variable from year to year, being influenced by many factors. These include, but are not limited to, the annual rainfall and snowfall amounts, types of storm events, conveyance and other wastewater or stormwater system improvements, and operational causes.

The City currently is implementing projects in several of Spokane's CSO basins, including basins 20, 24, 33 and 34. Improvements in CSO Basin 20 will control that outfall through outfall elimination. The up basin substorage projects under way in both CSO Basins 24 and 34 are part of a multi-tank control strategy, which will require additional facilities to control those outfalls.

Details on these projects can be found in the 2013 CSO Plan Amendment (CH2M HILL, 2013b).

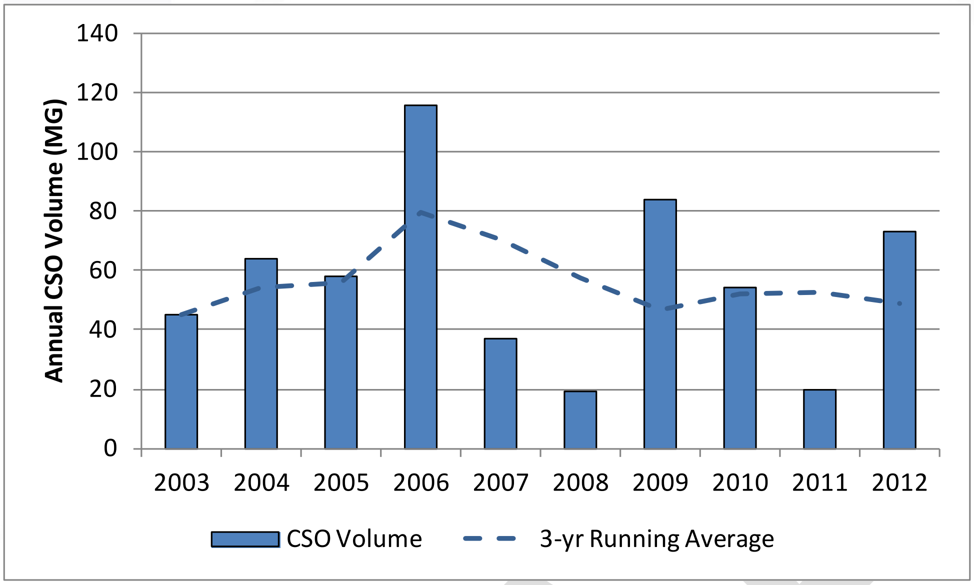

FIGURE 2-5
Annual CSO Volumes from 2003-2012 (City of Spokane, 2013a)

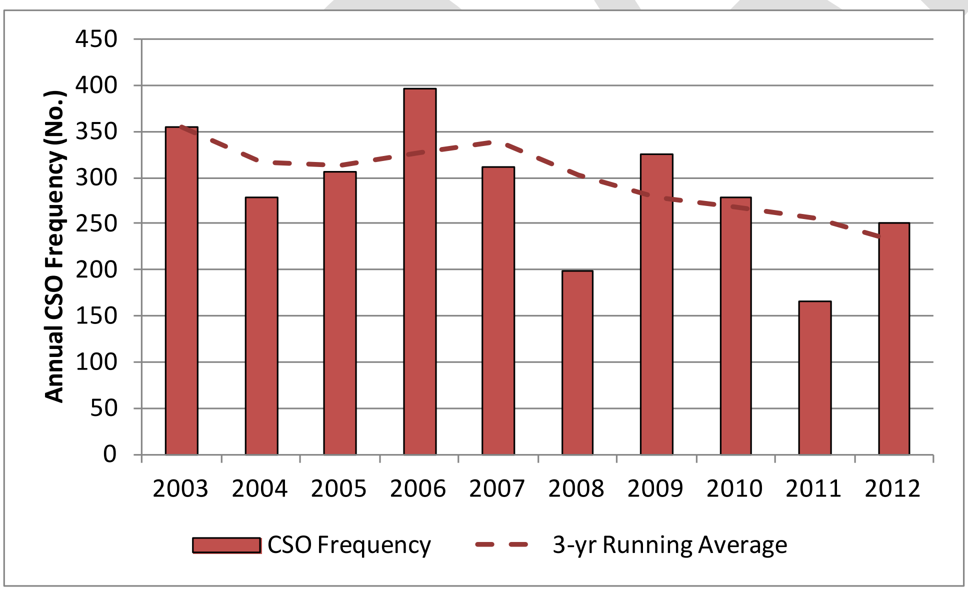

FIGURE 2-6
Annual CSO Frequencies from 2003-2012 (City of Spokane, 2013a)

2.1.4.1 Current CSO Pollutant Load Estimates

Figure 2-7 presents the current estimated pollutant load discharged by CSOs in the City of Spokane. Details on the calculation of these pollutant loads are presented in the technical memorandum "Pollutant Removal Benefits of City of Spokane CSO Basin Solutions" (CH2M HILL, 2014a), which is included as Appendix B.

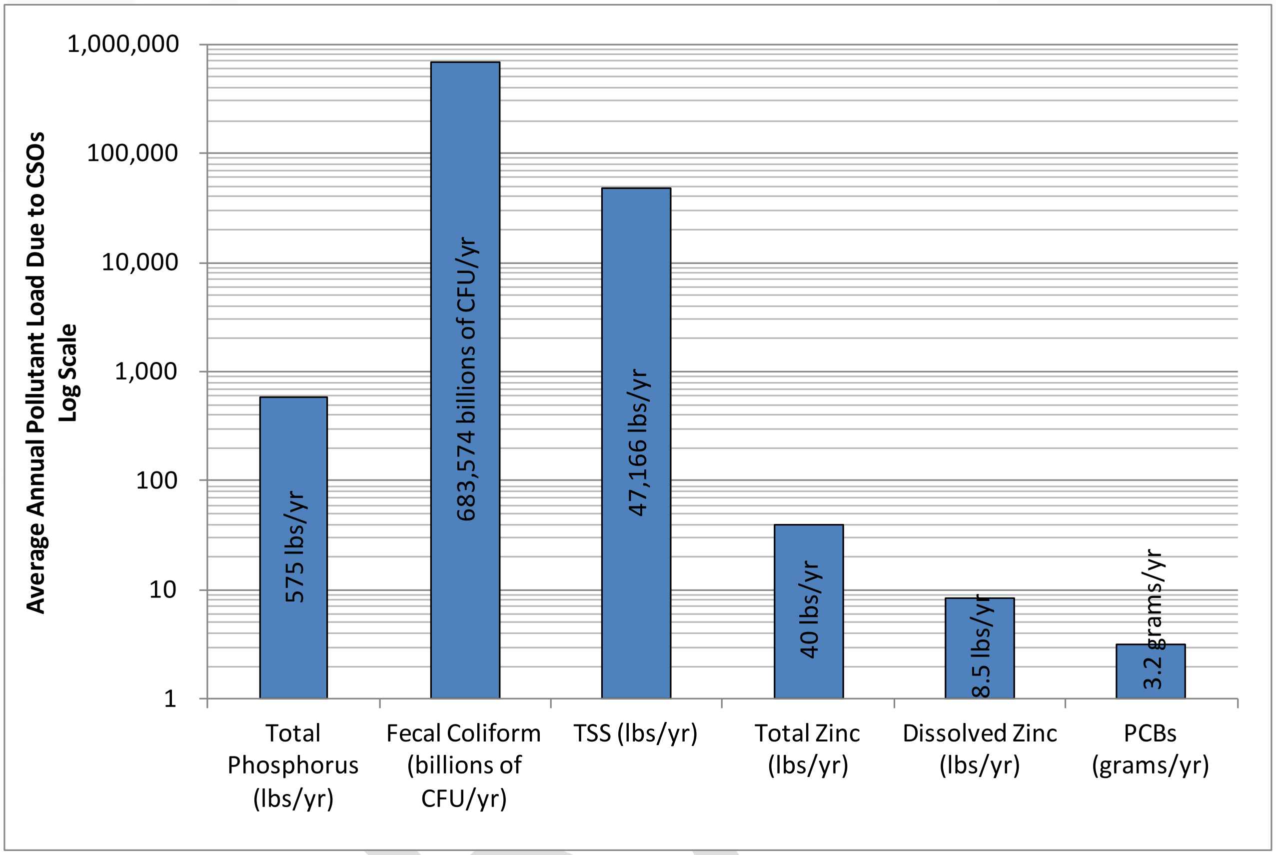

FIGURE 2-7
Average Annual Pollutant Loads Due to CSO Discharges in the City of Spokane

2.1.5 Infiltration and Inflow

I/I is an issue that affects almost all sewer systems. Infiltration is water that seeps through the ground and into the wastewater collection system through cracks in pipes, offset joints, and other underground defects. Inflow is water that enters the system through inappropriate connections, such as stormwater runoff that enters the system through the holes of a maintenance hole lid or around a cracked plug intended to prevent runoff from entering the sewer system through a former combined sewer storm inlet. I/I can be a significant source of flow in some sewer systems, can exacerbate or cause CSOs and/or sanitary sewer overflows, and can cause issues at water reclamation facilities.

Since the early 1970s, the City has been aggressively targeting the elimination of I/I in its sewer collection system through adopting policies and procedures, setting measurable goals for I/I reduction, and completing specific projects and programs. Some of these efforts are summarized as follows, with a more comprehensive list in the following sections:

- Implemented city-wide design standards for the construction of sewer/storm sewer/combined sewer design, construction and operation that minimize I/I into the collection system.
- Adopted development standards for new construction and redevelopment that requires separation of stormwater runoff from the combined sewer system where stormwater conveyance is available.
- Considered aggressive goals of I/I reduction as part of wastewater master planning and implementation.

- Adopted and funded an annual program completed by City staff to rehabilitate leaking pipes and structures using cured-in-place pipe slip lining technologies. Current capital planning budgets allocate $500,000/year towards slip lining and rehabilitation activities.
- Adopted a computerized maintenance and management system to schedule and track execution of necessary system management practices, including slip lining and other rehabilitation activities.
- Adopted an annual inspection program to visually inspect using closed circuit television and in some instances collect additional physical data on the condition and performance of the collection system as a means of identifying areas of excessive I/I and plan for appropriate I/I reduction measures.
- Adopted nationally recognized pipeline, manholes and laterals inspection and documentation protocols and received training for operations and maintenance staff.
- Completed the rehabilitation of 92,000 linear feet of sewer, storm, and combined sewer pipe and the rehabilitation of 110 manholes and other structures, removing 10 MG per year from the combined collection system.
- Removed two stream connections to the combined system in the South Hill area (Liberty Creek and Cowley Creek), removing approximately 1 mgd from the combined sewer system.
- Installed local weather stations throughout the City to better identify areas of rainfall derived I/I.
- Completed the North Side Separation Project (to Francis Street), removing 79 MG per year from the combined sewer system.
- Identified strategic areas or portions of the conveyance system within the City's service areas with significant I/I, including the South Hill and North Spokane commercial districts, River Interceptor (Sections I04, I05 (Upper and Lower), I07), and the Spokane Valley Interceptor; Completed planning and analysis, and began development and implementation of near and long-term I/I reduction and mitigation strategies for these areas.
- Implemented an ongoing flow monitoring program within the City's collection system to progressively identify areas of continued high I/I flows and to determine the effectiveness of previous I/I reduction measures put in place.
- Implemented ongoing groundwater level monitoring along the River Interceptor to identify Spokane River influence on infiltration into the collection system during spring runoff events.

2.1.5.1 Spokane River I/I

Flow monitoring throughout the City's collection system and at the RPWRF indicates that the Spokane River can sometimes be the source of I/I into the wastewater collection system. This form of I/I, called River I/I, typically occurs only when the flow in the Spokane River exceeds a certain flow threshold usually during late spring and early summer, although historic flooding has occurred in mid-winter. River I/I events can take up a significant amount of capacity in the City's wastewater collection system, which could cause surcharging of the interceptor and a washout event like that presented in Figure 2-1.

These events were also a key consideration in the City's analysis of the Membrane Filtration facility, because River I/I events can cause elevated flows to be sent to the RPWRF for extended periods of time. The City's long-term strategies to identify and eliminate them are discussed in more detail in Section 6.3.

2.1.6 Relationship to Spokane County System

Spokane County also owns and operates a wastewater collection and treatment system in the Spokane region that serves a population of approximately 65,000 people in North Spokane and Spokane Valley (Ecology, 2011b). However, the County continues to implement a septic tank elimination program, which is expected to increase the population serviced by the County's wastewater collection system to approximately 161,000 people by 2020. The ongoing goal of the sewer program is the elimination of septic tanks above the SVRP aquifer, which is Spokane's sole source for drinking water (Ecology, 2011b).

Key components of the County's collection system include approximately 270 miles of sanitary sewer and 20 pump stations (Ecology, 2011b). In late 2011 the County completed construction of the SCRWRF, which is an 8 mgd membrane bioreactor (filtration) plant located in east Spokane that receives flows from the County's Spokane Valley service area.

Flows from the North County and those in excess of the capacity of the SCRWRF currently are conveyed to the City's RPWRF. Future improvements to the County's treatment plant are expected to increase the capacity to 12 mgd by approximately 2021, further decreasing the volume of flow sent to the City.

2.2 WASTEWATER TREATMENT SYSTEM

2.2.1 Description and History of the RPWRF

As described in the NPDES Permit Factsheet (Ecology, 2011b), Spokane's RPWRF is located on a 28-acre site in northwest Spokane along the right (north) bank of the Spokane River. The facility provides wastewater treatment for flows from the City of Spokane, Spokane County (which serves the City of Spokane Valley and Town of Millwood), City of Airway Heights (currently treating and discharging its own flow), and Fairchild Air Force Base. The plant began operation in 1958 as a primary wastewater treatment plant. The treatment capacity was expanded in 1962. Major upgrades occurred from 1975 to 1977.

The RPWRF is considered a Class IV treatment plant at all times except during significant storm events. The RPWRF currently provides advanced secondary wastewater treatment, which includes conventional secondary treatment plus seasonal nitrification of ammonia, and seasonal chemical phosphorus removal (Ecology, 2011b).

Hydraulic overloading at the plant as a result of extreme storm events can cause occasional bypasses of the secondary treatment portion of the treatment plant. These bypasses have been historically regulated as a treated CSO, requiring the discharge to receive primary clarification and disinfection. The primary treated portion is blended with the portion receiving secondary treatment and disinfected. The blended effluent has been in compliance with effluent limitations (Ecology, 2011a). Since 2001, nine treated CSO discharges have occurred from the RPWRF.

2.2.2 Ongoing Upgrades at the RPWRF

As described in the NPDES Permit Factsheet (Ecology, 2011b), the current upgrades for the RPWRF began in 1997. These upgrades have included improvements in hydraulic capacity, replacing bar screens with fine screens in the headworks, a new influent box, a new septage receiving station, and two new digesters. The clarifiers and aeration basins have also been upgraded with pump replacements, and electrical system, telemetry, and supervisory control and data acquisition (SCADA) upgrades. In addition, fine bubble diffusers were added to the original aeration basins, a fifth aeration basin was added including denitrification capability, the laboratory has been relocated and expanded, and solids thickening, dewatering equipment, and odor control facilities have been added. The disinfection system was converted from gaseous to liquid chlorine, the primary solids pump station was upgraded, and a new boiler/cogen facility was constructed.

Additional upgrades to the RPWRF that are currently being planned include a new primary clarifier, new digester, solids recycle pump station, chemically enhanced primary treatment (CEPT)/chemical storage facility, storm clarifier improvements, various heating and odor control upgrades, and numerous equipment replacements.

2.2.3 Next Level of Treatment

As discussed in Chapter 1, multiple sections of the Spokane River, the receiving water body for the treated RPWRF effluent, are on Ecology's 303(d) list. In response to the dissolved oxygen 303(d) listings, Ecology prepared the Spokane River and Lake Spokane Dissolved Oxygen TMDL Quality Improvement Report (Ecology, 2010), which recommended substantial reductions in phosphorus, CBOD, and ammonia discharged to the Spokane River from point and non-point sources.

As a result of the Water Quality Improvement Report, the City's 2011 NPDES permit included requirements to implement an additional phosphorus removal treatment process at the RPWRF. The City's current NPDES permit (Ecology, 2011a) states that:

> *"Beginning March 1, 2018 the Permittee must have installed the full phosphorus removal process train including chemical addition and have operational the technology needed to comply with the following effluent limitations during the season March 1 to October 31. Beginning March 1, 2021 the Permittee is authorized to discharge municipal wastewater at the permitted location subject to complying with the following limitations".*

As described in the Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013c), the NLT will consist of a membrane filtration system with a nominal capacity of 50 mgd. The analysis to select 50 mgd as the capacity of the Membrane Filtration facility was conducted with the assumption that the flow rate coming into the RPWRF from IO2 does not exceed 120 mgd. This is an important parameter to achieve to protect the integrity of this interceptor, and because if the flow in IO2 frequently exceeds 120 mgd during storm events, the RPWRF would discharge larger amounts of secondary effluent during the critical season. The City is undertaking several actions to limit the flow in IO2 to less than 120 mgd, as described in Section 4.1.1.2.

2.3 STORMWATER SYSTEM

2.3.1 Stormwater Collection System Components

Apart from the City's combined sewer system, described in Section 2.1.1, the stormwater collection system is made up primarily of three systems:

- Separated stormwater sewer system (MS4), which conveys only stormwater runoff
- Bioinfiltration swales, drywells, and other facilities that treat and infiltrate stormwater runoff
- Evaporation facilities

The following subsections describe the separated stormwater system and drywell/infiltration facilities.

2.3.1.1 Separated Stormwater System

Approximately 22 percent, or nearly 10,000 acres, of the City is served by a separated stormwater system. Most of this area is located north of the Spokane River, as shown in Figure 2-8. Table 2-5 presents the components of the City's separated stormwater system.

As indicated by the number of stormwater outfalls, the City has approximately 130 stormwater basins, including 100 draining to the Spokane River and 30 draining to Latah Creek, the majority of which are less than 10 acres in size. Six of the City's priority stormwater basins (the Cochran, Kiernan, Hollywood, Rifle Club, Washington, and Union basins) make up approximately 75 percent of the total area served by a separated stormwater system. Most of these larger stormwater basins were created in the 1980s and 1990s as part of the City's stormwater separation projects for CSO reduction, and thus overlap with the Incomplete Separation Areas discussed in Section 2.1.1. Table 2-6 characterizes the area, land uses, and average annual runoff volumes for these six priority basins (CH2M HILL, 2013d).

TABLE 2-5
Stormwater Collection System Components[a]

Component	Value
Length of Stormwater Pipe	366 miles
Length of Storm Channels	0.5 miles
Stormwater lift stations	1
Stormwater Manholes	4,460
Inlets	16,690
Stormwater Outfalls	130
Stormwater Management Facilities	11
Wastewater Treatment Plan Outfalls (includes treated CSO discharge)	1
[a] Information from the City's Stormwater Pollution Prevention Operations and Maintenance Plan (City of Spokane, 2013b).	

TABLE 2-6
Characterization of the Priority Stormwater Basins in the City

Basin Characteristic	Cochran	Hollywood	Rifle Club	Washington	Kiernan	Union
Basin Area (acres)	5,328	711	647	453	397	82
Basin Impervious Area						
Acres	1,069	122	101	124	81	24
Percent of Total Area	20%	17%	16%	27%	20%	29%
Land Use Breakdown						
Residential	85%	99%	98%	51%	99%	0%
Commercial	12%	1%	2%	49%	1%	0%
Industrial	3%	0%	0%	0%	0%	100%
Approximate Average Annual Runoff Volume (MG/year)	297	35	30	34	22	7

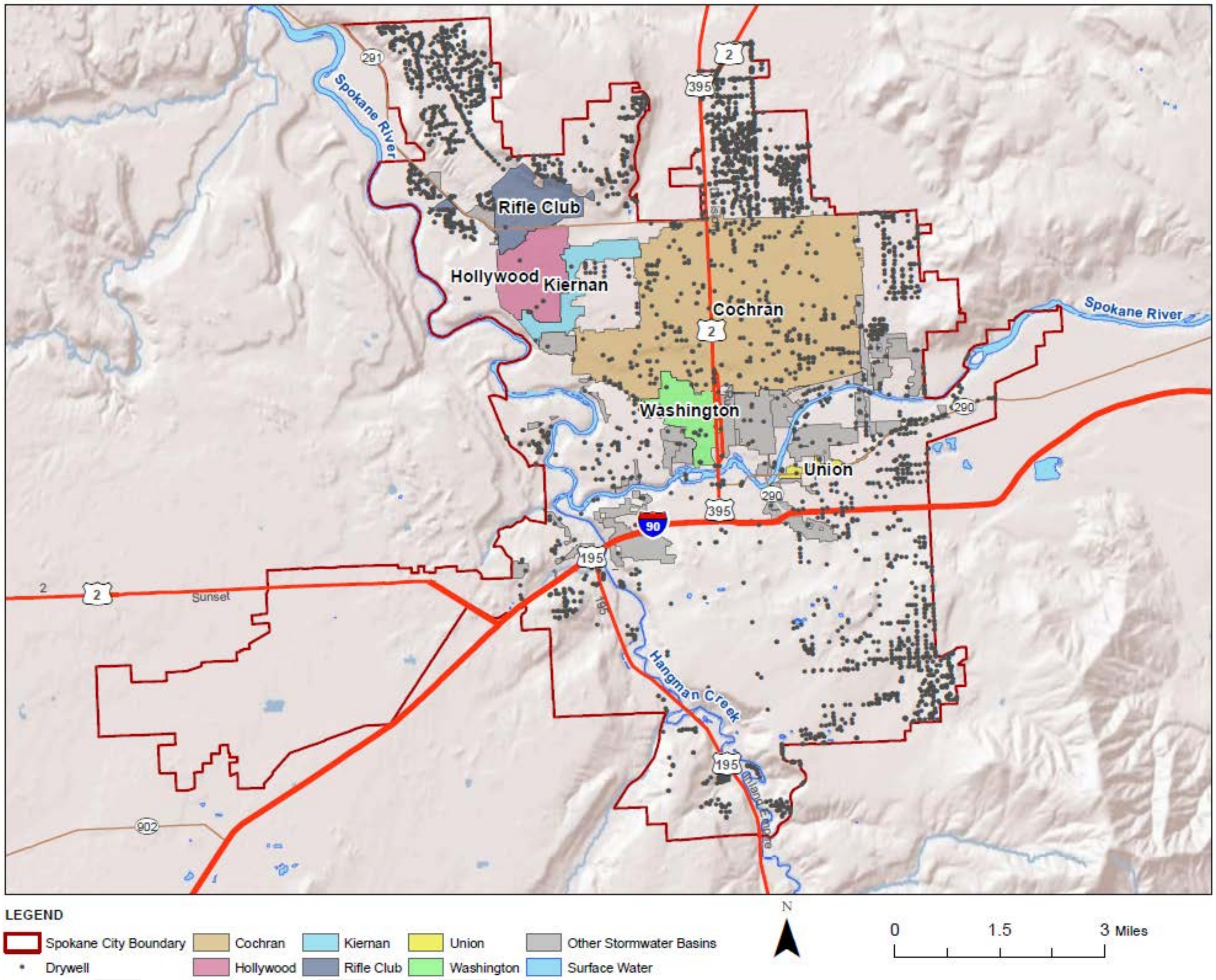

FIGURE 2-8
Stormwater System Overview

2.3.1.2 Bioinfiltration Swales, Drywells, and Other Infiltration Facilities

As described in the Final System Characterization Report (URS, 2000), drywells have been a commonly used method for stormwater treatment and disposal in Spokane because of the high-permeability soils in many parts of the City. Drywells typically consist of a perforated, pre-cast concrete maintenance hole surrounded by gravel backfill, which allows collected stormwater runoff to infiltrate into the surrounding soil. The City of Spokane owns approximately 3,650 drywells. See Section 1.3.4 for details on the regulations governing drywells.

The City also owns and operates a variety of swales used to infiltrate stormwater. These facilities include the typical grass-lined swales that are common throughout the City, as well as three GI pilot projects, such as the one shown in Figure 2-9 along Broadway Avenue.

FIGURE 2-9
Existing Green Infrastructure Facilities along Broadway Avenue in Spokane

2.3.1.3 Evaporation Facilities

In certain areas of the City where infiltration of stormwater is not feasible, evaporation facilities have been implemented. These evaporation facilities were constructed during development or re-development to manage stormwater because infiltration was not allowed.

2.3.2 Stormwater Monitoring (Flow and Quality)

The City collected flow monitoring data in several of the larger stormwater basins during the 2012-2013 wet season. These data were used to help estimate the average annual stormwater runoff volumes generated in these basins (see Table 2-6) to gain a better understanding of the wet weather response in these basins and to estimate current pollutant loads discharged to the Spokane River (Figure 2-10). The basins monitored were Cochran, Washington, and Union.

The City also has collected water quality data in the same three stormwater basins. Table 2-7 presents a summary of the water quality data collected for the pollutants of concern (see Section 1.2.3).

TABLE 2-7

City of Spokane Stormwater Quality Data

Pollutant	Cochran	Washington	Union
TSS (mg/L)			Not Sampled
Median	224	229	
Minimum	40	61	
Maximum	1,388	1,766	
No. of Samples	16	5	
Total Phosphorus (mg/L)			Not Sampled
Median	0.73	1.02	
Minimum	0.30	0.29	
Maximum	2.92	4.18	
No. of Samples	15	5	
Dissolved Zinc (µg/L)			Not Sampled
Median	15	25	
Minimum	15	15	
Maximum	28	35	
No. of Samples	3	2	
Total Zinc (µg/L)			Not Sampled
Median	220	380	
Minimum	30	80	
Maximum	730	920	
No. of Samples	16	4	
Fecal Coliform (CFU/100 mL)			Not Sampled
Median	170	965	
Minimum	26	175	
Maximum	>1,600	16,000	
No. of Samples	13	4	
PCB (ng/L)			
Median	5.6	6.4	45.8
Minimum	0.9	3.4	13.8
Maximum	24.2	13.0	136.2
No. of Samples	12	6	14

2.3.3 Current Stormwater Pollutant Load Estimates

Figures 2-10 and 2-11 present the current estimated pollutant load discharged by the six priority stormwater basins in the City of Spokane for the representative pollutants. The pollutant loads discharged from the Hollywood, Rifle Club, and Kiernan basins were estimated based on the stormwater quality data collected for the Cochran and Washington basins. Details on the calculation of these pollutant loads are presented in the technical memorandum "Stormwater Data Summary, Drainage Basin Prioritization, and Initial Runoff and Pollutant Calculations" (CH2M HILL, 2013d). For comparison, the total pollutant load resulting from all of the City's CSO discharges combined is also included in Figures 2-10 and 2-11.

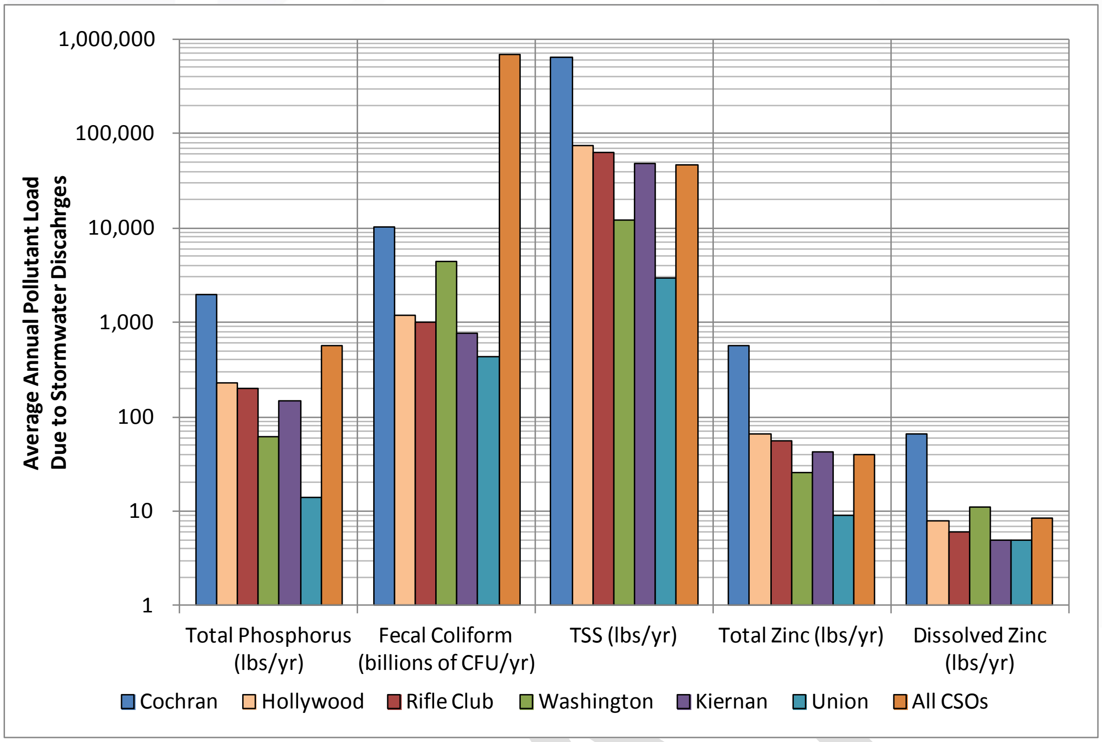

FIGURE 2-10

Average Annual Pollutant Loads Due to Priority Stormwater Basin Discharges in the City of Spokane

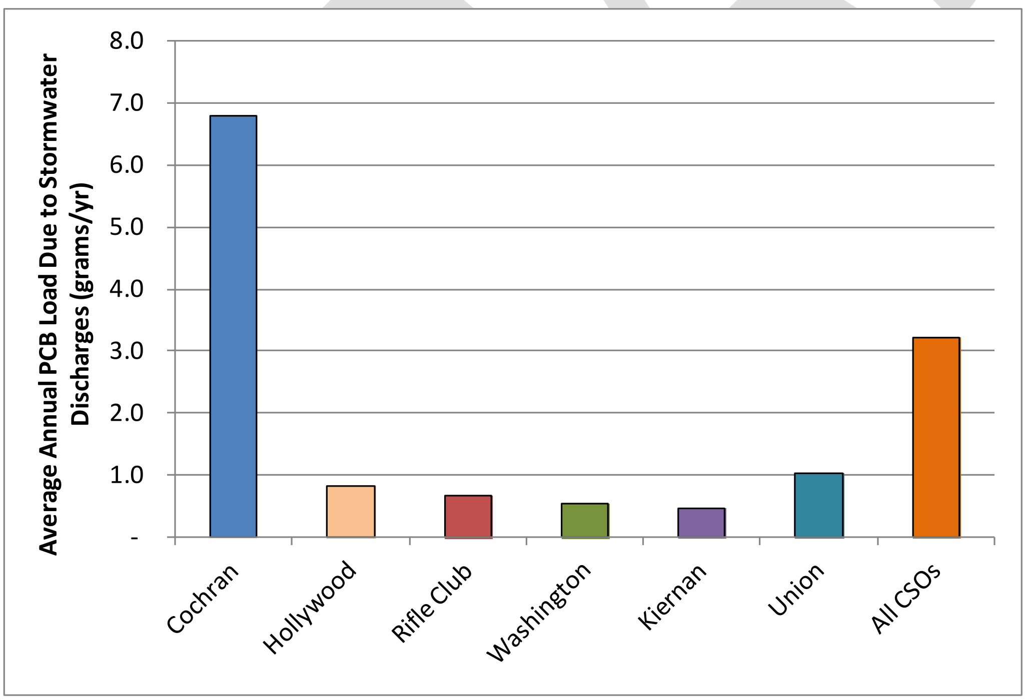

FIGURE 2-11

Average Annual PCB Loads Due to Priority Stormwater Basin Discharges in the City of Spokane

Chapter 3: Public, Stakeholder, and Regulatory Agency Involvement

This chapter follows the guidance of the USEPA's Integrated Planning Framework Element 3, and includes a process that opens and maintains channels of communication with relevant community stakeholders in order to give full consideration of the views of others in the planning process and during implementation of the plan.

- Municipalities developing integrated wastewater and stormwater plans should provide appropriate opportunities that allow for meaningful input during the identification, evaluation, and selection of alternatives and other appropriate aspects of plan development
- Municipalities participating in an integrated wastewater and stormwater plan should, during the implementation of the plan, make pertinent new information available to the public and provide opportunities for meaningful input into the development of proposed modifications to the plan
- Where a permit or enforcement order incorporates GI requirements, municipalities required to implement the requirements should allow for public involvement to assist in evaluating the effectiveness of the approach and to assist in successful implementation of the approach

3.1 PUBLIC AND STAKEHOLDER PROCESS

Throughout the development of this Integrated Clean Water Plan, the City has endeavored to open and maintain communication channels with the public, interested stakeholders, and regulatory agencies.

The City developed and implemented a communications action plan that relied on multiple communication approaches—from in-person presentations and meetings, to outreach to local media, to use of internet resources and social media—to reach more people in ways that are convenient for them. City staff went to their meetings, where they were already gathering, and worked to give the audiences a compelling reason to listen and to learn more. The City used relevant information to tie the Integrated Clean Water Plan to the larger story and create relevance.

In parallel efforts, the City also kept staff from regulatory agencies and the Spokane Tribe engaged and informed and reached out to specialized interested stakeholders, including environmental advocates, users of the Spokane River, owners of property along the River's shore, and neighborhoods that would experience construction projects.
These and other activities have resulted in a shift from public outreach to public engagement.

When public outreach work began, the City immediately recognized that the challenge included a general lack of understanding by the public of the problems that were being addressed and why the work being done was important. Initial communications with the public focused on the basics—what is a combined sewer, how is stormwater managed throughout the City, what do flows from combined and stormwater sewers bring to the Spokane River, and what is "green" infrastructure.

Building on that, the City explained how the proposed work would meet the goals of the Integrated Clean Water Plan:

- Achieve a Cleaner River Faster
- Implement cost-effective and innovative technologies
- Opportunistically address other critical infrastructure needs with Integrated Clean Water Plan projects

The City also explained that it was working to make the work more affordable and to provide greater value to citizens for the dollars spent. The City was working to be both environmentally and financially responsible.

3.1.1 Outreach by the Numbers

The following are several statistics on the City's public and stakeholder involvement process:

- More than 40 presentations to interested stakeholders and citizen groups, reaching nearly 1,400 people.
- More than 30 meetings with regulators, Spokane Tribe representatives, and elected officials. Additionally, City elected officials were updated through twice-monthly public works meetings.

- More than three dozen "earned" media stories, including newspaper articles, television and radio stories, blog posts, and newsletter features, covering the City's work and presenting it to the community.
- Dozens of additional communications touches, including two inserts that went to all of the City's utility bill customers; news releases; Facebook and Twitter posts; videos on the local government-access cable station; information on the City web site, and more.

Additional communications highlights include:

- **Green Solutions Seminar:** The City organized and co-sponsored a 1-day seminar with environmental groups, businesses, and others in October, focusing on the uses, mechanics, and benefits of GI. The City's Utilities Director provided the luncheon keynote address on the Integrated Clean Water Plan and its use of GI. Ninety people attended the event, with a particular interest in the luncheon speech. The City also replayed the speech on their government-access cable station and made it available on-line on the City web site. Comments from participants about the seminar and the keynote speech were overwhelmingly positive.
- **Pilot Project with the Lands Council in the Shadle Park Neighborhood:** In September the City launched a stormwater pilot project with a local environmental group, The Lands Council. The Lands Council went door-to-door in the neighborhood, talking about stormwater and the benefits of using GI to help mitigate the impacts of CSOs and seeking volunteers for a few sample projects. City staff and volunteers from The Lands Council went to 1,591 homes, talked to 216 people in person, and left information at the remaining homes. Ninety-five percent of the people were supportive of the general project, and 56 homeowners were interested in having GI installed at their properties.
- **Downtown Library Display:** The City developed a display that told the story of the Integrated Clean Water Plan, combined sewers, and stormwater, and placed it in Spokane's downtown library for 90 days, in conjunction with an historical display on the Spokane River. The City routinely refilled the take-away information at the display, and received many positive comments from library patrons.
- **Link Spokane Publication:** As the City's work has evolved, a long-term strategy to link street rehabilitation and stormwater mitigation has been developed. The City is updating the transportation chapter of their Comprehensive Plan and linking in utility infrastructure planning. To advance the concept, the City developed and distributed more than 35,000 copies of a 12-page brochure that includes overviews of the Integrated Clean Water Plan.

Throughout the City's communications work, the response from the public, stakeholders, and regulators has been positive. The public involvement process found great ownership of the Spokane River in the community, leading to support of the City's work to improve the River's health.

Groups and media representatives are now approaching the City to set up presentations and to provide them with information for articles and follow-ups. More and more people have engaged the City on the topic on social media. Contractors are recognizing the value of the work to the economy and seeking out more information. And the Mayor routinely is asked about this plan and the projects it includes as he participates in community events. In these outcomes, the City has seen the switch to an engaged public, not just one that is being reached out to. That is the direct result of the City's communications plan and approach.

3.1.2 Integrated Clean Water Plan Public Meeting

As the City finalized the Integrated Clean Water Plan, it was critical to take the completed plan out for a final formal public meeting. Working with Ecology, the City presented the final approach and sought public comments. The City also promoted the opportunity to provide comment on the City's web site, social media accounts, and through a news release to media. The Final Integrated Clean Water Plan will contain an overview of public input received.

3.1.3 Ongoing Communication

The City will continue to inform and engage the public as it moves ahead with individual construction projects and on the overall results of the plan. In particular, the City has already begun individualized communications with those neighborhoods that will have a facility built within their boundaries.

The City believes this plan to be a comprehensive effort to clean up and celebrate the Spokane River, and sees it as an opportunity to increase the number of people who recreate in or around the River. The City believes that these communication efforts must continue in order to support this long-term goal.

3.2 COORDINATION WITH ECOLOGY

When deciding to develop an Integrated Clean Water Plan approach, the City understood that communication and cooperation with its regulators was critical. The City and the Eastern Regional Office of the Department of Ecology set up a Steering Committee for both organizations to cooperate in the City's development and implementation of this Integrated Clean Water Plan. Because there are few examples and limited experience with Integrated Planning, both parties expected that such cooperation would produce a higher-quality Integrated Clean Water Plan, avoid pursuing approaches that are not approvable, and reduce cost in both time and resources. The City understands that cooperation between the parties does not imply that Ecology is pre-approving, or consenting to approve, this Integrated Clean Water Plan.

USEPA has published a Framework for Integrated Planning and has included guidance in two recently-issued consent decrees for the City of Seattle and King County. However, there are no detailed criteria or guidance to be followed in the development of an Integrated Plan, particularly for a riverine system with multiple management issues such as the Spokane River. To diligently move forward with the timely development of this Integrated Clean Water Plan, the City and Ecology developed a process that:

1. Provided timely and accurate communication
2. Supported planning schedules and timelines
3. To the best of each party's ability, communicated regulatory and or other concerns related to the multiple requirements influencing the allocation of financial or other resources to pollutant control
4. Responded in a timely manner to requests for information and or review of technical questions and or documents
5. Shared information and knowledge to assist in the prioritization of resources
6. Documented policy considerations that need to be considered in the sequencing and prioritization of project investments

The role of the Steering Committee has been to work together to understand the technical aspects and address issues of concern to either party. The Steering Committee participated in face-to-face meetings on a monthly basis to address specific technical topics as part of the development of the CSO Plan Amendment, Wastewater Facilities Plan Amendment No. 3, and Integrated Clean Water Plan.

The Steering Committee team is composed of individuals from the City and Ecology as listed in Table 3-1.

TABLE 3-1
Integrated Clean Water Plan Steering Committee

Ecology	City of Spokane
• Grant Pfeifer, Eastern Region Office Director • Ellie Key, Permit Writer • Jim Bellatty, Water Quality • Diana Washington, Water Quality • Cynthia Wall, Project Manager	• Theresa Sanders, City Administrator • Rick Romero, Utilities Director • Marcia Davis, Capital Programs • Lars Hendron, Wastewater Engineering • Jennifer Price, CH2M HILL

The Steering Committee identified key topics to be addressed that included the updated CSO control volumes, overall evaluation criteria, NLT analysis, and public involvement. Additional topics are summarized in the monthly schedule for working sessions shown in Table 3-2.

The City has relied on the Steering Committee as the main form of regulatory discussion on the Integrated Clean Water Plan. However, the City recognizes that other regulatory agencies and parties will be involved in discussions as well, including Ecology Headquarters, USEPA, and the Spokane Tribe. The City has been briefing the Tribe and USEPA, and attending joint briefings with Ecology Headquarters throughout the process.

TABLE 3-2

Integrated Clean Water Plan Steering Committee Monthly Working Sessions

Month	Topic
June	• Formation of Steering Committee • Updated CSO control volumes
July	• Regulatory approach and approval process • Coordination with RPWRF and NLT • Update on CSO control volume modeling approach
August	• Public engagement • Integrated Clean Water Plan schedule and status • Evaluation criteria
September	• Integrated Clean Water Plan approach • CSO Project for Basin 24/25/26 • Cochran stormwater project alternatives
October	• Proposed NLT project alternatives • CSO Plan amendment and Integrated Clean Water Plan outlines • Pollutants to be included in the Integrated Clean Water Plan
November	• Technical review sessions for the CSO Plan Amendment and Wastewater Facilities Plan Amendment No. 3
December	• Proposed Integrated Clean Water Plan
January	• Regulatory framework • Funding strategy • Regulatory approval process

Chapter 4: Alternative Development, Evaluation, and Selection

This chapter follows the guidance of the USEPA Integrated Planning Framework Element 4, and includes a process for identifying, evaluating, and selecting alternatives and proposing implementation schedules that address:

- The use of sustainable infrastructure planning approaches, such as asset management, to assist in providing information necessary for prioritizing investments in and renewal of major wastewater and stormwater systems
- The use of a systematic approach to consider and incorporate, where appropriate, GI and other innovative measures where they provide more sustainable solutions
- Identification of criteria, including those related to sustainability, to be used for comparing alternative projects and a description of the process used to compare alternatives and select priorities
- Identification of alternatives, including cost estimates, potential disproportionate burdens on portions of the community, projected pollutant reductions, benefits to receiving waters and other environmental and public health benefits associated with each alternative
- An analysis of alternatives that documents the criteria used, the projects selected, and why they were selected
- A description of the relative priorities of the projects selected including a description of how the proposed priorities reflect the relative importance of adverse impacts on public health and water quality and the permittee's financial capability
- Proposed implementation schedules
- For each entity participating in the plan, a financial strategy and capability assessment that ensures investments are sufficiently funded, operated, maintained and replaced over time. The assessment of the community's financial capability should take into consideration current sewer rates, stormwater fees and other revenue, planned rate or fee increases, and the costs, schedules, anticipated financial impacts to the community of other planned stormwater or wastewater expenditures, and other relevant factors impacting the utility's rate base.

This chapter describes the development of the clean water investments that are included in this Integrated Clean Water Plan, how they were combined into Systems Wide Alternatives, and the evaluation and selection of the recommended Systems Wide Alternative.

4.1 ALTERNATIVE DEVELOPMENT

The first step in developing alternatives for this Integrated Clean Water Plan was compiling a list of proposed clean water investments. These investments include projects to control CSOs, to reduce and treat stormwater runoff, and to increase the pollutant removal at the RPWRF using membrane filtration. The second step was combining these projects into Systems Wide Alternatives. Each Systems Wide Alternative meets the City's NPDES permit requirements for the reduction of CSO discharges and implementation of membrane filtration and takes various approaches to accomplishing the City's goal of achieving a Cleaner River Faster. Each of the Systems Wide Alternatives includes required NLT at the RPWRF during the critical season.

4.1.1 Clean Water Investments Considered in the Integrated Clean Water Plan

The City can make many different clean water investments to reduce pollutants entering the Spokane River. This Integrated Clean Water Plan focuses on three types of clean water investments, following the guidance in the USEPA's Integrated Planning Approach Framework (USEPA, 2012): CSO reduction projects, stormwater projects, and wastewater treatment plant projects. The following subsections describe the various projects from among the three types of clean water investments described above that are included in this Integrated Clean Water Plan. This is followed by descriptions of how those projects were combined into Systems Wide Alternatives.

Table 4-1 summarizes all the projects that were considered in this Integrated Clean Water Plan and used to develop the Systems Wide Alternatives.

4.1.1.1 CSO Reduction Projects

Various types of CSO reduction projects were developed for this Integrated Clean Water Plan, including storage facilities, conveyance improvements, and stormwater infiltration facilities such as GI and conventional grass-lined bioinfiltration swales. The City developed various conceptual projects to reduce CSOs using the types of projects mentioned above. There are other methods for reducing CSOs, such as wet weather treatment, which were evaluated and screened out by the City prior to this Integrated Clean Water Plan (AECOM, 2005; CTE, 2000).

4.1.1.1.1 Storage Facilities and Conveyance Improvements

These projects consist of underground storage facilities that store CSO events, preventing them from being discharged untreated to the Spokane River. These facilities can be combined with improvements to the City's wastewater collection and conveyance system that allow more flow to be conveyed to and treated at the RPWRF. The 2013 CSO Reduction Plan Amendment (CH2M HILL, 2013b) describes these types of projects in more detail, and recommends a set of storage and conveyance improvement projects to control the remaining uncontrolled CSO outfalls.

These types of projects have been widely implemented across the country to reliably reduce CSOs. As described in Chapter 2, the City has completed several of these facilities in recent years, including construction of six storage facilities and weir modifications in nine CSO basins. Each of the basins in which storage facilities were constructed has been in compliance with the CSO performance measure since the completion of construction.

4.1.1.1.2 Stormwater Infiltration Facilities

As described in Chapter 2, the City traditionally has used a combination of drywells and grass-lined bioinfiltration swales to manage stormwater in areas of the City where stormwater can be safely infiltrated. These facilities can reduce CSO volume and frequency by reducing the amount of stormwater that enters the combined sewer system, and they also infiltrate and/or treat stormwater.

GI consists of a suite of practices to reduce the volume of stormwater runoff entering the sewer system. GI seeks to mimic natural hydrologic functions through infiltration, evaporation, and storage rather than a single regulatory purpose such as temporary storage to reduce peak flows within the conveyance system, which is common for "gray" infrastructure strategies. The bioinfiltration swales that are commonly used in Spokane are a form of GI.

GI also provides an enhanced opportunity to integrate stormwater benefits with improvements in other service areas, such as transportation, bicycle/pedestrian mobility, business revitalization, urban canopy, etc. Not only can these facilities reduce the frequency and volume of CSOs, they treat and infiltrate stormwater runoff, which also contains significant amounts of pollutants. In addition, the USEPA Integrated Planning Framework memorandum encourages the consideration of GI, stating that the use of "innovative technologies, including green infrastructure… may be fundamental aspects of municipalities' plans for integrated solutions" (USEPA, 2012).

4.1.1.2 Projects to Protect IO2

As described in Section 2.1.1, protecting the IO2 interceptor from surcharging is a key requirement for the City both in terms of protecting the interceptor itself and to equalize the flow sent to the RPWRF for membrane filtration treatment (see Section 2.2.3). Although the capacity of IO2 in the critical reach is 130 mgd, the City is taking several steps to limit the flow in the pipe to no more than 120 mgd. These steps include;

- Constructing interceptor protection tanks (storage tanks) in the incomplete separation areas (IO3, IO4-1, IO4-2, and IO7)
- Reducing regulator flow control settings in CSO basins to limit flow from the entire system to 120 mgd
- Addressing inflow into the interceptor from the Spokane River during high river conditions (see Section 2.1.5)

Building interceptor protection tanks and regulator structures in the incomplete separation areas is 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 enters the piped collection system in these areas enters the interceptor and flows to the RPWRF. New regulator structures and interceptor protection tanks currently are planned 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 is 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 risk tolerance for exceeding the storage volume of the interceptor protection tanks is zero exceedances per year.

TABLE 4-1
Projects Evaluated in this Integrated Clean Water Plan

Project Type	Project Name[a]	Storage Facility Size	Regulator Flow Control Setting Modification?	Stormwater Infiltrated (% of Basin Area / Area Infiltrated)	Estimated Total Capital Cost ($M)	Estimated Life-Cycle Cost ($M)[b]	Estimated Average Annual Pollutant Removal						Notes
							Total Phosphorous (lbs/year)	Fecal Coliform (Billions of CFU/year)	TSS (lbs/year)	Total Zinc (lbs/year)	Dissolved Zinc (lbs/year)	PCBs (grams/year)	
CSO	CSO Basin 6 - Storage Only	0.90 MG	Yes	0%	$11.38	$10.62	40	57,800	3,600	2.2	-	0.06	
CSO	CSO Basin 6 - Storage + Stormwater Infiltration	0.39 MG	Yes	11% / 55 ac	$12.69	$11.84	68	57,800	6,500	14.5	5.3	0.11	
CSO	CSO Basin 6 – Stormwater Infiltration Only	None	Yes	20% / 98 ac	$13.36	$12.48	90	57,800	8,700	24.0	9.5	0.15	
CSO	CSO Basin 7 - Regulator Setting Adjustment	0.005 MG	Yes	0%	$0.52	$0.41	2	3,200	200	0.1	-	0.002	
CSO	CSO Basin 12 - Storage Only	0.69 MG	Yes	0%	$8.72	$8.10	30	44,800	2,800	1.7	-	0.05	
CSO	CSO Basin 12 - Storage + Stormwater Infiltration	0.35 MG	Yes	11% / 41 ac	$11.71	$13.42	52	44,800	5,000	11.5	4.2	0.07	
CSO	CSO Basin 12 – Stormwater Infiltration Only	None	Yes	23% / 82 ac	$13.80	$12.83	74	44,800	7,20	21.2	8.4	0.12	
CSO	CSO Basins 14 & 15 - Storage	0.05 MG (CSO Basin 14) 0.06 MG (CSO Basin 15) 0.11 MG (Total)	Yes	0%	$3.16	$3.44	2	3,600	200	0.1	-	0.004	
CSO	CSO Basins 14 & 15 - Storage + Stormwater Infiltration	0.03 MG (CSO Basin 14) 0.02 MG (CSO Basin 15) 0.05 MG (Total)	Yes	10% / 19 ac	$3.72	$4.20	12	3,600	1,300	5.0	2.1	0.02	
CSO	CSO Basins 14 & 15 - Stormwater Infiltration Only	None	Yes	20% / 37 ac	$2.57	$2.85	20	3,600	2,200	9.2	3.9	0.04	
CSO	CSO Basin 23 - Regulator Setting Adjustment	0.005 MG (23-1) 0.005 MG (23-2) 0.010 MG (Total)	Yes, at both interceptor inlets	0%	$1.14	$1.04	10	15,100	900	0.6	-	0.02	An additional interceptor inlet structure to be constructed, allowing flow to enter the interceptor system at two locations.
CSO	CSO Basins 24, 25 & 26 - Storage Only	2.0 MG (CSO Basin 24 & 25) 2.0 MG (CSO Basin 26) 4.0 MG (Total)	Yes, in all three basins	0%	$42.23	$42.07	202	294,700	18,500	11.3	-	0.20	
CSO	CSO Basin 33 – Storage Only	2.0 MG (CSO Basin 33a,c,b) 0.4 MG (CSO Basin 33d) 2.5 MG (Total)	Yes, in both basins	0%	$32.66	$32.85	58	78,500	5,000	3.0	-	0.10	
CSO	CSO Basin 34/IO7 - Storage Only	1.3 MG	Yes, in both basins	0%	$15.89	$16.50	105	156,400	9,700	6.0	-	2.70	CSO Basin 34 storage facility to be joined with interceptor storage facility for IO7.
CSO	CSO Basin 41 - Regulator Setting Adjustment	None	Yes	0%	$1.28	$1.03	2	3,300	200	0.1	-	0.004	
Interceptor Basin	Incomplete Storage Area IO3 – Storage Only	1.2 MG	Yes	0%	$12.80	$12.06	-	-	-	-	-	-	Incomplete separation area does not currently contain a flow control device. No pollutant removal due to these storage facilities.
Interceptor Basin	Interceptor Basin IO4 – Storage Only	0.9 MG (IO4 East) 0.1 MG (IO4 West)	Yes	0%	$14.17	$15.08	-	-	-	-	-	-	
Stormwater	Cochran Basin - Bioinfiltration Facility	NA	NA	NA	$20.00	$18.00	1,600	2,000	504,300	487.0		5.44	Location of facility to be determined.
RPWRF	Non-Critical Season Membrane Filtration	NA	NA	NA	$0	$15.46	84,700	2,200	330,900	426.0	-	6.65	Membrane filtration during the non-critical season (November – February), with alum addition and CEPT.
RPWRF	Upsize Membrane Filtration from 50 mgd to 85 mgd	NA	NA	NA	$28.11	$35.72	350	50	6,900	1.4	-	0.13	

[a] Ongoing water quality projects like the CSO reduction projects in CSO Basins 20, 24, and 34 are not included in this table.

[b] Based on a 25-yr life-cycle cost analysis using a 2% discount rate. The life-cycle cost includes capital, property, operations and maintenance, and replacement costs, as well as additional or reduced cost of treatment at the RPWRF (if applicable).

During the CSO planning process, the regulator settings for all CSO basins and incomplete separation areas were set to keep peak flow under this 120-mgd ceiling to protect the interceptor. The City used a computer model run with a 20 year precipitation record to determine the regulator settings that would keep the flow in the interceptor below this 120-mgd ceiling over that 20 year period. The city recognizes that this 120-mgd ceiling will be exceeded in the case of significant events larger than those in the 20 year modeled period; 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 CSO reduction projects that the 120-mgd ceiling does not provide enough protection, green infrastructure can be implemented, storage facilities can be upsized, and/or regulator settings can be reduced, all of which allow less flow to the interceptor.

4.1.1.3 Cochran Basin Stormwater Project

As described in Chapter 2, six of the City's highest priority stormwater basins account for approximately 75 percent of the total area serviced by a separated stormwater system. The City conducted an analysis to select one or more stormwater basins for which stormwater projects would be developed in the Integrated Plan. This analysis was conducted based on the average annual volume of stormwater runoff discharged and the average annual pollutant load discharged (see Figures 2-10 and 2-11). Based on this analysis, the City decided to focus its efforts on reducing the runoff from the largest of its stormwater basins: the Cochran basin. This basin accounts for approximately 50 percent of the total area served by a separated stormwater system, and is the largest discharger of pollutants among all of the City's stormwater basins.

Although only the Cochran basin is included in this Integrated Clean Water Plan, the City is committed to reducing the discharge of pollutants from other significant MS4 basins. For example, the City has identified the Union basin as another high-priority basin, mainly because of the high concentration of PCBs found in its stormwater discharges, and is currently designing a system to treat and infiltrate stormwater in the basin using GI methods.

The Cochran basin stormwater project focuses on reducing the discharge of stormwater through infiltration. This could be accomplished with a centralized bioinfiltration facility located either near the TJ Meenach Bridge or near the existing Downriver Disc Golf Course. Although there is no regulatory requirement to reduce the volume of stormwater discharged from the Cochran basin at this time, this project provides a cost-effective way to remove large amounts of pollutants and helps place the City in a better position to respond to potential future stormwater regulations. Details on the evaluation of various stormwater projects in the Cochran basin are presented in the technical memorandum "Cochran Basin Stormwater Alternatives Analysis" (CH2M HILL, 2014f), included as Appendix C.

4.1.1.4 Non-Critical Season Membrane Filtration

As described in Section 2.2.2, one of the City's NPDES permit requirements is to implement an additional phosphorous removal process, also known as NLT, at the RPWRF. The permit requires that this additional phosphorus removal process be operated from March through October (the critical season), because during that time the discharge of phosphorous and CBOD to the Spokane River presents the greatest impact to dissolved oxygen levels. Although there is no requirement to operate the Membrane Filtration facility from the months of November through February (the non-critical season), there is a cost-effective opportunity to remove a significant amount of pollutants during those months by operating the facilities year-round.

Membrane filtration at a nominal capacity of 50 mgd was selected as the recommended technology for additional phosphorus removal at the RPWRF (CH2M HILL, 2013c). To achieve the NPDES permitted total phosphorus effluent limit, the membrane filtration is preceded by CEPT. In addition, alum is added to enhance the removal of phosphorus during the membrane filtration stage. However, because there is no requirement for the City to operate the Membrane Filtration facility during the non-critical season, neither CEPT nor the additional of alum are required during the non-critical season. However, because CEPT and alum addition would result in higher pollutant removals, the evaluation of the non-critical season membrane filtration includes both of these treatment components and their associated higher costs. Upon construction of the Membrane Filtration facility, the City may decide to operate the membrane filtration during the non-critical season without one or both of these treatment components. See Section 6.5 for details on the impact that this could have on cost and pollutant removals.

4.1.1.5 Upsize Membrane Filtration Facility from 50 mgd to 85 mgd (Critical Season Operation Only)

Although constructing the Membrane Filtration facility at 50 mgd is anticipated to meet the City's NPDES permit effluent limits, constructing the facility with a higher capacity would removal more pollutants by reducing the amount of secondary effluent discharged. Because of this, the Upsize Membrane Filtration from 50 mgd to 85 mgd project was developed to be evaluated and compared with other water quality projects included in this Integrated Clean Water Plan, such as CSO reduction projects and stormwater projects.

4.1.2 Ongoing Clean Water Investments

In addition to the projects described above and presented in Table 4-1, the City has several clean water investments that are currently ongoing (Table 4-2). These investments will be implemented regardless of which projects from the sections above are selected for implementation from this Integrated Clean Water Plan.

TABLE 4-2
Ongoing Clean Water Investments

Project	Description	Estimated Total Capital Cost ($M)[b]	Estimated Life-Cycle Cost ($M)[b,d]
Storage Facility in 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 the basin, because it discharges to the sensitive Latah Creek and poses safety problems and an erosion risk.	$4.30	$4.30
Storage Facilities in 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 stormwater separation projects using drywells. These projects will aid in control of this outfall.	$1.8	$1.8
Storage Facilities 34-2 and 34-3 in CSO Basin 34	The City is currently constructing a 1.5-MG storage facility (34-2) and a 0.9-MG storage facility (34-3) in CSO Basin 34. Both facilities will be located in the middle of the basin, and are being constructed to reduce localized basement flooding as well as to reduce CSO events.	$17.85 (34-2) $14.78 (34-3)	$17.85 (34-2) $14.78 (34-3)
Subtotal of Ongoing CSO Investments		$38.73[e]	$38.73[e]
Membrane Filtration at the RPWRF[a]	The City is preparing to begin design of membrane filtration at the RPWRF. This new treatment process is meant to significantly reduce the amount of phosphorus and CBOD discharged from the RPWRF and is required per the City's NPDES permit.	$106.65[c]	$126.83[c]
Total of Ongoing Clean Water Investments (CSO and Membrane Filtration at the RPWRF)		$145.38	$165.56

[a] Other upgrades to the RPWRF are being planned; however, these upgrades are not included in this Integrated Clean Water Plan.

[b] In April 2013 dollars.

[c] Cost of membrane filtration based on the Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013c), deflated from October 2013 dollars to April 2013 dollars.

[d] Based on a 25-year life-cycle cost analysis using a 2% discount rate. The life-cycle cost includes capital, property, operations and maintenance, and replacement costs, as well as additional or reduced cost of treatment at the RPWRF (if applicable).

[e] Life-cycle costs for ongoing CSO investments were not available. However, analysis of similar CSO projects evaluated as part of this Integrated Clean Water Plan indicated that the life-cycle cost of a Storage Only CSO project is typically very close to the project's total capital cost. For ongoing CSO investments, life-cycle cost is estimated as equal to total capital cost.

4.1.3 Develop Systems Wide Alternatives

The various clean water investments described above were combined into groups and called Systems Wide Alternatives. As described above, each of these Systems Wide Alternatives includes the ongoing clean water investments presented in Table 4-2 including NLT at the RPWRF during the critical season. Five Systems Wide Alternatives were developed, as summarized below:

- **Systems Wide Alternative 1a – Storage Only**: This Systems Wide Alternative focuses on reducing the frequency and volume of CSO discharges, and consists of the recommended set of projects from the 2013 CSO Reduction Plan Amendment (CH2M HILL, 2013b). The 2013 CSO Plan Amendment recommended 11 storage facility projects and 4 conveyance improvement projects.
- **Systems Wide Alternative 1b – Storage + Green**: Like Systems Wide Alternative 1a, this Systems Wide Alternative focuses on reducing the frequency and volume of CSO discharges, but expands the strategy used to reduce CSOs from just storage to storage and GI. Systems Wide Alternative 1b consists of 11 storage facility projects, 4 conveyance improvement projects, and stormwater infiltration projects in four CSO basins.
- **Systems Wide Alternative 2a – Storage + Cochran**: This Systems Wide Alternative focuses on reducing the frequency and volume of CSO discharges and the volume of stormwater discharged from the Cochran basin. This would be

accomplished by implementing the 11 storage facility projects and 4 conveyance improvement projects from Systems Wide Alternative 1a, along with a bioinfiltration facility in the Cochran basin.

- **Systems Wide Alternative 2b – Storage + Non-Critical Season Membrane Filtration**: This Systems Wide Alternative focuses on reducing the frequency and volume of CSO discharges and reducing the amount of pollutants discharged from the RPWRF during the non-critical season. This would be accomplished by implementing the 11 storage facility projects and the 4 conveyance improvement projects from System Wide Alternative 1a, along with operating the Membrane Filtration facility at the RPWRF during the non-critical season.
- **Systems Wide Alternative 3 – Storage + Green + Cochran + Non-Critical Season Membrane Filtration**: This Systems Wide Alternative combines components from all of the other Systems Wide Alternatives, and focuses on reducing the frequency and volume of CSO discharges, reducing the volume of stormwater discharged from the Cochran basin, and reducing the amount of pollutants discharged from the RPWRF during the non-critical season. This would be accomplished by implementing nine storage facility projects, four conveyance improvement projects, implementing stormwater infiltration in two CSO basins to reduce CSOs, a bioinfiltration facility in the Cochran basin, and operating the Membrane Filtration facility at the RPWRF during the non-critical season.

4.2 EVALUATE SYSTEMS WIDE ALTERNATIVES

The following subsections present the process of evaluating the five Systems Wide Alternatives. This included continuous modeling, the development of life-cycle costs, a MODA analysis, and a financial and schedule assessment of the City's ability to implement each Systems Wide Alternative.

4.2.1 Continuous Model Verification

The City has completed several continuous modeling efforts to validate two key requirements of the CSO program:

- Proposed CSO facilities bring uncontrolled CSO outfalls into compliance with the CSO performance standard
- The peak flow in IO2 does not normally exceed 120 mgd, for the reasons discussed in Section 4.1.1.2

These requirements were validated using a number of different models. Individual Basin Models and historic data were used to validate compliance with the CSO performance standard by simulating 20 years of basin-specific precipitation and estimating the number of CSO events that would have occurred with a proposed CSO storage facility in place. Each Basin Model simulates the hydraulics and hydrology in an individual CSO basin. The methodology and results of this modeling process are summarized in the 2013 CSO Reduction Plan Amendment (CH2M HILL, 2013b), and the memorandum "Integrated Planning: Basin Compliance Validation Results" (AECOM, 2013a).

The Interceptor Model was used to validate the 120-mgd flow ceiling for IO2 by simulating the City's interceptor. A 20-year model run was completed, and the results indicated that the peak flow in IO2 with all of the planned CSO reduction projects and interceptor protection tanks in place is not expected to exceed 120 mgd.

4.2.2 Develop Planning Level Cost Estimates

Planning level 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. 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 estimates of 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 are expressed as April 2013 dollars.

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

Life-cycle costs include the total capital cost of the project, commissioning cost, annual operations and maintenance cost, additional flow monitoring, replacement cost of facility equipment, reduction in Spokane Parks Department stormwater fee revenue, land acquisition cost for property not already owned by the City, and additional treatment cost at the RPWRF resulting from an increase in flow sent to the facility. Life-cycle costs were calculated over a 25-year time period and used a 2 percent discount rate. A 25-year time period for life-cycle cost analysis was selected because it aligns with typical payback periods for various financing strategies (discussed later in this chapter). The actual useful life for most storage facilities and other large pieces of infrastructure is typically much longer than 25 years.

Table 4-3 presents the estimated capital cost and life-cycle cost for each of the five Systems Wide Alternatives. These costs include the ongoing clean water investments listed in Table 4-2 including required critical season membrane filtration. Required critical season membrane filtration has an estimated capital cost of $107 million and an estimated life-cycle cost of $127 million (see Table 4-2).

TABLE 4-3
Estimated Systems Wide Alternative Capital Cost and Life-Cycle Cost

Systems Wide Alternative[c]	Estimated Capital Cost[a] ($M)	Estimated Life-Cycle Cost[a, b] ($M)
Systems Wide Alternative 1a – Storage Only	$289	$309
Systems Wide Alternative 1b – Storage + Green	$294	$316
Systems Wide Alternative 2a – Storage + Cochran	$310	$327
Systems Wide Alternative 2b – Storage + Non-Critical Season Membrane Filtration	$289	$325
Systems Wide Alternative 3 – Storage + Green + Cochran + Non-Critical Season Membrane Filtration	$310	$344

[a] In April 2013 dollars.

[b] Based on a 25-yr life-cycle cost analysis using a 2% discount rate. The life-cycle cost includes capital, property, operations and maintenance, and replacement costs, as well as additional or reduced cost of treatment at the RPWRF (if applicable).

[c] Each systems wide alternative includes required critical season membrane filtration at a 50 mgd Membrane Filtration facility with estimated capital cost of $107M and estimated life-cycle cost of $127M.

4.2.3 Characterize Pollutant Load Reduction

One way the City characterized how well each Systems Wide Alternative would achieve the goal of providing a Cleaner River Faster was estimating the pollutant load reduction resulting from implementing the alternative. Table 4-4, Figure 4-1, and Figure 4-2 present the estimated pollutant removal for each Systems Wide Alternative, along with the estimated cost per unit of pollutant removed on a life-cycle basis. The process of estimating the pollutant removal is summarized in the technical memorandums "Cochran Basin Stormwater Alternatives Analysis" (CH2M HILL, 2013e), "Pollutant Removal Benefits of City CSO Basin Solutions" (CH2M HILL, 2014a), and "Cost per Unit Pollutant Removed for Next Level of Treatment Alternatives in the Integrated Plan" (CH2M HILL, 2014c). These technical memorandums are included as Appendix C, Appendix B, and Appendix D, respectively.

TABLE 4-4

Estimated Pollutant Load Reductions and Cost per Unit of Pollutant Removed

	SWA 1a – Storage Only	SWA 1b – Storage + Green	SWA 2a – Storage + Cochran	SWA 2b – Storage + Non-Critical Season Membrane Filter	SWA 3 – Storage + Green + Cochran + Non-Critical Season Membrane Filter
Total Phosphorus					
Annual Load Reduction (lbs/year)	450	510	2,100	85,110	86,770
Life-Cycle Load Reduction (lbs)	6,900	7,800	33,700	1,692,700	1,719,800
Life-Cycle Cost per Pound Removed ($/lb)	$45,000	$40,500	$9,700	$190	$200
Fecal Coliform					
Annual Load Reduction (Billions of CFU/year)	657,400	657,400	659,500	659,600	661,600
Life-Cycle Load Reduction (Billions of CFU)	9,980,000	9,980,000	10,020,000	10,030,000	10,060,000
Life-Cycle Cost per Billion CFU Removed ($/Billion CFU)	$31	$32	$33	$32	$34
Total Suspended Solids					
Annual Load Reduction (lbs/year)	41,300	47,400	545,600	372,100	877,500
Life-Cycle Load Reduction (lbs)	627,000	724,000	8,873,000	7,215,000	15,480,000
Life-Cycle Cost per Pound Removed ($/lb)	$490	$440	$40	$50	$20
Total Zinc					
Annual Load Reduction (lbs/year)	25	52	512	451	943
Life-Cycle Load Reduction (lbs)	400	800	8,300	8,900	16,900
Life-Cycle Cost per Pound Removed ($/lb)	$810,000	$390,000	$39,000	$37,000	$20,000
Dissolved Zinc					
Annual Load Reduction (lbs/year)	None	12	59	None	61
Life-Cycle Load Reduction (lbs)	None	180	970	None	1,000
Life-Cycle Cost per Pound Removed ($/lb)	NA	$1,710,000	$340,000	NA	$340,000
PCBs					
Annual Load Reduction (grams/year)	3.1	3.2	8.6	9.8	15.2
Life-Cycle Load Reduction (grams)	47	49	136	180	269
Life-Cycle Cost per Gram Removed ($/gram)	$6,540,000	$6,490,000	$2,400,000	$1,810,000	$1,280,000
MF = membrane filtration SWA = Systems Wide Alternative					

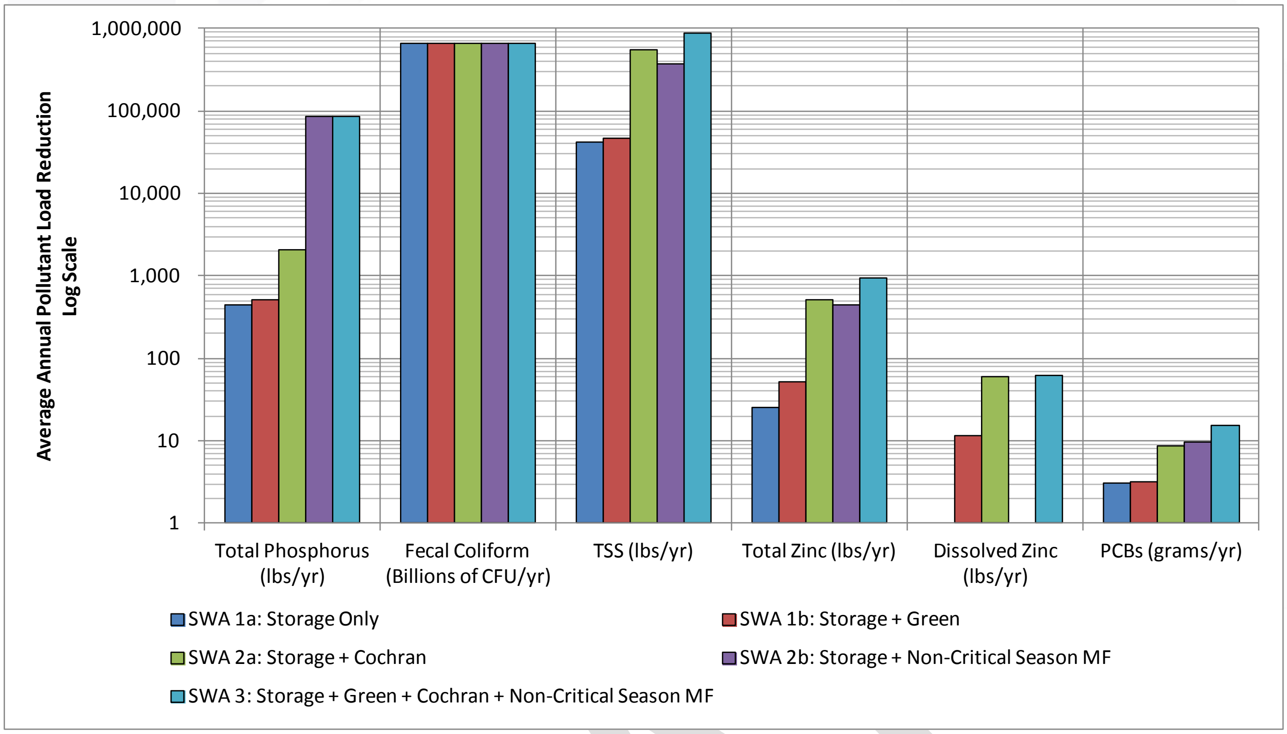

FIGURE 4-1

Comparison of Estimated Average Annual Pollutant Load Reductions for Evaluated Systems-Wide Alternatives

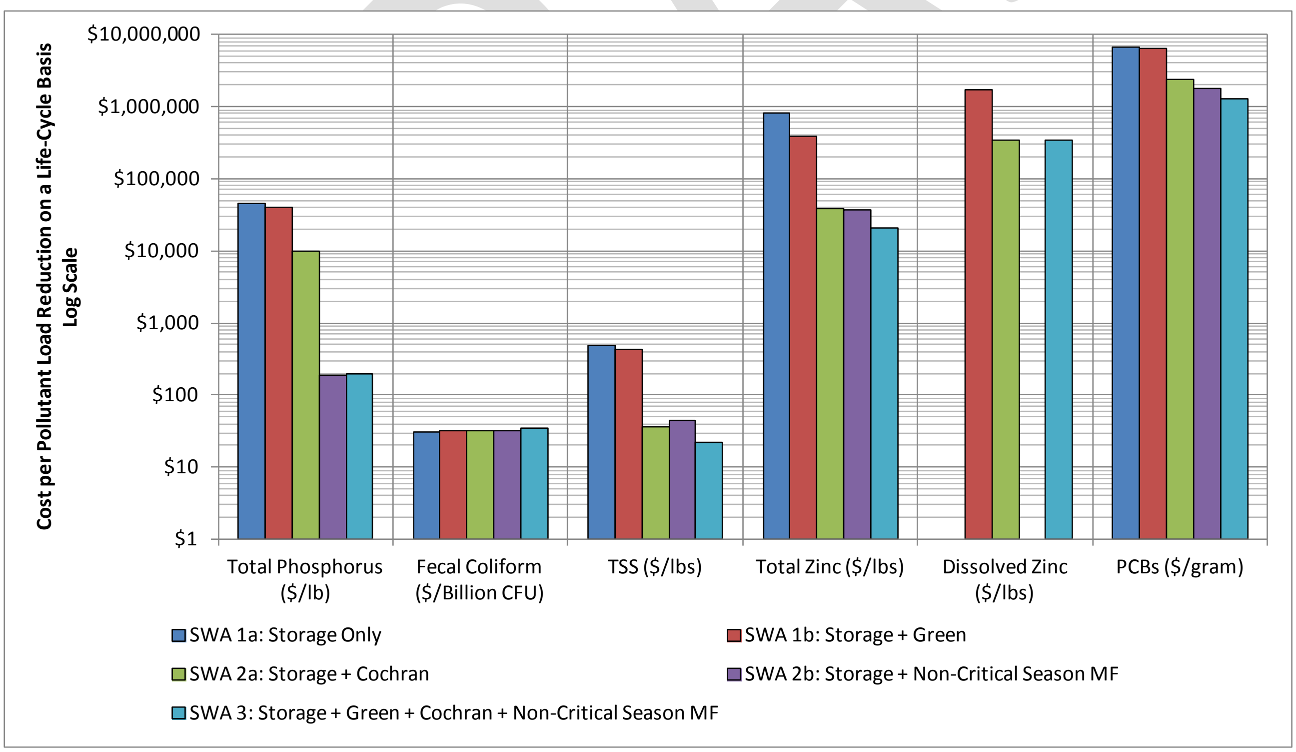

FIGURE 4-2

Comparison of Estimated Cost per Pollutant Load Reduction on a Life-Cycle Basis for Evaluated Systems-Wide Alternatives

4.2.4 Conduct Multi-Objective Decision Analysis

MODA is a quantitative technique for making decisions that involve multiple financial, environmental, and social objectives. MODA proceeds through a series of defined steps. The steps include:

- **Establish the decision goal**, or the overall purpose of the evaluation. For the Integrated Plan, the decision goal was to decide on the best mix of CSO reduction and other water quality projects that will remove as many pollutants as rapidly as possible with the highest environmental and public benefit at the lowest long-term life-cycle cost.
- **Identify and specify decision criteria**. Decision criteria are the important non-monetary aspects of a decision that answer a simple question: "What are the important issues relevant to making a decision?" Table 4-5 presents the decision criteria used in the Integrated Plan.
- **Develop measurement scales** to measure how well alternatives meet each decision criterion. These measurement scales are also presented in Table 4-5.
- **Assign scores for each decision criterion under each alternative**.
- **Assign weights to the decision criteria**. Based on the value system of the decision maker(s), some decision criteria may be more or less important than other decision criteria. Different stakeholders faced with the same problem may have different underlying value systems and, therefore, may have a different sense of what is most important in the given problem. This leads to the concept of "weighting" objectives, resulting in relative value weights.
- **Calculate total value scores and conduct sensitivity analysis**. Figures 4-3 and 4-4 present the total value scores for the evaluated Systems Wide Alternatives. Sensitivity analyses give decision makers an additional opportunity to think carefully about what is most important to them in selecting between alternatives, then acting accordingly.

A detailed description of the MODA process is presented in the technical memorandum "Decision-Making Framework for City Combined Sewer Overflow Planning and Integrated Planning" (CH2M HILL, 2014d) in Appendix E.

TABLE 4-5
Measurement Scales

1. Systems Benefits and Risks	
1.1 Reduce Functional Risk	• Complexity of the system • Understanding of operations and maintenance requirements • City experience • Used elsewhere
1.2 Reduce Regulatory Risk	• How understood and predictable are the impacts that technologies and designs have on CSO frequency • Effectiveness at reducing CSO frequency
1.3 Increase Adaptability	• Inherent vulnerability to natural hazards and changes in standards • Ability to respond to future changes in flows and pollutant loads greater than 25% of design capacity
2. Environmental Outcomes – Cleaner Water	
2.1 Reduce Human Exposures	Weighted annual average reduction in indicator pollutant quantities that may affect human health: • Fecal coliform bacteria (weight: 20) • Total suspended solids (weight: 10) • Total phosphorus (weight: 15) • PCBs (weight: 100)
2.2 Reduce Aquatic Life Exposures	Weighted annual average reduction in indicator pollutant quantities that may affect aquatic life: • Total suspended solids (weight: 60) • Total phosphorus (weight: 40) • Total zinc (weight: 100)
2.3 Improve Aesthetics	The percentage of combined sewage or stormwater volume controlled for solids, floatables, and/or odors by mechanisms such as screening, advanced treatment, and constructed stormwater wetlands.
2.4 Protect Aquifer	The facilities' likely effect on the risk of negative impacts to the aquifer.
3. Integrated Benefits	
3.1 Minimize Potential Community Impacts During Construction	Comparison to impacts to the community associated with development of the City's CSO reduction project in Basins 38-39-40.
3.2 Increase Opportunity for Economic Development	Likelihood of the facilities' ability to contribute to substantive local economic development.
3.3 Create Lasting Public Benefit from Improvement to Other City Infrastructure Systems	• Potential contribution to improvement of other infrastructure systems • Alleviation of local residents' current concerns (odor, noise, and aesthetics) • Mitigation required for the facility to be acceptable to the community
4. Operations and Maintenance Considerations	

4.1 Beneficial Operations & Maintenance	• Required level of effort to operate
	  o Onsite or remotely
	  o Number of operators required during peak times
	  o Time to shut down
	• Required level of effort for cleanup (potential automation, integration with other work)
	• Frequency of necessary preventive maintenance (annual or monthly)
	• Amount of mechanical and instrumentation components
	• Reliability of equipment in intermittent use

4.2 Safety and Security to Staff, Public, and Assets	• Requirements during routine operations and maintenance:
	  o Right-of-way access
	  o Confined space entry
	  o Traffic control
	• Vulnerability to vandalism and tampering

5. Low Cost (minimize net present value of capital, operations, maintenance and replacement)[a]	
[a] Will be measured in dollars and is not weighted. The total value from the non-monetary decision criteria will be compared to cost in a benefit-cost type of comparison.	

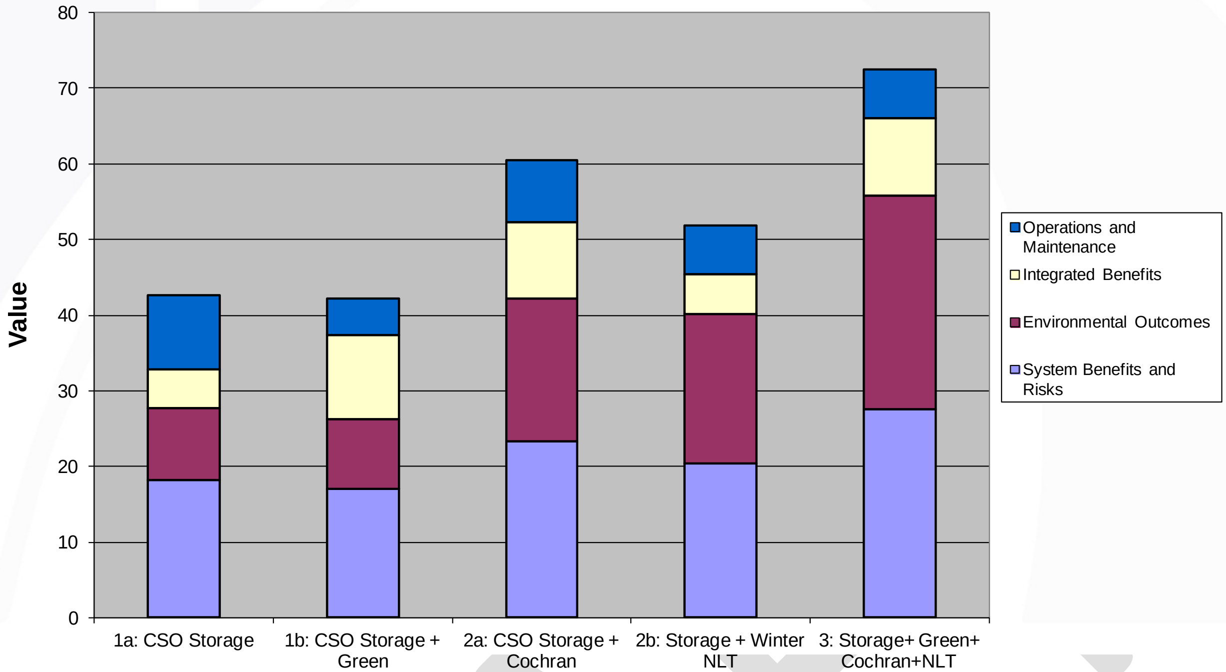

FIGURE 4-3
Total Value Scores for the Systems Wide Alternatives

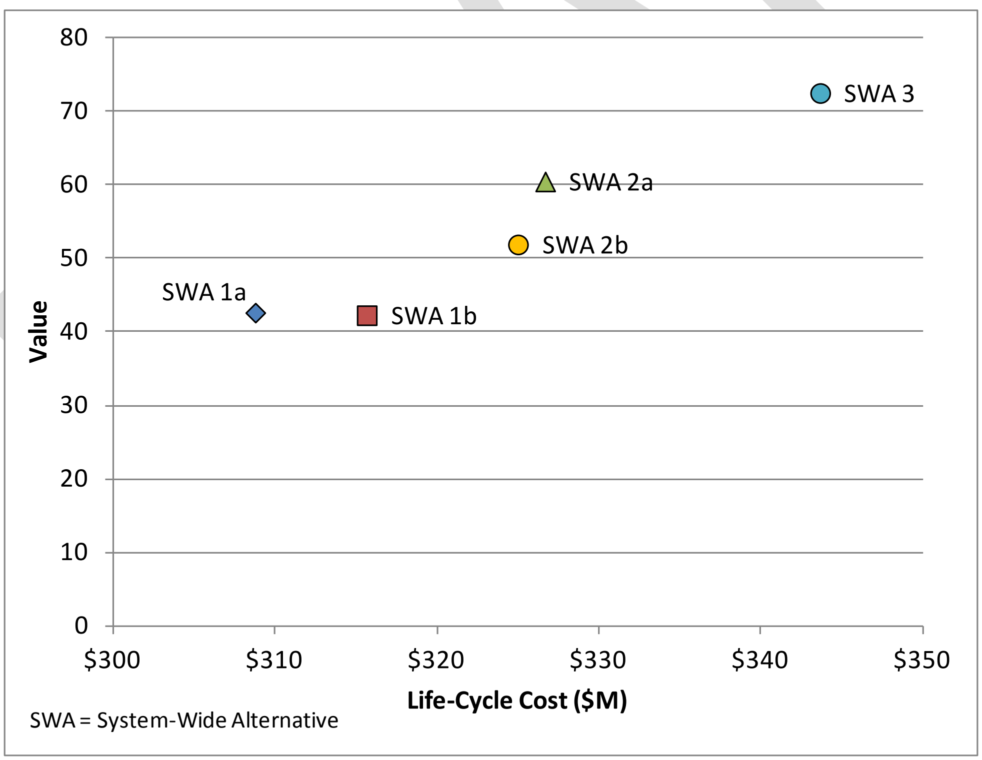

FIGURE 4-4
Total Value Scores versus Life-Cycle Cost for the Evaluated Systems Wide Alternatives

4.3 OPTIMIZATION OF MEMBRANE FILTRATION FACILITY SIZING

A separate evaluation was completed to compare the cost per unit of pollutant removed by membrane filtration at the recommended capacity of 50 mgd versus the full build-out capacity of 85 mgd. To conduct this evaluation, the cost per unit of pollutant removed by upsizing the planned Membrane Filtration facility was compared with the cost per unit of other projects being proposed in this Integrated Clean Water Plan. This analysis is documented in the technical memorandum "Cost per Unit Pollutant Removed for Next Level of Treatment Alternatives in the Integrated Plan" (CH2M HILL, 2014c), and is included as Appendix D.

The first step to calculating the life-cycle cost per pound of pollutant removed for the upsize membrane filtration alternative was to estimate the additional pounds of pollutants removed during the critical season by upsizing the Membrane Filtration facility, as presented in Table 4-6. This was estimated for the representative pollutants that were selected for the analysis in the Integrated Clean Water Plan (CH2M HILL, 2013a). The pollutant removals were estimated by modifying existing analyses completed for the Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013c). The additional pollutant removals are based on the average removals over a time period of 10 years (2002-2011).

In order to develop accurate life-cycle cost per unit of pollutant removed, the life-cycle pollutant removals were calculated based on the average annual pollutant removals. These were calculated based on a 25-year life-cycle, using a 2 percent discount rate, which matches the parameters used to develop the life-cycle cost estimates for other Integrated Clean Water Plan projects.

TABLE 4-6

Additional Pollutant Removal From Upsizing the Membrane Filtration Facility from 50 mgd to 85 mgd (35 mgd additional capacity)[a]

Pollutant	Additional Annual Pollutant Removal Due to Upsizing	Additional Life-Cycle Pollutant Removal Due to Upsizing [b]
Total Phosphorus	345 lbs/year	4,897 lbs
Fecal Coliform	45 billion CFU/year	643 billion CFU
Total Suspended Solids	6,855 lbs/year	97,348 lbs
Total Zinc	1.4 lbs/year	20 lbs
Dissolved Zinc	0 lbs/year	0 lbs
PCBs	0.13 grams/year	1.9 grams

[a] Additional pollutant removal only achieved during the critical season. In this alternative the Membrane Filtration facility would not be operated during the non-critical season.

[b] 25-year life-cycle pollutant removal using a 2% discount rate, which matches the parameters used for the life-cycle cost analysis.

Life-cycle cost estimates were completed as part of the Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013c) for both the 50-mgd and 85-mgd Membrane Filtration facility capacities. The life-cycle cost estimates in the Wastewater Facilities Plan Amendment were recalculated for a 25-year life cycle using a 2% discount rate consistent with the approach taken for the other projects in this Integrated Plan. These life-cycle costs in this Integrated Clean Water Plan were then used to calculate the life-cycle cost per pound of pollutant removal due to upsizing the facility, as presented in Table 4-7. Table 4-7 shows that the cost per pound of pollutant removal is much less for the 50 mgd facility sizing as compared to the 85 mgd facility sizing.

The life-cycle cost per unit of pollutant removed shown in Table 4-7 were calculated by taking the life-cycle cost of the alternative and dividing it by the life-cycle amount of pollutants removed during the 25-year life-cycle analysis period. The life-cycle cost estimates for the Membrane Filtration facility at 50-mgd and at 85-mgd are $127M and $163M, respectively (in April 2013 dollars), with a $36M difference in added life-cycle cost for the higher-capacity facility.

TABLE 4-7

Life-Cycle Cost per Unit of Pollutant Removed for Upsizing the Membrane Filtration Facility from 50 mgd to 85 mgd[a]

Pollutant	50 mgd [b] Life-Cycle Cost per Pound of Pollutant Removed	Upsize from 50 to 85 mgd Life-Cycle Cost Per Pound of Pollutant Removed (by the additional 35 mgd)
Total Phosphorus	$240	$7,300
Fecal Coliform	$17,800	$55,500
Total Suspended Solids	$10	$350
Total Zinc	$35,000	$1,744,000
Dissolved Zinc	NA [c]	NA [c]
PCBs	$580,000	$19,120,000

[a] Additional pollutant removal only achieved during the critical season. In this alternative the Membrane Filtration facility would not be operated during the non-critical season.

[b] Provided for comparison, to demonstrate increase in cost per pound of pollutant removed.

[c] No Dissolved Zinc removal expected.

Figure 4-5 and Table 4-8 present the life-cycle cost per unit of pollutant removed for operating the Membrane Filtration facility during the non-critical season, upsizing the facility from 50 mgd to 85 mgd, typical CSO projects, and the Cochran stormwater project. As shown in Figure 4-5, operating the Membrane Filtration facility during the non-critical season results in the lowest life-cycle cost per unit of pollutant removed for all pollutants except fecal coliform, for which the CSO reduction projects have a slightly lower cost per unit. The cause for the low life-cycle cost per unit of pollutant removed for operating the Membrane Filtration facility during the non-critical season is that a large volume of wastewater is treated. Specifically, operating the Membrane Filtration facility during the non-critical season would treat on average 4,000 MG per year, while CSO reduction projects are expected to reduce CSO discharges by approximately 40 MG per year, and the Cochran stormwater project is expected to reduce stormwater discharges by approximately 250 MG per year.

TABLE 4-8

Comparison of the Life-Cycle Cost per Unit of Pollutant Removed

Pollutant	Membrane Filtration Facility During the Non-Critical Season	Upsize from 50 to 85 mgd Life-Cycle Cost Per Pound of Pollutant Removed (by the additional 35 mgd)	CSO Reduction Projects[a]	Cochran Stormwater Project
Critical Season Total Phosphorus ($/lb)	NA[c]	$7,300	$64,000	$1,600
Non-Critical Season Total Phosphorus ($/lb)	$13	NA[d]	$151,000	$1,100
Fecal Coliform ($/Billion CFU)	$500	$55,500	$30	$540
Total Suspended Solids ($/lb)	$3	$370	$490	$2
Total Zinc ($/lb)	$2,600	$1,744,000	$810,000	$2,200
Dissolved Zinc ($/lb)	NA[b]	NA[b]	NA[b]	$18,600
PCBs ($/gram)	$163,000	$19,120,000	$6,540,000	$200,000

[a] Average life-cycle cost per pound pollutant removed for CSO projects evaluated in the 2013 CSO Plan Amendment.
[b] No Dissolved Zinc removal expected.
[c] No critical season total phosphorus is removed during the non-critical season.
[d] No non-critical season total phosphorus removed.

NA = Not applicable

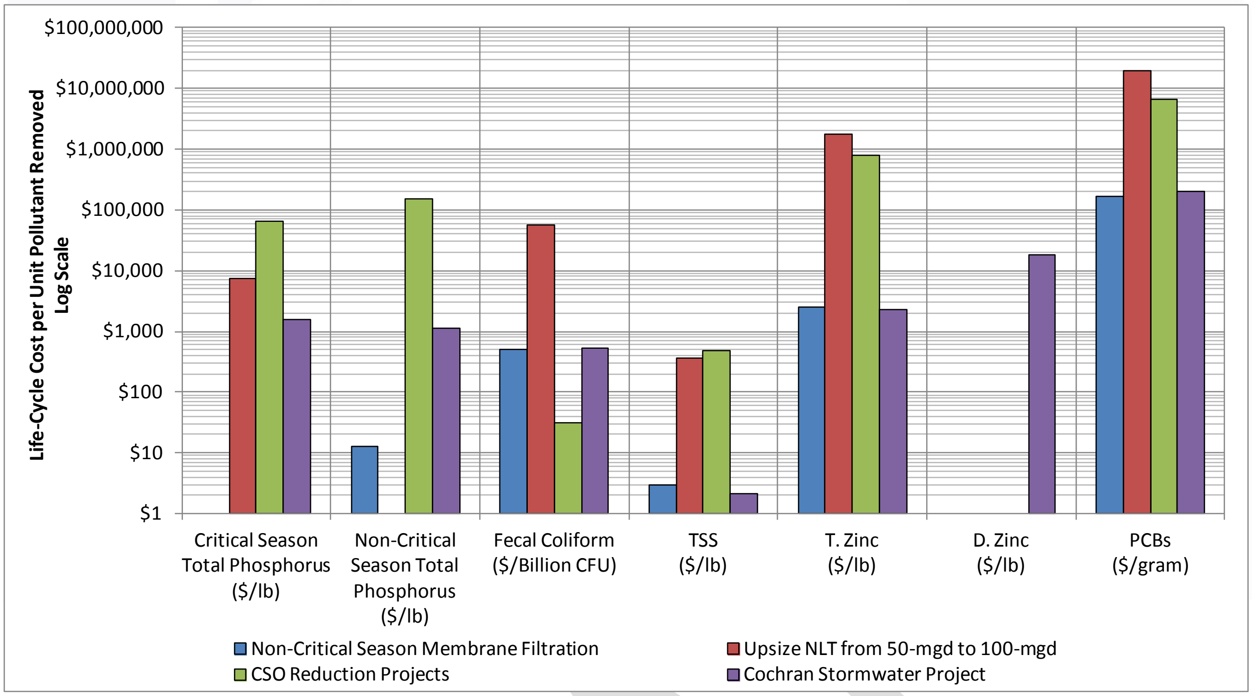

FIGURE 4-5
Comparison of the Life-Cycle Cost per Unit of Pollutant Removed for Various Water Quality Projects

Figure 4-5 and Table 4-8 indicate that, for most pollutants, upsizing the Membrane Filtration facility from 50-mgd to 85-mgd results in a higher life-cycle cost per unit of pollutant removed than both the Cochran stormwater project and operating the Membrane Filtration facility during the non-critical season. Although constructing the facility at an 85-mgd capacity would remove additional pollutants compared to constructing the facility at a 50-mgd capacity, the 70 percent increase in capacity only results in a one percent increase in pollutants removed. Details on this analysis can be found in Appendix D. Table 4-8 also indicates that membrane filtration during the non-critical season is more cost-effective than upsizing the Membrane Filtration facility from 50 mgd to 85 mgd during the critical season.

4.4 ALTERNATIVE SELECTION

After completing the evaluations described in the section above, the City selected Systems Wide Alternative 3 (Storage + Green + Cochran + Membrane Filtration during the Non-Critical Season) as the recommended alternative in this Integrated Clean Water Plan and selected 50 mgd as the optimal Membrane Filtration facility sizing. This Systems Wide Alternative was selected as the recommended alternative for the following reasons:

- Provides the highest pollutant removal at the lowest cost per pound pollutant removed (see Figure 4-2)
- Provides the highest total value score as developed in the MODA process (see Figure 4-3)
- Removes pollutants from all three different pollutant sources: CSOs, stormwater discharge, and RPWRF effluent (see Figure 4-5)

While Systems Wide Alternative 3 is the most expensive of the five alternatives evaluated, the additional pollutant removal and other benefits that the alternative provides the greatest value for Spokane utility ratepayers, making this the most cost-effective alternative that meets the regulatory requirements.

Table 4-9 presents the projects included in Systems Wide Alternative 3, along with the total capital cost and life-cycle cost. The approximate locations of the projects are presented in Figure 4-6.

4.4.1 Long-Term Effort to Implement Green Infrastructure

In addition to the projects listed in Table 4-9, the recommended Systems Wide Alternative allows the City to implement GI in conjunction with other infrastructure improvements.

TABLE 4-9
Projects Included in Recommended Systems Wide Alternative 3

Project Type	Project Name	Project Description	Estimated Total Capital Cost[a] ($M)	Estimated Life-Cycle Cost[a,b] ($M)		
				Capital Cost Component of Life-Cycle Cost	O&M Cost Component of Life-Cycle Cost	Total Life-Cycle Cost
Planned Future Water Quality Projects						
CSO	CSO Basin 6	Storage Only	$11.4	$9.2	$1.4	$10.6
CSO	CSO Basin 7	Regulator Upsize	$0.5	$0.4	$0.01	$0.4
CSO	CSO Basin 12	Storage Only	$8.7	$6.9	$1.2	$8.1
CSO	CSO Basin 14	Storage + Stormwater Infiltration	$1.6	$1.4	$0.4	$1.8
CSO	CSO Basin 15	Storage + Stormwater Infiltration	$2.1	$2.0	$0.4	$2.4
CSO	CSO Basin 23	Regulator Upsize	$1.1	$0.9	$0.2	$1.0
CSO	CSO Basin 24, 25, & 26	Storage Only	$42.2	$37.5	$4.5	$42.1
CSO	CSO Basin 33a, b, and c	Storage Only	$27.2	$23.0	$4.2	$27.2
CSO	CSO Basin 33d	Storage Only	$5.5	$4.5	$1.2	$5.7
CSO	CSO Basin 34/IO7	Storage Only	$15.9	$13.7	$2.8	$16.5
CSO	CSO Basin 41	Regulator Upsize	$1.3	$1.0	$0.0	$1.0
Interceptor Protection	IO3	Interceptor Protection Tank	$12.8	$13.0	$2.2	$12.1
Interceptor Protection	IO4-1 (East)	Interceptor Protection Tank	$10.8	$9.5	$1.2	$10.7
Interceptor Protection	IO4-2 (West)	Interceptor Protection Tank	$3.3	$2.7	$1.7	$4.4
Stormwater	Cochran	Bioinfiltration Facility	$20.0	$16.0	$1.6	$17.9
RPWRF	Non-Critical Season Membrane Filtration	Membrane Filtration	$0	$0	$5.1	$16.2
Subtotal, planned future water quality projects			$164.5	$141.7	$28.1	$178.1
Ongoing Water Quality Projects						
CSO	CSO Basin 20	Multiple Projects	$4.3	NA	NA	$4.3
CSO	CSO Basin 24	Multiple Projects	$2.1	NA	NA	$2.1
CSO	CSO Basin 34	34-2	$17.9	NA	NA	$17.9
CSO	CSO Basin 34	34-3	$14.8	NA	NA	$14.8
RPWRF	Membrane Filtration Facility	50 mgd membranes	$106.6	$100.5	$26.3	$126.8
Total, ongoing and planned future water quality projects			$310			$344

[a] In April 2013 dollars.

[b] Based on a 25-year life-cycle cost analysis using a 2% discount rate. The life-cycle cost includes capital, property, operations and maintenance, and replacement costs, as well as additional or reduced cost of treatment at the RPWRF (if applicable).

NA = Capital and O&M cost components of Life-Cycle Cost were not estimated. Life-cycle costs for ongoing CSO investments were not available. However, analysis of similar CSO projects evaluated as part of this Integrated Clean Water Plan indicated that the life-cycle cost of a Storage Only CSO project is typically very close to the project's total capital cost. For ongoing CSO investments, life-cycle cost is estimated as equal to total capital cost.

During the alternative evaluation phase, it was determined that implementing GI solely for the purpose of CSO reduction is not cost-effective when compared with storage and conveyance facilities. However, if GI can be implemented jointly with other infrastructure improvements, such as road repaving, water main replacements, and other improvements in the right-of-way, the marginal cost of implementing GI can be reduced. This is discussed in more detail in Chapter 6.

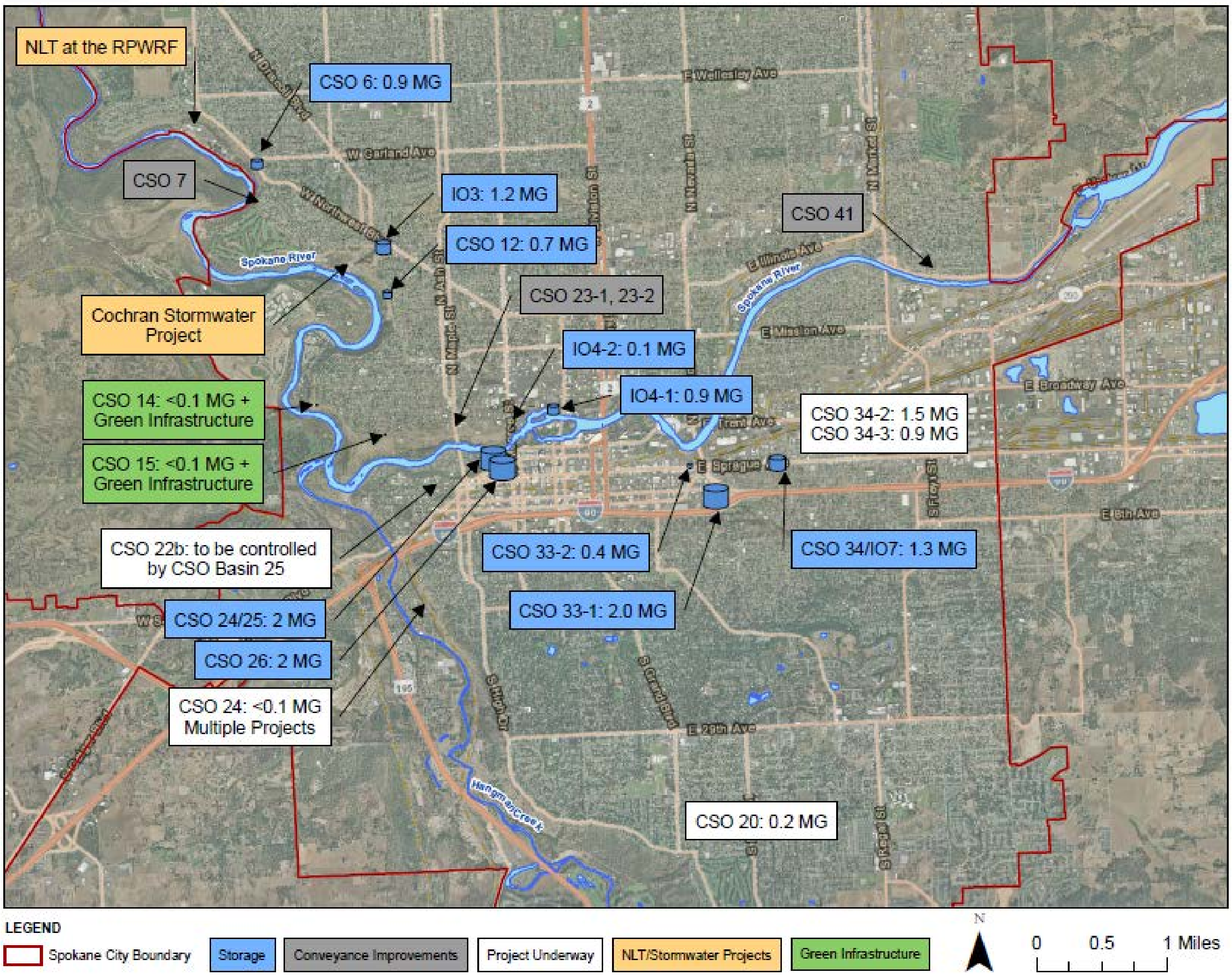

FIGURE 4-6
Map of Proposed Projects in the Selected Systems Wide Alternative 3

4.5 PROPOSED IMPLEMENTATION SCHEDULE

Figure 4-7 presents an implementation schedule for the selected Systems Wide Alternative that will control the City's remaining uncontrolled CSO outfalls by December 31, 2017, and a fully compliant Membrane Filtration facility by March 1, 2021. A needed cash flow of the proposed implementation schedule for the selected Systems Wide Alternative is presented in Figure 4-8 for the $310 million capital cost of that alternative.

The start and end dates for the recommended projects are staggered to allow efficient use of City staff time to deliver the projects. Large projects like the storage facilities in CSO Basins 24, 25, 26, and 34, and the Membrane Filtration facility, are under way to meet applicable NPDES permit deadlines and to achieve a Cleaner River Faster.

Some small projects, such as those in CSO Basins 7, 23, and 41, need to wait until other projects are implemented, because these projects increase the flow sent to the City's interceptor system. These small projects need to wait until other projects that reduce the flow to the interceptor system are completed before construction can begin.

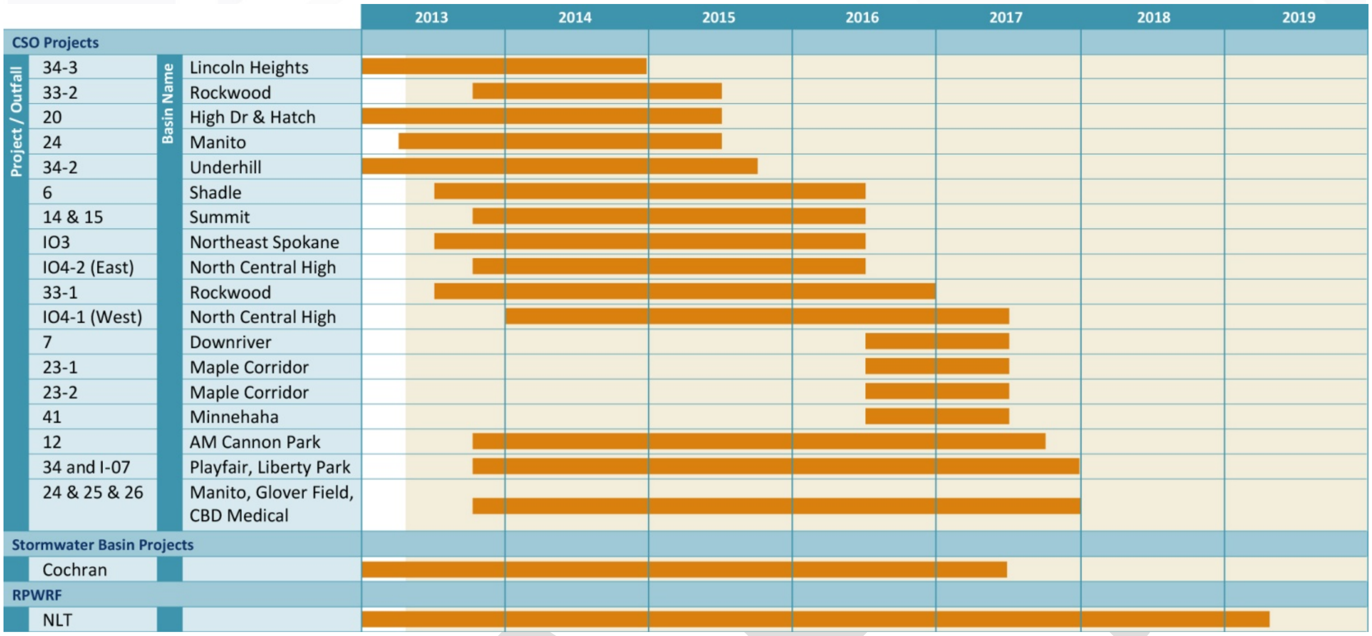

FIGURE 4-7

Integrated Clean Water Plan Implementation Schedule

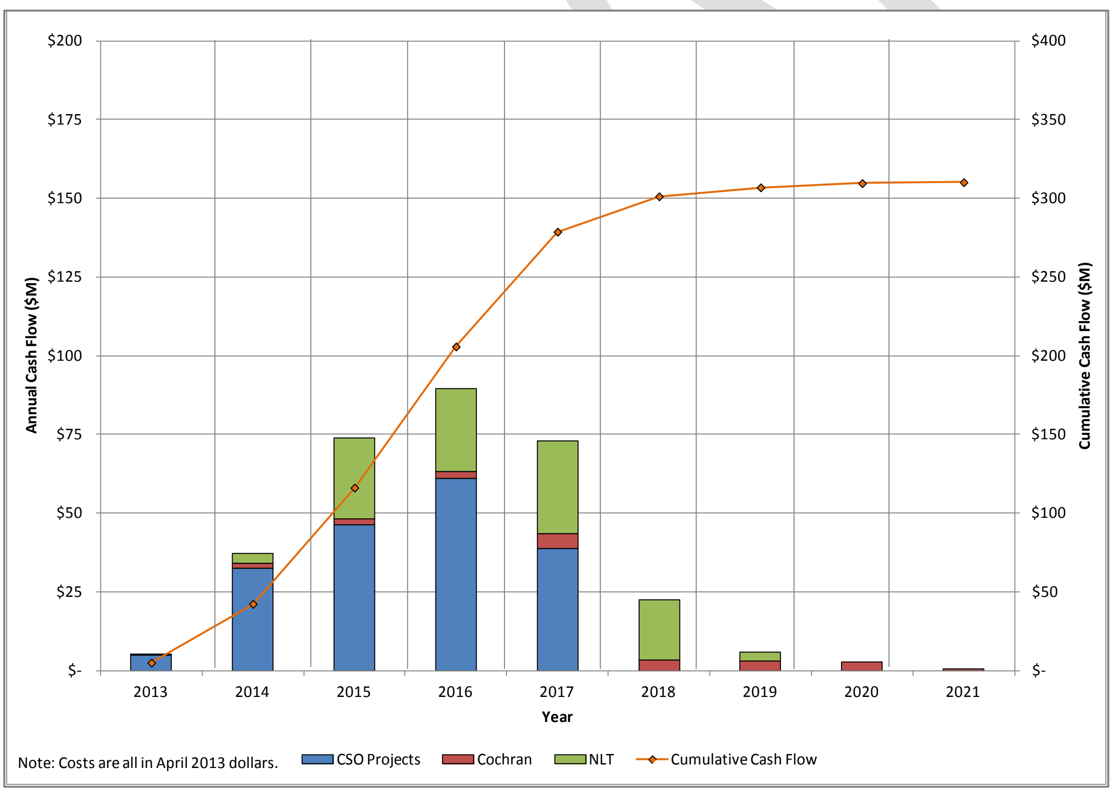

FIGURE 4-8

Integrated Clean Water Plan Cash Flow for Selected Systems Wide Alternative

Figure 4-9 presents the anticipated annual removal of PCBs through implementation of this Integrated Clean Water Plan. The majority of the annual PCB removal is achieved by controlling CSO Basin 34, the completing of the Cochran stormwater project, and Membrane Filtration facility operation during the non-critical season. Figure 4-9 shows a November 2021 date as the start of the first non-critical season of membrane filtration following the first critical season of membrane filtration from March through October of 2021.

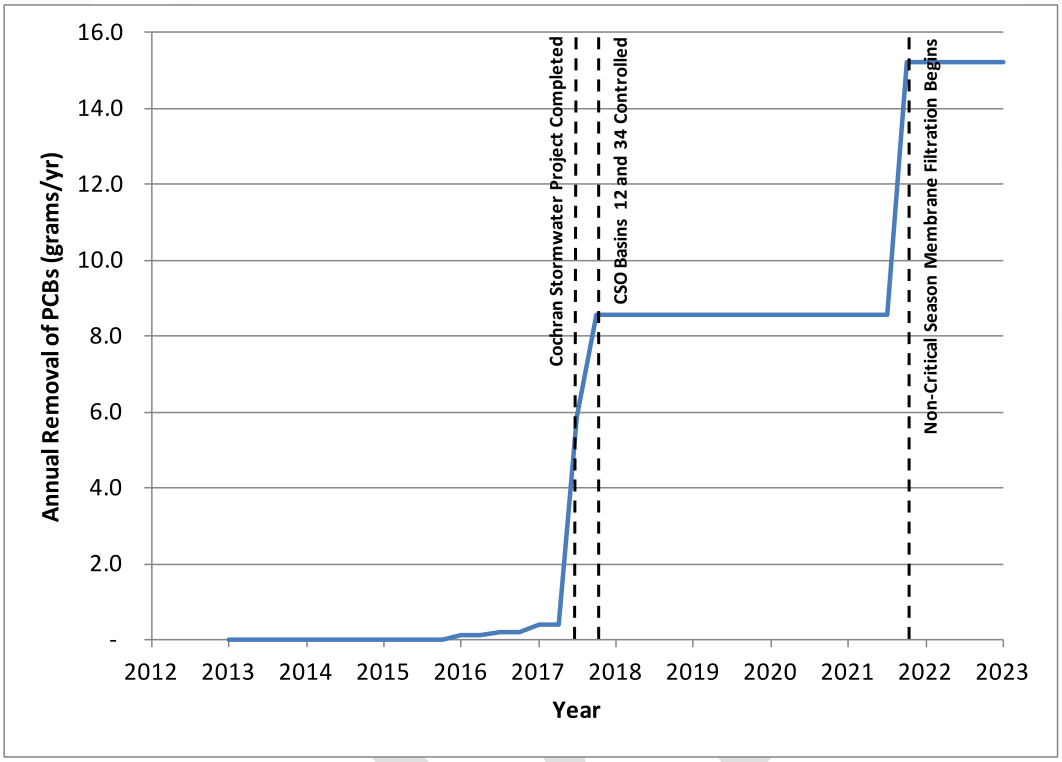

FIGURE 4-9

Anticipated Annual PCB Removals for the Selected Systems Wide Alternative

4.6 FINANCIAL AND SCHEDULE EVALUATION

Improving the health of the Spokane River provides a statewide benefit and is a statewide priority. The Spokane River flows through two states, several Washington counties, and the sovereign lands of the Spokane Tribe. It empties into the Columbia River. The Spokane River basin and the Columbia River basin represent two of the four priority water basins listed by the Ecology.

The City of Spokane has voluntarily developed this comprehensive Integrated Clean Water Plan that will deliver significantly greater pollution reduction benefit to the river, compared with previous plans. The plan includes projects that are required by our permits and others that simply just make sense for health of the river. This plan also anticipates meeting the City's regulatory deadlines on time, includes an adaptive management approach to continue to remove stormwater from wastewater systems in the future, and helps the region meet measurable progress toward PCB reduction in the river.

However, the projects in the plan require a significant financial investment – the selected Systems Wide Alternative has an estimated $310 million capital cost ($344 million in terms of life-cycle cost). But to serve Spokane's citizens well and maintain a healthy budget, the City must be both environmentally and financially responsible.

To achieve these superior results, the City requires financial partnership with Ecology that commits funding equal to 20 percent of the total project cost—or $62 million in today's dollars. The City would provide the other 80 percent of the funding and commit to completing the plan as detailed within existing deadlines. This partnership is very consistent with the economic health of the City and its citizens and acknowledges the additional environmental results for the river and the benefits that extend well beyond the City's boundaries.

Like other cities in Washington, Spokane has experienced a significant decline in economic activity over the last four years as well as anemic growth in municipal revenues to their general fund. Between 2008 and 2011, sales tax and property tax together increased 0.1 percent between 2008 and 2011, while sales tax, a mainstay of local government revenue, decreased by 6.7 percent over this same period.

At the same time, Spokane County's median household income decreased by about $2,000 from 2008 to 2011. Today, the median household income in the City is only 70 percent of the statewide average and 78 percent of the national average. Some 17 percent of households reported income below the poverty line for the 2010 Census, and one of the state's poorest legislative districts can be found in the heart of Spokane.

In preparation for their part of the partnership, the City raised its utility rates in anticipation of significant environmental and capital improvement requirements. Sewer rate increases of 15 percent, 17 percent, and 13.5 percent were enacted in 2009, 2010, and 2011, respectively, to enable the City to better meet these financial obligations. The City is planning future rate increases to be limited to the rate of inflation to address needed affordability for ratepayers, especially considering that the Spokane City Council has determined that any increase in utility rates has a "profound impact on low-income customers."

The City has found overall concurrence by the public and stakeholders with the approach laid out in this Integrated Clean Water Plan. Support can be found from environmental advocates, river users, Lake Spokane homeowners, local contractors, business, neighborhoods, and the general public. However, public acceptance, in part, hinges on the affordability of the work. To achieve public acceptance and the benefits detailed throughout this plan, the City must be both environmentally and financially responsible. Ultimately, it is critical for the City to find a path forward that enables these investments in water quality in a way that is affordable for its ratepayers.

Chapter 5: Measuring Success

This chapter follows the guidance of the USEPA's Integrated Planning Framework Element 5, and includes discussion on a process for evaluating the performance of projects identified in a plan, which may include evaluation of monitoring data, information developed by pilot studies and other studies, and other relevant information, including:

- Proposed performance criteria and measures of success
- Monitoring program to address the effectiveness of controls, compliance monitoring, and ambient monitoring
- Evaluation of the performance of GI and other innovative measures to inform adaptive design and management to include identification of barriers to full implementation

As discussed in Chapter 1, anticipated water quality benefits used to prioritize Integrated Clean Water Plan projects were quantified using a presumptive approach. Consistent with this decision, the City will also rely on performance criteria that are presumptively based. This means that any reduction in pollutant loading is presumed to produce immediate and/or cumulative benefit to water and sediment quality. Measures of success include improved receiving water conditions, from both an ambient monitoring and a beneficial use perspective.

As the City implements the projects identified in Chapter 4, success will be adaptively measured to determine whether the projects are performing as expected and achieving the goal of a Cleaner River Faster. The City will accomplish this through three steps described in this chapter:

- Step 1. Document Pre-Integrated Clean Water Plan Baseline Condition
- Step 2. Collect Post-Implementation Performance Data
- Step 3. Evaluate Information and Modify Actions as Needed

5.1 STEP 1. DOCUMENT PRE-INTEGRATED CLEAN WATER PLAN BASELINE CONDITION

This Integrated Clean Water Plan documents current baseline conditions based on currently available information. Chapter 2 provides a summary of existing conditions for the wastewater collection system (CSO monitoring), wastewater treatment system (NPDES influent and effluent monitoring at the RPWRF), and stormwater (Cochran, Washington, and Union basins). In addition, Chapter 2 provides a summary of existing conditions for receiving waters, namely the Spokane River and Latah Creek.

5.2 STEP 2. COLLECT POST-IMPLEMENTATION PERFORMANCE DATA

As the City implements projects within the recommended alternative, the City will continue to collect monitoring data to assess the extent to which the projects are improving system performance and achieving a Cleaner River Faster, consistent with the City's preferred presumptive approach to measuring water quality and human health impacts discussed in Section 1.2.4 of this Plan. The City's plan to collect post-implementation performance data is summarized below:

1. Wastewater collection system monitoring will continue to focus on monitoring and modeling of CSO overflow frequency and volumes. As part of post-construction monitoring, the City will select 2 representative outfalls that help demonstrate that meeting the presumptive standard of one untreated CSO event per year is protective of water quality and will conduct water effluent monitoring of those outfalls. The effluent quality data from these representative outfalls will be used to characterize water quality of effluent at all the CSO outfalls, and will be selected in consultation with Ecology as part of the Steering Committee as the construction schedule is finalized.
2. Wastewater treatment system monitoring will continue to focus on NPDES monitoring of influent and effluent volumes and quality at the RPWRF.
3. Post-construction monitoring and modeling of stormwater and GI projects will build on data collected in the 2012-2013 wet season. The City will continue to work cooperatively with the Spokane River Regional Toxics Task Force to develop stormwater monitoring strategies.

The City will measure success by relying on the existing ambient monitoring program that Ecology implements for the Spokane River and its tributaries. Ecology maintains two long-term monitoring stations for this reach of the Spokane River (57A150 - Spokane River @ Stateline Br and 54A120 - Spokane River @ Riverside State Park) that document the existing levels of pollutants in the Spokane River (as summarized in Chapter 2). Similar to how the City evaluated and ranked potential projects, evaluation of ambient monitoring data will focus on potential human and aquatic life exposure. All of the uncontrolled CSO discharges enter the Spokane River upstream from Station 54A120 - Spokane River @ Riverside State Park. Therefore, this will be the primary location of long-term trend analysis for the Spokane River. Consistent with CWA timelines, the City will evaluate ambient monitoring data approximately every 5 years in alignment with TMDL implementation adaptive management schedules.

It is important to note that the City will also use other information, as pertinent, to assess post-implementation performance, because there are other sources of pollutants measured at this station that are unrelated to City activities.

5.3 STEP 3. EVALUATE INFORMATION AND MODIFY ACTIONS AS NEEDED

As part of the adaptive management process discussed in Chapter 6, the City will assess the monitoring data collected, compare it against pre-Integrated Clean Water Plan baseline conditions, and use the results to identify how well the project(s) are working, and/or whether control designs should be improved. More information on the City's adaptive management approach is included in Chapter 6.

Chapter 6: Improvements to the Plan

This chapter follows the guidance of the USEPA's Integrated Planning Framework Element 6, and discusses improvements to the plan, and includes:

- A process for identifying, evaluating, and selecting proposed new projects or modifications to ongoing or planned projects and implementation schedules based on changing circumstances
- In situations where a municipality is seeking modification to a plan, or to the permit or enforcement order that is requiring implementation of the plan, the municipality should collect the appropriate information to support the modification and should be consistent with Elements 1 – 5.

This chapter describes the process for making improvements to this Integrated Clean Water Plan by identifying, evaluating, and selecting proposed new projects.

6.1 ADAPTIVE MANAGEMENT

The City has adopted an adaptive management process for CSO reduction, stormwater reduction, and sizing the Membrane Filtration facility. This approach provides a robust decision-making process that is well-suited for situations with considerable uncertainty. Applying an adaptive management approach to CSO reduction and sizing the Membrane Filtration facility allows the City to make decisions based on the best information available and to subsequently gather new information upon which new decisions can be made.

An adaptive management process is suitable for implementing this Integrated Clean Water Plan because there are many sources of uncertainty that could impact the success of the proposed projects. Several of the primary sources of risk include, but are not limited to, the following:

- **Growth**: Growth could require assumptions to be revised if population growth in the City and Sewer Service Area exceeds the estimates that the CSO modeling and Membrane Filtration facility sizing are based on, planned projects may not be sufficient to meet control requirements.
- **Climate change**: According to available literature, total annual precipitation in the City is projected to increase two to three percent by 2050, with some estimates as high as 10 percent (Washington Climate Preparation and Adaptation Work Group, 2007). Seasonal patterns show a decrease in overall precipitation in summer (June -September), with the largest increases in late fall and early winter (October -December) (SimCLIM results) (CLIMsystems, 2013). More extreme and earlier winter storms are expected for the Pacific Northwest (Salathe et al., 2013). However, despite 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 by 2 to 5 degrees Fahrenheit by 2050 (Washington Climate Preparation and Adaptation Work Group, 2007). 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 inherent in planning tools (flow monitoring data, modeling, etc.)**: There is uncertainty inherent in planning tools, including models, flow monitoring data, and precipitation data. All monitoring data are limited by the ability of the equipment to accurately and precisely measure true conditions. Because models are typically built using measured or monitored data, the uncertainty in monitoring data is passed along to modeling. Models also contain inherent uncertainty because they are based on calculations that simulate natural processes.

6.1.1 CSO Control

The City will apply an adaptive management process to achieve the CSO performance standard. As discussed in the 2013 CSO Reduction Plan Amendment (CH2M HILL, 2013b), the CSO reduction projects have been sized to take into account various uncertainties and risks specific to each CSO basin. Although the proposed CSO reduction projects are expected to control uncontrolled CSO outfalls, the future is uncertain, and the City needs to plan for how to identify when additional CSO reduction projects are needed, and what those new projects could be.

A key component of an adaptive management process is to collect and analyze data to evaluate the success of a decision. This concept will be applied to the City's CSO reduction efforts by continuing to monitor the frequency, volume, and duration of CSO events at all CSO outfalls, as required in the City's NPDES permit and described in Chapter 5. These data will be the primary source for determining the control status of each CSO outfall according to the CSO performance criteria and will be used to identify the need for new CSO reduction projects.

The City has prepared a variety of "safety outs" that can be implemented if future flow monitoring data indicate that a CSO outfall remains out of compliance with the CSO performance measure. These safety outs include, but are not limited to, the following:

- Implement GI, where feasible, to reduce the volume of stormwater runoff sent to the combined sewer system and, ultimately, the RPWRF. As discussed in Section 6.2, the City is planning to adopt a long-term approach to implementing GI throughout the City as part of other public infrastructure projects and to promote use among private developers of its recently-adopted LID ordinance. These approaches are expected to provide long-term reductions in stormwater runoff volumes and corresponding reductions in CSO frequency and volume.
- Select sites for storage facilities that are large enough to accommodate a second phase of construction to increase the size of a storage facility and/or identify/acquire additional storage site locations.
- Evaluate and implement, if feasible, an adjustment to the CSO regulator setting, which controls the release of flow into the interceptor system. It will be important to balance this adjustment with the need to keep the flow in IO2 below 120 mgd, as described in Section 4.1.1.2.

The City will determine which type of project will control the outfall if future flow monitoring indicates that CSO outfalls remain out of compliance. These decisions will be based on an evaluation that considers the technical feasibility, financial impacts, water quality and human health benefits, and other factors, as appropriate.

6.1.2 Next Level of Treatment

One of the main sources of uncertainty for the Membrane Filtration facility providing NLT is whether or not future flows to the RPWRF will increase, and by how much. Also, the current trend of reduced flows to the plant adds to this uncertainty. As described in the Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013c), the City intends to construct the Membrane Filtration facility sized for the immediate need, and then to expand using a "just in time" approach if increases in future flows put the City at risk of exceeding effluent limits.

However, the variation in flow to the RPWRF caused by I/I is much greater than the projected flow increases from growth, and I/I reduction may actually reduce flows in the future. Because of this, the City is committed to identifying and eliminating sources of I/I in order to lower the likelihood that the Membrane Filtration facility needs to be expanded in the future. Section 6.2 provides details on planned future I/I reduction efforts.

6.2 LONG-TERM APPROACH TO GREEN INFRASTRUCTURE

As discussed in Chapter 4, GI is a key component of the City's efforts to achieve long-term compliance with the CSO performance measure. However, implementing GI has many additional benefits beyond just CSO reduction, such as treating stormwater, enhancing environmental quality, and providing economic and community benefits (USEPA, 2012). Because of the multiple benefits provided by GI, the City of Spokane has adopted a long-term approach to implementing GI by coupling these improvements with other public infrastructure projects, and by encouraging use of its LID ordinance on private projects.

6.2.1 Implementing Green Infrastructure with Other Infrastructure Projects

In addition to the projects described in Chapter 4, the recommended Systems Wide Alternative from this Integrated Clean Water Plan will include a long-term effort by the City to implement GI throughout the City in conjunction with other infrastructure improvements. During the alternative evaluation phase, it was determined that implementing GI solely for the purpose of CSO reduction is not cost-effective when compared with storage and conveyance facilities. However, if GI can be implemented jointly with other infrastructure improvements as an integrated infrastructure strategy, such as road repaving, water main replacements, and other improvements within the right-of-way, the incremental cost of implementing GI can be reduced while providing additional non-CSO benefits. This strategy would, therefore, evaluate GI with other planned infrastructure projects and prioritize implementation based on cost-benefit achieved by coupling the improvements into a single project.

The City completed a case study that estimated the cost savings that could be achieved by implementing GI with other infrastructure improvements (CH2M HILL, 2014e, also included as Appendix F to this Plan). The case study focused on the recently completed Euclid Water Main Replacement Project, which consisted of replacing a water main in the right-of-way, pavement restoration, and making some sidewalk improvements. The case study explored a wide-range of GI practices that could have been implemented with the water main replacement project and estimated the relative costs and benefits. The results of the case study indicated that, depending on the type of GI being implemented, savings could range from a reduction of 9 percent to a reduction of 67 percent in the cost of implementing GI.

Figure 6-1 presents the results of this case study, comparing the cost of implementing GI with the cost of constructing storage to achieve CSO reduction. The cost is presented per gallon of control volume in order to allow a fair comparison between GI and storage. As Figure 6-1 indicates, on a case-by-case basis, GI may be more cost-effective than using storage as a method for reducing CSOs when it is implemented with other infrastructure projects. However, there remains significant potential variability in costs for both GI and storage that varies from basin to basin and as a result of site-specific conditions.

A similar integrated infrastructure strategy for implementing GI will also be applied to parts of the City that have separated stormwater systems. Although implementing GI in these areas will not reduce CSOs, it will treat stormwater before discharge to the Spokane River, reduce the impact of this stormwater on the interceptor in incomplete separation areas, and is in alignment with the City's goal of achieving a Cleaner River Faster.

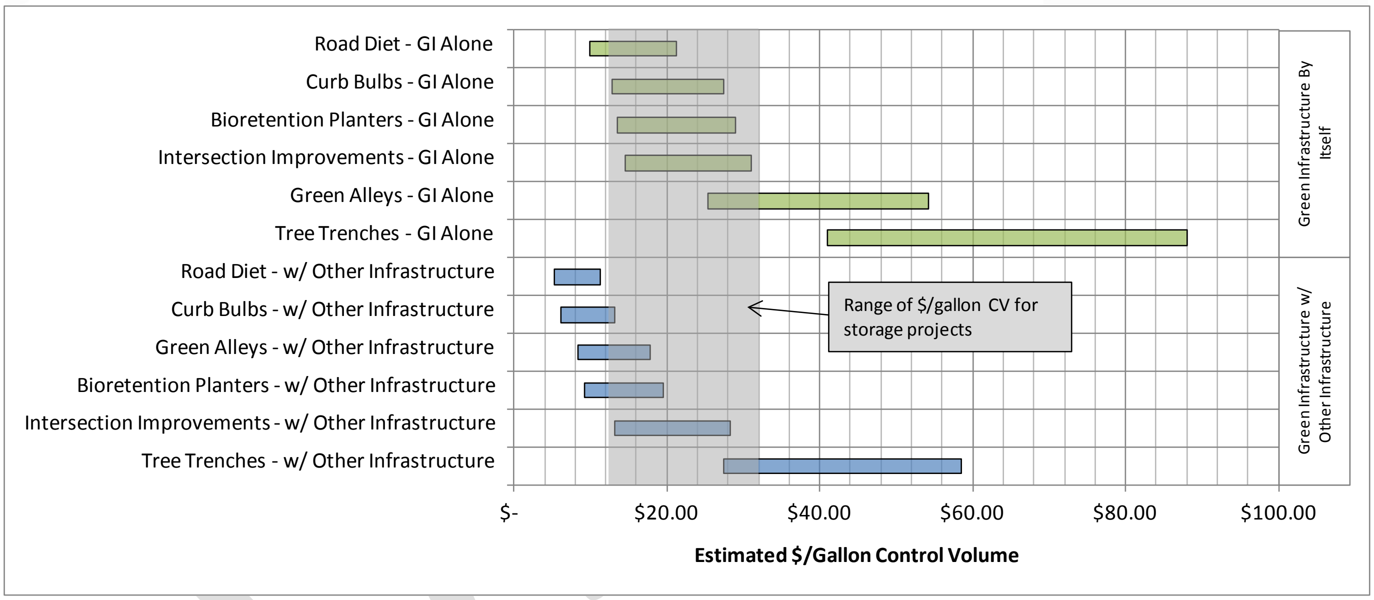

FIGURE 6-1
Comparison of Cost per Gallon Control Volume for Green Infrastructure and Storage

Implementing GI with other infrastructure improvements could make GI a cost-effective method for achieving CSO reductions. The strategy requires opportunistic identification of projects and therefore has an uncertain timeline. Given this uncertainty and the December 31, 2017, deadline for bringing all uncontrolled CSO outfalls under control, relying solely on an integrated infrastructure strategy to implement GI would not likely result in compliance with the NPDES permit requirement.

As such, the City is planning a long-term control strategy independent of GI and will adopt the integrated infrastructure strategy to implement GI with other projects as opportunities arise, which would result in long-term reductions in CSO frequency and volume, as well as reductions in stormwater discharges. This strategy also serves to mitigate uncertainties associated with growth and climate change.

The City has already begun incorporating the concept of prioritizing projects that provide multiple benefits into the City's Comprehensive Plan, with a planning effort called Link Spokane. This effort will include an update to the transportation chapter of the Comprehensive Plan that describes how the City can meet its goals, which include:

- Provide transportation choices
- Accommodate access to daily needs and regional destinations
- Maximize benefits with integrated public investments
- Promote economic opportunity and fiscal responsibility
- Enhance public health and safety
- Respect natural and neighborhood assets

The effort takes a more expansive view of the functions (transportation, commerce, water, sewer, stormwater conveyance, etc.) of street right-of-way, and is a holistic approach to infrastructure planning.

6.2.2 Low Impact Development Ordinance

The City has recently adopted a low impact development ordinance that encourages the incorporation of low impact development techniques and practices into public and private development (ordinance number C35021). This ordinance also was a requirement of a consent decree between the City of Spokane and the Spokane Riverkeeper, a program of the Center for Justice in Spokane.

The ordinance provides discounts on commercial stormwater charges to properties that implement low impact development, such as rainwater harvesting, vegetated roofs, permeable pavement, bioretention, infiltration planters, storm gardens, and other emerging technologies as approved by Ecology and the City.

This ordinance is expected to reduce the volume of stormwater discharged into the Spokane River, and may also reduce CSO volumes if properties located in CSO basins that were developed prior to current stormwater management requirements incorporate low impact development into their properties.

6.3 INFILTRATION & INFLOW REDUCTION EFFORTS

I/I is an issue that affects almost all sewer systems. Infiltration is water that seeps through the ground and into the wastewater collection system through cracks in pipes, offset joints, and other underground defects. Inflow is water that enters the system through inappropriate connections, such as stormwater runoff that enters the system through the holes of a maintenance hole lid. I/I can be a significant source of flow in some sewer systems, and can exacerbate or cause CSOs.

Flow monitoring throughout the City's collection system and at the RPWRF indicates that the Spokane River can be the source of I/I into the wastewater collection system. This form of I/I, called River I/I, occurs only when the flow in the Spokane River exceeds a certain flow rate. The City has been aware of this issue for some time, and has taken steps to systematically identify and eliminate River I/I sources. These steps have been successful, as demonstrated by the increasing river flow threshold above which River I/I is significant.

The City remains committed to reducing the amount of I/I and River I/I that enters the wastewater collection system. Since the early 1980s, the City has been aggressively targeting the elimination of I/I in its wastewater collection systems through adopting policies and procedures, setting measurable goals for I/I reduction, and completing specific projects and programs. The technical memorandum "Review and Summary of City of Spokane Past I/I Strategy and Practices" (CH2M HILL, 2014b) summarizes ongoing and completed I/I reduction efforts by the City.

6.4 "DELTA MANAGEMENT" FOR CSO, STORMWATER, AND WASTEWATER WASTELOAD ALLOCATIONS

As discussed in Chapter 1, the Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load Water Quality Improvement Report (Ecology, 2010) established wasteload allocations (WLAs) for ammonia, total phosphorus, and CBOD for the City of Spokane and other Washington State dischargers to the River. The WLAs were established for wastewater discharges, stormwater discharges from separated stormwater systems, and CSOs.

The TMDL also provides for "Delta Elimination" and "Target Pursuit Actions" in recognition that the implementation of additional treatment technologies alone at a point source may not be able to reduce permitted discharges to the levels derived from the WLAs established in the TMDL. Documents describing the Delta Elimination and Target Pursuit Actions began development in the form of "toolboxes" with Ecology in 2012. The City of Spokane defined a toolbox called, "Delta Management for Stormwater, CSO, and Wastewater Wasteload Allocations." This toolbox concept addresses the cumulative effect of a single discharger with multiple sources such as the City of Spokane. In the case where a discharger has more than one type of system, compliance with the total WLA for that discharger is measured by the sum of all of its discharge contributions from each system. Credits may be traded *internally* so that the final sum of all WLAs determines compliance rather than each individual system addressed separately.

A second toolbox that the City of Spokane is interested in implementing is “Pollutant Equivalency – Static Permit Limits.” The predicted dissolved oxygen water quality in Lake Spokane reacts differently to increases or decreases in each of the three TMDL parameters, phosphorus, ammonia, and CBOD. Various combinations of these three parameters discharged to the river may result in more or less impacts to water quality in Lake Spokane. Phosphorus has the most pronounced impact to water quality in the lake, while ammonia has the least impact. If one of these three parameters in effluent is reduced sufficiently, then one of the other parameters may be increased, while still maintaining or improving the predicted water quality in Lake Spokane. The Static Permit Limits tool defines a single equivalent combination of ammonia, phosphorus, and CBOD that complies with the TMDL, based on modeling specific to the discharger employing this toolbox.

A third toolbox the City may elect to use is “Pollutant Equivalency – Dynamic Permit Limits.” This toolbox is nearly identical to the Static Permit Limits tool, with the exception that the concentration of each of the three TMDL parameters can be dynamically adjusted rather than fixed.

These concepts are still in draft form, and if adopted would be incorporated into the City’s NPDES permit. Ecology has requested that each discharger work individually with the Department to develop and adopt the required tools into NPDES permits. Prior to implementing this type of a concept, additional stormwater and CSO water quality sampling would be needed to accurately characterize the discharges from those sources in coordination with Ecology. Modeling may be required to determine static or dynamic equivalencies specific to the City of Spokane.

Because the City is subject to regulatory requirements across its range of stormwater, CSO, and municipal wastewater treatment services, this Integrated Clean Water Plan represents a significant step toward recognizing potential water quality benefits from an integrated point source control approach.

6.5 NON-CRITICAL SEASON MEMBRANE FILTRATION VARIATIONS

As discussed in Section 4.1.1.4, the City may choose to operate membrane filtration during the non-critical season without CEPT or alum addition. The impact of this requires further study, but would generally be a reduction in total phosphorus and CBOD removal, and to a lesser extent, a reduction in the removal of metals. However, operating the membrane filtration system during the non-critical season without CEPT or alum addition would still remove a significant amount of PCBs, which are a water quality issue during both the critical and non-critical seasons because of their bioaccumulative nature.

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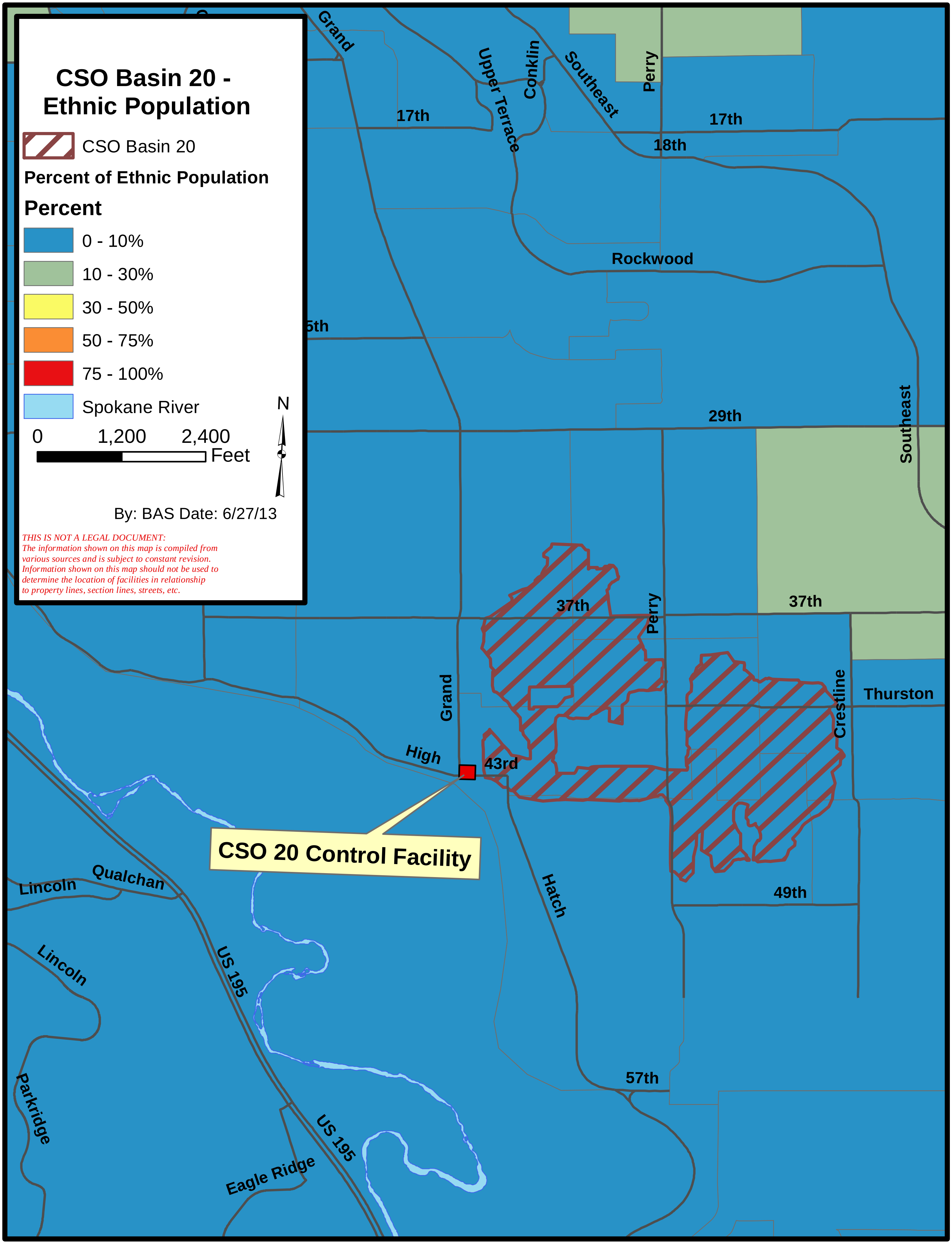
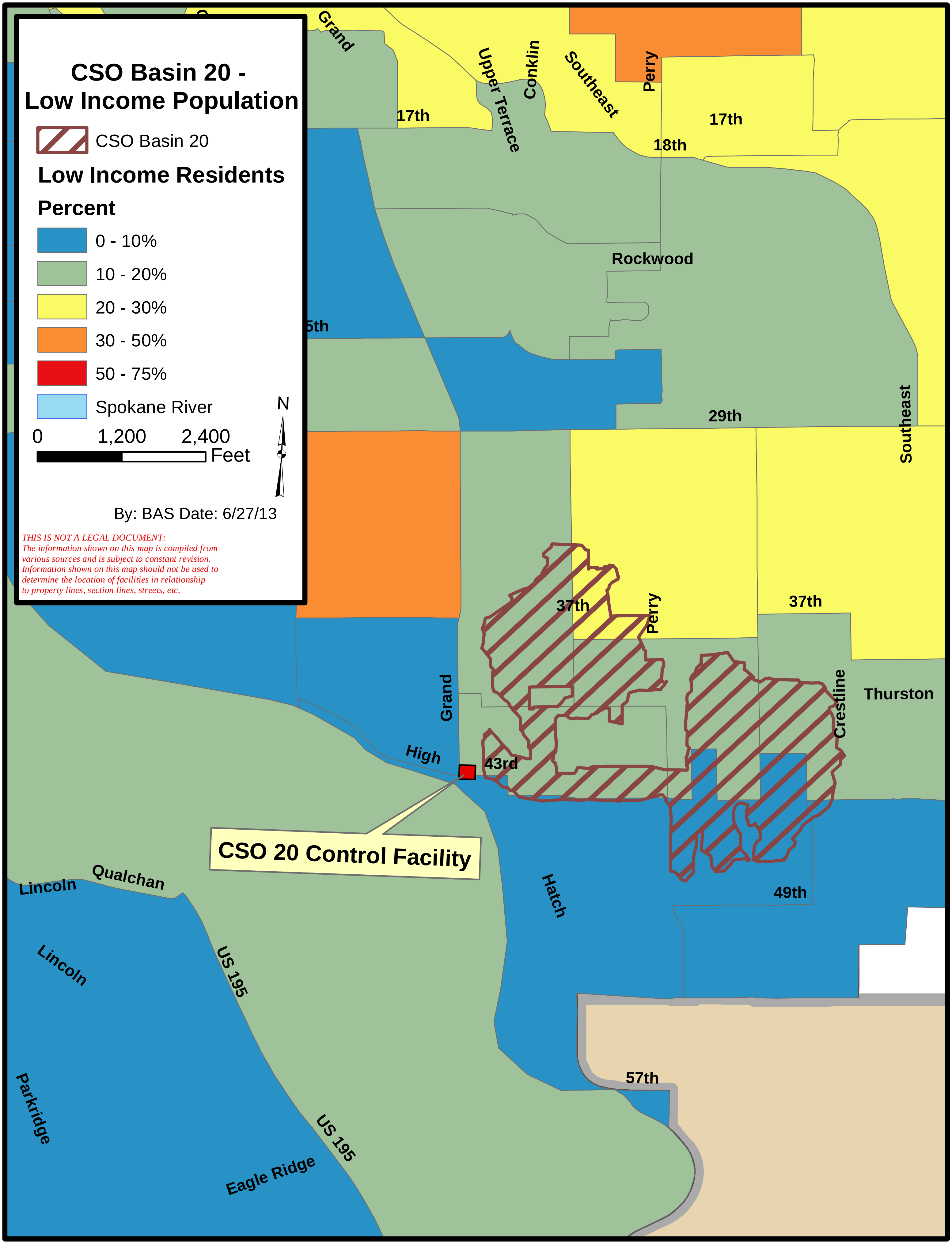
APPENDIX A

Maps of Ethnic Population and Low-Income Distribution for CSO Basin 20



CSO Basin 20 -
Ethnic Population
CSO Basin 20
Percent of Ethnic Population
Percent
0 - 10%
10 - 30%
30 - 50%
50 - 75%
75 - 100%
Spokane River
0
1,200
2,400
Feet
N
By: BAS Date: 6/27/13
THIS IS NOT A LEGAL DOCUMENT:
The information shown on this map is compiled from
various sources and is subject to constant revision.
Information shown on this map should not be used to
determine the location of facilities in relationship
to property lines, section lines, streets, etc.
Grand
17th
Upper Terrace
Conklin
Southeast
Perry
17th
18th
Rockwood
29th
Southeast
37th
Perry
37th
Crestline
Thurston
Grand
High
43rd
CSO 20 Control Facility
Hatch
49th
57th
Lincoln
Qualchan
Lincoln
US 195
Parkridge
Eagle Ridge
US 195



CSO Basin 20 -
Low Income Population
CSO Basin 20
Low Income Residents
Percent
0 - 10%
10 - 20%
20 - 30%
30 - 50%
50 - 75%
Spokane River
0
1,200
2,400
Feet
N
By: BAS Date: 6/27/13
THIS IS NOT A LEGAL DOCUMENT:
The information shown on this map is compiled from various sources and is subject to constant revision.
Information shown on this map should not be used to determine the location of facilities in relationship to property lines, section lines, streets, etc.
Grand
Upper Terrace
Conklin
Southeast
Perry
17th
17th
18th
Rockwood
29th
Southeast
37th
Perry
37th
Crestline
Thurston
Grand
High
43rd
CSO 20 Control Facility
49th
Hatch
Lincoln
Qualchan
Lincoln
US 195
57th
Parkridge
Eagle Ridge
US 195

APPENDIX B

Pollutant Removal Benefits of City of Spokane CSO Basin Solution

Pollutant Removal Benefits of City of Spokane CSO Basin Solutions

PREPARED FOR:	City of Spokane
COPY TO:	Jennifer Price/SEA File
PREPARED BY:	Santtu Winter/SEA
REVIEWED BY:	Dustin Atchison/SEA
DATE:	March 3, 2014
PROJECT NAME:	City of Spokane Integrated Plan
PROJECT NUMBER:	382918.T7.02.06

Purpose

The purpose of this technical memorandum is to document the estimated benefit, in terms of pollutant removal and cost per pound pollutant removed, of the various combined sewer overflow (CSO) reduction basin solutions being considered as part of the City of Spokane's (City's) Integrated Plan. Each basin solution will reduce the frequency of CSOs to below the regulatory threshold of no more than one CSO event per outfall on a 20-year moving average. The pollutant removal from the basin solutions are estimated to enable a comparison of the benefits, in terms of pollutant removal and life-cycle cost per pound pollutant removed, of CSO, stormwater, and other water quality projects as part of the Integrated Plan.

Summary

Five types of basin solutions were evaluated: Storage Only, Regulator Upsize, Storage + Green, Storage + Centralized Infiltration, and Green Only. These five basin solution types remove pollutants using three different pollutant removal mechanisms: storage and/or conveyance of CSOs, infiltration of stormwater during CSO events, and infiltration of stormwater during non-CSO events. The infiltration of stormwater during CSO events and non-CSO events are considered different pollutant removal mechanisms because the pollutant removal percentages differ between the two (see Table 8).

Pollutant removal amounts were estimated for the basin solutions being considered in the Integrated Plan, as shown in Table 9. Those amounts were converted into life-cycle costs per pound pollutant removed based on the basin solution's life cycle costs, as shown in Table 10. The resulting life-cycle cost per pound pollutant removed can be an effective way to evaluate the cost-effectiveness of pollutant removal of various water quality projects.

Conclusions from this analysis include:

- In general, the Green Only basin solutions have the lowest life-cycle cost per pound pollutant removed because they remove the most pollutants, and the Storage Only basin solution has the highest life-cycle cost per pound pollutant removed. The exception is for fecal coliform, where the trend is reversed due to the low concentration of fecal coliform in stormwater and the higher cost of the Green Only basin solutions.
- Regulator Upsize basin solutions are cost-effective ways to remove pollutants in basins with smaller CSO discharge volumes, because they require only small investments in infrastructure compared to storage facilities.

Although the life-cycle cost per pound pollutant removed is a useful tool to measure the cost-effectiveness of a water quality project, it should be used in conjunction with other evaluation methods, such as a multi-objective decision analysis. A decision on what projects to recommend in the Integrated Plan should not be based solely on the life-cycle cost per pound of pollutant removed.

Basin Solutions Evaluated

Five types of basin solutions were evaluated, as summarized below:

- **Storage Only**: These basin solutions consist primarily of a CSO storage facility. Pollutant removal is achieved by storing CSO events that used to overflow to the Spokane River, and sending them to the City's Riverside Park Water Reclamation Facility (RPWRF) for treatment once capacity is available in the conveyance system.
- **Regulator Upsize**: These basin solutions consist primarily of increasing the regulator flow control setting, which controls the release of flow from a CSO basin to the interceptor system. In other words, these basin solutions increase the amount of flow that is released from the CSO basin. Pollutant removal is achieved by conveying flow to the RPWRF for treatment.
- **Storage + Green**: These basin solutions include the construction of a CSO storage facility plus a combination of drywells and/or swales to infiltrate stormwater. In addition to the pollutant removal described above for the Storage Only basin solution, this basin solution achieves a significant amount of additional pollutant removal through the infiltration of stormwater.
- **Storage + Centralized Infiltration**: This basin solution is only feasible for CSO Basin 34, and involves the addition of swales for stormwater infiltration along the corridor for the currently planned upgrade to Interstate 90 to the east of downtown Spokane, along with a CSO storage facility. Pollutant removal is achieved in the same way as for the Storage + Green basin solutions.
- **Green Only**: These basin solutions only include a combination of drywells and/or swales for stormwater infiltration. Pollutant removal is achieved by infiltrating stormwater and by creating additional capacity in the wastewater collection system to convey flow to the RPWRF.

These five types of basin solutions remove pollutants through three different pollutant removal mechanisms, as summarized below:

- **Storage and/or Conveyance of CSOs:** This pollutant removal mechanism involves storing and/or conveying most CSO events to the RPWRF for treatment and discharge to the Spokane River. Under current conditions, all CSO events discharge a combination of untreated raw sewage and stormwater runoff to the Spokane River. This pollutant removal method applies to all basin solutions[1].
- **Stormwater Infiltrated during CSO Events:** This pollutant removal mechanism involves infiltrating stormwater runoff that occurs during CSO storm events into the ground. Under current conditions this flow is discharged untreated to the Spokane River. This pollutant

[1] This pollutant removal method applies to the Green Only basin solution because additional conveyance capacity is created by infiltrating stormwater.

removal method applies to the Storage + Green, Storage + Centralized Infiltration, and Green Only basin solutions.

- **Stormwater Infiltrated during Non-CSO Events:** This pollutant removal mechanism involves infiltrating stormwater runoff that occurs during non-CSO storm events into the ground. Stormwater infiltration facilities treat stormwater runoff during all events, regardless of whether the storm event causes a CSO or not. This pollutant removal mechanism accounts for pollutant removal caused by infiltrating stormwater runoff that occurs during storm events that do not cause CSOs. Under current conditions this flow is conveyed to and treated at the RPWRF. This pollutant removal method applies to the Storage + Green, Storage + Centralized Infiltration, and Green Only basin solutions.

Overview of Methodology

The process of estimating the pollutant removal amounts for each of the evaluated basin solutions differs, depending on whether or not the basin solution includes stormwater infiltration. The following is an overview of the steps:

General steps (applicable to all basin solutions):

Step 1.) Select pollutants to be included in the analysis.

Step 2.) Estimate typical concentrations for those pollutants in CSOs and in stormwater.

Step 3.) Determine the mechanisms for how CSO reduction will be achieved; either through storage and/or conveyance, infiltration, or a combination.

Step 4.) Estimate the reduction in the average annual CSO volume discharged to the Spokane River as a result of reducing the frequency of CSO events to less than one event per year.

Step 5.) Evaluate the percentage of pollutants removed at the RPWRF and through stormwater infiltration.

Steps to estimate the pollutant removal resulting from the storage and/or conveyance of CSOs (applicable to all basin solutions):

Step 6.) Calculate the volume of CSO reduction that will be controlled through storage and/or conveyance.

Step 7.) Multiply the volume of CSO reduction resulting from storage and/or conveyance by the pollutant concentration and the removal percentage at the RPWRF (varies by pollutant) to obtain the pollutant removal amount.

Steps to estimate the pollutant removal resulting from infiltration of stormwater (applicable to Storage + Green, Storage + Centralized infiltration, and Green Only basin solutions):

Step 8.) Estimate the average annual stormwater runoff volume infiltrated.

Step 9.) Multiply the remaining CSO reduction volume that was not controlled through storage and/or conveyance, and multiply that by the pollutant concentration and the removal percentage resulting from infiltration (100%) to obtain the pollutant removal amount of stormwater infiltrated during CSO events.

Step 10.) Subtract the volume calculated in Step 9 from the average annual stormwater runoff volume from Step 8, and multiply that volume by the pollutant concentration and the removal percentage resulting from infiltration (varies by pollutant) to obtain the pollutant removal amount of stormwater infiltrated during non-CSO events.

Final Steps (applicable to all basin solutions):

Step 11.) Combine the pollutant removal amounts from Step 7, 9, and 10 to obtain the total pollutant removal amount.

These steps are described in more detail in the following sections.

Pollutants Evaluated, and Concentrations (Steps 1 and 2)

The pollutants evaluated in this analysis are presented in Table 1, and are based on the recommendations made in the technical memorandum *Recommended Pollutants for Consideration in Integrated Plan Preparation* (CH2M HILL, 2013a). As discussed in the memorandum, the pollutants were selected to "encompass the full range of pollutant load reduction."

TABLE 1
Pollutants Included in Analysis

Pollutant	Pollutant Category	Typical Pollutant Sources[a] in Stormwater and Combined Sewage	Regulatory Driver
Total Phosphorus	Nutrients	Leaf litter, wildlife and pets; various residential and commercial activities; site development (erosion)	Total maximum daily load (TMDL) for dissolved oxygen (related to phosphorus inputs); Category 4a 303(d) listing; effluent limitation in City's National Pollutant Discharge Elimination System (NPDES) permit; numeric criteria in surface water standards (dependent on water body trophic state)
Fecal Coliform	Bacteria	Human waste; wildlife and pets	Category 5 303(d) listing; effluent limitation in City's NPDES permit; numeric criteria in surface water standards
Total Suspended Solids (TSS)	Conventionals	Pavement wear; automotive (tire wear, brake linings), snow/ice mitigation; human waste	Surrogate for turbidity, which has a numeric criterion; effluent limitation in City's NPDES permit
Total Zinc	Metals	Residential: automotive (tire wear, brake linings); building exteriors; commercial/industrial: galvanizing, electroplating	Category 4a 303(d) listing, also effluent limitations in City's NPDES permit
Dissolved Zinc	Metals	Residential: automotive (tire wear, brake linings); building exteriors; commercial/industrial: galvanizing, electroplating	TMDL under development for dissolved zinc (and lead and cadmium); numeric criteria in surface water standards
Polychlorinated Biphenyls (PCBs)	Organics	Industrial: hydraulic fluids, lubricants, plasticizers, adhesives, inks	City's NPDES permit requires action to reduce sources of PCBs and engagement in a task force to move directly to the development of PCB limits; numeric criteria in surface water standards

[a] Pollutant source information from Minton 2011

CSO Pollutant Concentrations (Step 2)

A variety of available monitoring data and literature values was reviewed to estimate concentrations of the pollutants selected for analysis. Sources included a combination of sampling programs completed by city and county municipalities, academic sources, and data from the United States Environmental Protection Agency (USEPA). The primary source for the concentrations used in the analysis was the CSO sampling completed by the City of Spokane in 2013 at CSO Basin 34. Table 2 presents the compiled CSO pollutant concentrations gathered from the sources.

TABLE 2
Compilation of CSO Pollutant Concentration Data Used in this Analysis

Data Source	Total Phosphorus (mg/L)	Fecal Coliform (CFU/100 mL)	TSS (mg/L)	Total Zinc (ug/L)	Dissolved Zinc (ug/L)	PCBs (ng/L)
City of Seattle (Herrera, 2010)	0.62	62,000	26.8	38.0	4.0	
King County (King County, 2011)	1.55		131	153	26.7	
City of Spokane (Spokane, 1994)	2	2,000,000				
City of Omaha (CH2M HILL, 2009)		393,000	680	300	99.9	
EPA Report to Congress (EPA, 2004)	0.7	215,000	127	156	48	
Multiple Municipalities[a] (EVS, 2000)		1,130,000		130		
Ecology (WSDOE, 2010)	0.95					
City of Spokane 2013 Monitoring[b]	1.50	>16,000	123	103.7	22.2	See Table 4
Range from Sources	0.1 – 20.8	3 – 40,000,000	1 – 7,260	10 – 3,740	5.7 – 3,480	See Table 4
Concentration Used in Analysis	**1.50**	**393,000[c]**	**123**	**103.7**	**22.2**	**See Table 4**

[a] Study compiled CSO pollutant concentrations from several municipalities.
[b] Based on sampling results available through 7/19/2013.
[c] Median value of compiled concentrations for Fecal Coliform.
mg/L = milligrams per liter
CFU = colony-forming unit
TSS = total suspended solids
µg/L = micrograms per liter
ng/L = nanograms per unit

The concentrations of PCB used in the analysis were gathered from several reports by the Washington State Department of Ecology (WSDOE) and monitoring by the City of Spokane in 2013, and varies from CSO basin to CSO basin. Table 3 presents the PCB sources and concentrations used in this analysis. To provide some regional context, the average measured PCB concentration in an industrial area in King County was 65.2 nanograms per liter (ng/L), with a range of 8 to 455 ng/L (King County, 2011).

TABLE 3
Compilation of PCB Pollutant Concentration Data Used in this Analysis

Data Source	CSO Basin 7	CSO Basin 10	CSO Basin 24A	CSO Basin 26	CSO Basin 33	CSO Basin 34	All Other CSO Basins[a]
City of Spokane 2013 Monitoring[b] (ng/L)						10.64	
WSDOE, 2012 (ng/L)		6.33			5.85	14.8	
WSDOE, 2011 (ng/L)	2.49		2.56	3.38		177	
Used in Analysis (ng/L)	**2.49**	**6.33**	**2.56**	**3.38**	**5.85**	**67.48**	**4.62**

[a] Median of PCB concentration from CSO basins with measured concentrations.
[b] Based on sampling results available through 7/19/2013.

Stormwater Pollutant Concentrations (Step 2)

Stormwater pollutant concentrations were based on sampling conducted by the City of Spokane in 2013 in the Cochran, Washington, and Union stormwater basins. Table 4 presents the concentrations used in this analysis.

TABLE 4
Stormwater Pollutant Concentration Data Used in this Analysis

City of Spokane 2013 Monitoring[a]	Total Phosphorus (mg/L)	Fecal Coliform (CFU/100 mL)	TSS (mg/L)	Total Zinc (ug/L)	Dissolved Zinc (ug/L)	PCBs (ng/L)
Cochran Basin	0.73	900	224	216	8	5.9
Washington Basin	1.02	3,417	229	382	21	8.8
Union Basin	0.24	1,581	50	140	80	40.6
Concentration used in Analysis	**0.70**	**1,966**	**168**	**250**	**40**	**7.3[b]**

[a] Based on sampling results available through 7/19/2013.
[b] Average value not including Union, which has an unusually high PCB concentration.

Establish Breakdown of How CSO Reduction is Achieved (Step 3)

The various basin solutions being evaluated reduce CSOs by storing and/or conveying flows to the RPWRF, infiltrating stormwater runoff, or a combination. Table 5 presents a summary of how each basin solution reduces CSOs, and what percentage of the reduction in the annual CSO volume is a result of each CSO control method. These percentages were based on the 1.2-yr/24-hr design storm CSO modeling results of the various basin solutions performed by AECOM.

TABLE 5
Basin Solutions Evaluated and the Breakdown of How CSO Reduction is Achieved

CSO Basin	Basin Solution	Percentage of CSO Volume Reduction Due to Storage/Conveyance	Percentage of CSO Volume Reduction Due to Stormwater Infiltration
6	Storage Only	100%	0%
6	Storage + Green	39%	61%
6	Green Only	0%	100%
7	Regulator Upsize	100%	0%
12	Storage Only	100%	0%
12	Storage + Green	46%	54%
12	Green Only	0%	100%
14 & 15	Storage Only	100%	0%
14 & 15	Storage + Green	51%	49%
14 & 15	Green Only	0%	100%
20	Storage Only	100%	0%
23	Regulator Upsize	100%	0%

TABLE 5
Basin Solutions Evaluated and the Breakdown of How CSO Reduction is Achieved

CSO Basin	Basin Solution	Percentage of CSO Volume Reduction Due to Storage/Conveyance	Percentage of CSO Volume Reduction Due to Stormwater Infiltration
24, 25, & 26	Storage Only	100%	0%
24, 25, & 26	Storage + Green	75%	25%
33	Storage Only	100%	0%
34	Storage Only	100%	0%
34	Storage + Green	89%	11%
34	Storage + Centralized Infiltration	92%	8%
41	Regulator Upsize	100%	0%

Annual CSO Volume and Frequency Reduction (Step 4)

Table 6 presents the current and estimated future CSO volumes and frequencies. Figure 1 presents an overview of the City's combined sewer system (CSS), and is color-coded based on the current average annual CSO volume. Also included are the approximate locations of the City's operational CSO storage facilities.

For most CSO basins, the current CSO frequencies and volumes listed in Table 6 are based on measured CSO events from 2001-2012 as documented in the City of Spokane's monthly CSO reports. The exception is for CSO basins that have had storage facilities constructed in them in recent years (CSO Basins 10, 38, and 42). For these CSO basins there was insufficient flow monitoring data available with the storage facility in place to be able to determine current CSO frequencies and volumes. As an estimate of the current CSO frequencies and volumes for these basins, the measured events prior to the construction of the storage facilities were evaluated for each basin, and an estimate of how many overflows would have occurred had the storage facilities been in place was developed. This was accomplished by comparing the measured historical CSO volume to the actual constructed storage facility volume. If the volume of the historical CSO event was smaller than the volume of the storage facility, it was presumed that the historical event would not have occurred had the storage facility been in place during the event. If the measured historical CSO volume was larger than the constructed storage volume, it was presumed that a CSO would have occurred even if the tank had been in place, and it would have had a volume equal to the difference between the measured historical CSO event and the constructed storage volume.

Future CSO frequencies and volumes were estimated in a manner similar to the methodology used for the current values in basins with recently constructed storage facilities in them. In short, this method estimates what volume of CSO would have occurred had a storage facility been in place. The volume of the hypothetical storage facility is selected based on a volume that would reduce the frequency of CSO events in the basin to less than one event per year. This was done by selecting the 12th largest measured CSO event from 2001 to 2012, and comparing it to the volume of other measured CSO events. If a storage facility had been constructed in a currently uncontrolled CSO basin with a volume equal to the 12th largest measured CSO event from a list of 12 years worth of CSO data, it can be estimated that only 11 CSO events would have occurred. All other CSO events would have been smaller than the volume of the storage facility, and would not have occurred had the storage been in place. This corresponds with an average annual CSO frequency of 0.92 per year (11 CSO events over 12 years), which meets the regulatory criteria for CSOs.

Estimating the future CSO volumes and frequencies in this manner is an approximation, and does not take into account changes to regulator flow rates, errors in flow monitoring data, or the impact of back-to-back storms. However, because any CSO reduction project ultimately implemented in an uncontrolled CSO basin will be designed to reduce the frequency of CSO events to less than one per year, the estimation of the future CSO volumes and frequencies in the manner described above is sufficient for the purposes of estimating pollutant removal amounts. In other words, the estimated future CSO volumes and frequencies presented in Table 6 are meant to be approximate values, and are independent of how the CSO basin is brought into control.

TABLE 6
Current and Estimated Future CSO Volumes and Frequencies

CSO Basin	Controlled? (Yes/No)	CSO Frequency (No./yr)			CSO Volume (MG/yr)			Notes
		Current[a]	Estimated Future	% Red.	Current	Estimated Future	% Red.	
2	Yes	0	0	0%	0	0	0%	Storage facility operational since 2003
6	No	26	0.9	97%	4.47	0.58	87%	
7	No	11	0.9	92%	0.29	0.07	74%	
10	Yes	0.1	0.1	0%	0.01	0.01	0%	Storage facility operational since 2011[b]
12	No	27	0.9	97%	3.31	0.30	92%	
14	No	14	0.9	92%	0.11	0.07	78%	May be controlled with one storage facility
15	No	8	0.9		0.19			
16	Yes	0.2	0.2	0%	0.01	0.01	0%	Storage facility operational since 2007[b]
19	Yes	0.4	0.4	0%	0.0002	0.0002	0%	Weir modification completed in 2010
20	Yes[c]	0.4	0	100%	0.03	0	100%	All overflows may be eliminated from CSO Basin 20, because basin overflows into Hangman Creek
22	No	1.3	0.9	31%	0.02	0.02	2%	Basin will be brought into control from improvements made in CSO Basin 25
23	No	16	0.9	94%	1.11	0.10	91%	
24	No	23	0.9	96%	7.35	1.44	81%	May be controlled with one storage facility
25	No	19	0.9		0.37			
26	No	23	0.9	96%	15.64	2.07	87%	
33	No	26	0.9	97%	6.22	0.94	85%	
34	No	18	0.9	95%	12.67	2.15	83%	
38	Yes	0.1	0.1	0%	0.007	0.007	0%	Storage facility operational since 2011[b]
41	No	11	0.9	92%	0.33	0.11	67%	
42	Yes	0	0	0%	0	0	0%	Storage facility operational since 2009
TOTAL		**224.5**	**12.5**	**94%**	**52.1**	**7.9**	**85%**	

[a] Based on average from 2001-2012 from City of Spokane monthly CSO reports (City of Spokane, 2012).
[b] Although there have been no measured events in CSO Basins 10, 16, or 38 since the completion of their storage facilities, analysis of historical CSO volumes from 2001 to 2012 suggests that there would have been one or more CSO events in each basin during that time period had the storage facilities been in place.
[c] Although CSO Basin 20 is currently in control, the basin discharges CSOs to the environmentally sensitive Hangman Creek, and the City of Spokane plans to eliminate all CSO discharges from this basin.

Annual Volume of Stormwater Infiltrated (Step 8)

The average annual volume of stormwater infiltrated was estimated using the Natural Resource Conservation Service Curve Number Method, which incorporates the area that is tributary to the infiltration facilities, the land use types within that area, and the annual average precipitation depth. Table 7 presents the area diverted to stormwater infiltration, along with the estimated average annual volume of stormwater infiltrated, for each applicable basin solution.

TABLE 7
Average Annual Volume of Stormwater Runoff Infiltrated[a]

CSO Basin	Basin Solution	Area Diverted to Stormwater Infiltration (acres)	% of Basin Area Infiltrated	Average Annual Volume of Stormwater Infiltrated (MG/yr)
6	Storage + Green	55	11%	18.5
6	Green Only	98	20%	32.8
12	Storage + Green	41	11%	14.6
12	Green Only	82	23%	29.1
14	Storage + Green	5	7%	1.7
14	Green Only	14	20%	4.7
15	Storage + Green	14	12%	5.2
15	Green Only	23	19%	8.1
24	Storage + Green	98	5%	32.8
34	Storage + Green	86	4%	35.4
34	Storage + Centralized Infiltration	51	3%	23.5

[a] See Appendix B for details on how the area suitable for infiltration was estimated, and how the breakdown between drywells and swales
was established.
MG – million gallons

Percentage of Pollutants Removed (Step 5)

The percentage of pollutants removed varies depending on the pollutant removal mechanism. Basin solutions remove pollutants through three different pollutant removal methods, as summarized below:

- **Storage and/or Conveyance of CSOs:** This pollutant removal method involves storing and/or conveying CSO events to the RPWRF for treatment and discharge to the Spokane River. Under current conditions, CSO events discharge a combination of untreated raw sewage and stormwater runoff to the Spokane River. The percentage of pollutants removed is equal to the future removal percentage at the RPWRF (varies by pollutant) minus the current removal percentage (0% for all pollutants).
- **Stormwater Infiltrated during CSO Events:** This pollutant removal method involves infiltrating stormwater runoff that occurs during CSO storm events into the ground. Under current conditions this flow is discharged untreated to the Spokane River. The removal percentage is equal to the future removal percentage of the infiltrated stormwater (100%) minus the current removal percentage (0% for all pollutants).
- **Stormwater Infiltrated during Non-CSO Events:** This pollutant removal method involves infiltrating stormwater runoff that occurs during non-CSO storm events into the ground. Under current conditions this flow is conveyed to and treated at the RPWRF. The percentage of pollutants removed is equal to the future removal percentage of the infiltrated

stormwater (100%) minus the current removal percentage at the RPWRF (varies by pollutant).

Figures 2 and 3 illustrate the differences between these three pollutant removal mechanisms.

The anticipated improvements in the treatment capability at the RPWRF resulting from implementation of the NPDES permit-driven upgrade to membrane filtration will result in higher pollutant removal amounts than are currently being achieved at the RPWRF. The City of Spokane's NPDES permit indicates that the RPWRF must meet two different effluent standards, depending on the month: the critical season (from March through October), and the non-critical season (November through February). Table 8 presents an estimate of the effluent pollutant concentrations for the pollutants of concern in this analysis.

TABLE 8.
Effluent Pollutant Concentrations and Resulting Pollutant Removal Percentages

Pollutant	Critical Season (March through October)				Non-Critical Season (November through February)			
	RPWRF Effluent Conc.[a]	Percentage Removal			RPWRF Effluent Conc.[a]	Percentage Removal		
		Stored/ Conveyed CSOs[b]	CSO Event Stormwater	Non-CSO Event Stormwater		Stored/ Conveyed CSOs[b]	CSO Event Stormwater	Non-CSO Event Stormwater
Total Phosphorus	0.05 mg/L	96.7%	100%	3.3%	0.6 mg/L	60.0%	100%	40.0%
Fecal Coliform	7.5 CFU/100mL	99.998%	100%	0.002%	50 CFU/100mL	99.987%	100%	0.013%
TSS	5 mg/L	95.9%	100%	4.1%	20 mg/L	83.7%	100%	16.3%
Total Zinc	33.7 ug/L	67.5%	100%	32.5%	37.5 ug/L	83.7%	100%	36.2%
Diss. Zinc	33.7 ug/L	0%[d]	100%	100%	33.7 ug/L	0%[d]	100%	100%
PCBs[c]	0.25 ng/L	90.0% to 99.6%	100%	0.4% to 10.0%	0.60 ng/L	75.9% to 99.1%	100%	0.9% to 24.1%

[a] Effluent concentrations based on estimated concentrations with NLT in place, analysis of RPWRF DMRs for 2012, and input from CH2M HILL Project Management Office staff (CH2M HILL, 2013b).
[b] Percentage removal calculated as (1 – RPWRF Effluent Concentration / CSO Concentration).
[c] Based on effluent concentrations seen at the Spokane County Regional Water Reclamation Facility. Removal percentage varies from basin to basin, depending on concentration of PCBs in the CSO.
[d] Concentration of dissolved zinc in CSOs is lower than the concentration of dissolved zinc in the RPWRF effluent; thus, no removal is expected.

Calculate Pounds of Pollutants Removed (Steps 6, 7, 9, and 10)

The following subsections describe the calculations to estimate the pounds of pollutants removed. The calculation of pollutant removal is broken down by the pollutant removal type. An example pollutant removal calculation for total phosphorous removal from the Storage + Green basin solution in CSO Basin 6 is also presented.

Pounds of Pollutants Removed as a Result of Storage and/or Conveyance of CSOs (Steps 6 and 7)

The pounds of pollutants removed as a result of the storage and/or conveyance of CSOs was estimated by first estimating the reduction in CSO volume discharged for both the critical and non-critical season (see Table 6 and Appendix A). These annual volumes were then multiplied by the percentage of the annual CSO reduction resulting from conveyance and/or storage (see Table 5), and then multiplied by the concentration of the pollutant being evaluated (see Table 3) and converted into units of pounds per year. The critical and non-critical season pounds per year were then multiplied by the appropriate removal percentage given in Table 8, and added together. A sample calculation is presented below for total phosphorus removal for the Storage + Green basin solution for CSO Basin 6.

1.) Critical Season: (2.73 million gallons [MG]/yr – 0.45 MG/yr) x 39% = 0.89 MG/yr (average volume of CSO prevented from overflowing annually as a result of conveyance and/or storage during the critical season)

    Non-Critical Season: (1.73 MG/yr – 0.12 MG/yr) x 39% = 0.63 MG/yr (average volume of CSO prevented from overflowing annually as a result of conveyance and/or storage during non-critical season)

2.) Critical Season: 0.89 MG/yr x 1.5 mg/L x 8.3454 (mg/L to lbs/MG) = 11.1 lbs/yr (amount of total phosphorus stored and/or conveyed annually during the critical season)

    Non-Critical Season: 0.63 MG/yr x 1.5 mg/L x 8.3454 (mg/L to lbs/MG) = 7.9 lbs/yr (amount of total phosphorus stored and/or conveyed annually during the non-critical season)

3.) Critical Season: 11.1 lbs/yr x 96.7% = 10.7 lbs/yr (amount of total phosphorus removed annually at the RPWRF during the critical season)

    Non-Critical Season: 7.9 lbs/yr x 60.0% = 4.7 lbs/yr (amount of total phosphorus removed annually at the RPWRF during the non-critical season)

4.) POLLUTANTS REMOVED DUE TO STORAGE/CONVEYANCE OF CSOs = 10.7 lbs/yr + 4.7 lbs/yr = 15.4 lbs/yr

Pounds of Pollutants Removed from Stormwater Infiltrated during CSO Events (Step 9)

The pounds of pollutants removed as a result of stormwater infiltration during CSO events was calculated by multiplying the average annual CSO reduction volume by the percentage of the reduction resulting from stormwater infiltration (see Table 5), multiplying by the concentration of each pollutant in CSOs[2], then multiplying that amount by the appropriate removal percentage given in Table 8, and adding the removal amounts together for the critical and non-critical seasons. A sample calculation is presented below for total phosphorus removal in the Storage + Green basin solution for CSO Basin 6.

1.) Critical Season: (2.73 MG/yr – 0.45 MG/yr) x 61% = 1.4 MG/yr (average volume of CSO prevented from overflowing annually as a result of stormwater infiltration during the critical season)

    Non-Critical Season: (1.73 MG/yr – 0.12 MG/yr) x 61% = 1.0 MG/yr (average volume of CSO prevented from overflowing annually as a result of stormwater infiltration during the non-critical season)

2.) Critical Season: 1.4 MG/yr x 1.5 mg/L x 8.3454 (mg/L to lbs/MG) = 17.5 lbs/yr (amount of total phosphorus sent to stormwater infiltration annually during the critical season)

    Non-Critical Season: 1.0 MG/yr x 1.5 mg/L x 8.3454 (mg/L to lbs/MG) = 12.5 lbs/yr (amount of total phosphorus sent to stormwater infiltration annually during the non-critical season)

[2] Note that the concentration of pollutants in CSOs is used here. This is because stormwater infiltration during CSO events reduces the volume of CSO discharges.

3.) Critical Season: 17.5 lbs/yr x 100% = 17.5 lbs/yr (amount of total phosphorus removed annually through stormwater infiltration during the critical season)

Non-Critical Season: 12.5 lbs/yr x 100.0% = 12.5 lbs/yr (amount of total phosphorus removed annually through stormwater infiltration during the non-critical season)

4.) POUNDS POLLUTANTS REMOVED DUE TO STORMWATER INFILTRATION DURING CSO EVENTS = 17.5 lbs/yr + 12.5 lbs/yr = 30.0 lbs/yr

Pounds of Pollutants Removed from Stormwater Infiltrated during Non-CSO Events (Step 10)

The pounds of pollutants removed as a result of stormwater infiltration during non-CSO events was calculated by first estimating the volume of stormwater infiltrated during non-CSO events. This was done by taking the average annual stormwater runoff volume (see Table 7) and subtracting the volume of stormwater infiltrated during CSO events. This volume was then multiplied by the concentration of each pollutant in stormwater, then multiplied by the appropriate removal percentage indicated in Table 8, and adding the removal amounts together for the critical and non-critical seasons. A sample calculation is presented below for total phosphorus removal in the Storage + Green basin solution for CSO Basin 6.

1.) Critical Season: (7.5 MG/yr – 1.4 MG/yr) = 6.1 MG/yr (average volume of stormwater infiltrated during non-CSO events during critical season)

Non-Critical Season: (11.0 MG/yr – 1.0 MG/yr) = 10.0 MG/yr (average volume of stormwater infiltrated during non-CSO events during non-critical season)

2.) Critical Season: 6.1 MG/yr x 0.7 mg/L x 8.3454 (mg/L to lbs/MG) = 35.6 lbs/yr (amount of total phosphorus sent to stormwater infiltration annually during the critical season)

Non-Critical Season: 10.0 MG/yr x 0.7 mg/L x 8.3454 (mg/L to lbs/MG) = 58.4 lbs/yr (amount of total phosphorus sent to stormwater infiltration annually during the non-critical season)

3.) Critical Season: 35.6 lbs/yr x 3.3% = 1.2 lbs/yr (amount of total phosphorus removed annually through stormwater infiltration during the critical season)

Non-Critical Season: 58.4 lbs/yr x 40.0% = 23.4 lbs/yr (amount of total phosphorus removed annually through stormwater infiltration during the non-critical season)

4.) POUNDS POLLUTANTS REMOVED DUE TO STORMWATER INFILTRATION DURING NON-CSO EVENTS = 1.2 lbs/yr + 23.4 lbs/yr = 24.6 lbs/yr

Total Pollutant Removal Amounts (Step 11)

Table 9 presents the estimated annual pollutant removal amounts for each CSO basin. These results are also presented in Figures 4 through 9. For the example in the sections above for the Storage + Green basin solution in CSO Basin 6, the total phosphorus removal amount is 15.4 lbs/yr + 30.0 lbs/yr + 24.6 lbs/yr = 70.0 lbs/yr (slight difference from value in Table 9 below because of rounding).

TABLE 9

Estimated Annual Pounds of Pollutants Removed

CSO Basin	Basin Solution	Total Phosphorus (lbs/yr)	Fecal Coliform (Billions of CFU/yr)	TSS (lbs/yr)	Total Zinc (lbs/yr)	Dissolved Zinc (lbs/yr)[c]	PCBs (grams/yr)
6	Storage Only	40	57,817	3,626	2.2	-	0.06
6	Storage + Green	68	57,820	6,476	14.5	5.3	0.11
6	Green Only	90	57,821	8,677	24.0	9.5	0.15
7	Regulator Upsize	2	3,210	205	0.1	-	0.002
12	Storage Only	30	44,811	2,801	1.7	-	0.05
12	Storage + Green	52	44,812	5,014	11.5	4.2	0.07
12	Green Only	74	44,814	7,206	21.2	8.4	0.12
14 & 15[1]	Storage Only	2	3,620	226	0.1	-	0.004
14 & 15[a]	Storage + Green	12	3,620	1,308	5.0	2.1	0.02
14 & 15[a]	Green Only	20	3,621	2,233	9.2	3.9	0.04
20	Storage Only	0.4	432	29	0.02	-	0.0005
23	Regulator Upsize	10	15,082	943	0.6	-	0.02
24, 25, & 26[b]	Storage Only	202	294,680	18,483	11.3	-	0.20
24, 25, & 26[b]	Storage + Green	254	294,684	23,495	32.7	9.3	0.34
33	Storage Only	54	78,514	5,029	3.0	-	0.11
34	Storage Only	105	156,399	9,741	6.0	-	2.67
34	Storage + Green	162	165,038	15,818	30.9	10.5	2.83
34	Storage + Centralized Infiltration	143	162,682	13,803	22.5	7.0	2.78
41	Storage Only	2	3,305	212	0.1	-	0.004

[a] CSO Basins 14 and 15 may be controlled with a joint facility.
[b] CSO Basins 24, 25, and 26 may be controlled with a joint facility.
[c] No additional dissolved zinc removal expected for Storage Only and Regulator Upsize basin solutions.

Life-Cycle Cost per Pound Pollutant Removed

The life-cycle cost per pound pollutant removed is a good measure of how cost-effective a water quality project is at removing pollutants relative to other water quality projects. Estimates of the life-cycle cost in terms of net present value have been prepared for each basin solution, along with estimates of the life-cycle pollutant removal amount[3], and the corresponding cost per pound pollutant removed are all presented in Table 10. Life-cycle costs are based on the control volumes for the 1.2-yr/24-hr design storm. Figures 10 through 15 present the cost per pound pollutant removed for the various basin solutions.

TABLE 10

Estimated Life-Cycle Cost per Pound of Pollutant Removed

CSO Basin	Basin Solution	Total Phosphorus ($/lbs)	Fecal Coliform ($/Billions of CFU)	TSS ($/lbs)	Total Zinc ($/lbs)	Dissolved Zinc ($/lbs)	PCBs ($/gram)
6	Storage Only	$18,658	$13	$204	$333,513		$11,915,651
6	Storage + Green	$13,807	$16	$145	$64,749	$177,144	$8,458,218
6	Green Only	$11,402	$18	$118	$42,758	$108,021	$6,887,236
7	Regulator Upsize	$14,436	$9	$141	$288,723		$14,436,146
12	Storage Only	$17,829	$12	$191	$314,635		$11,143,330
12	Storage + Green	$17,084	$20	$177	$77,250	$211,518	$12,169,550
12	Green Only	$14,546	$24	$149	$50,773	$128,140	$8,680,479

[3] Both the life-cycle cost and life-cycle pollutant removal amounts are based on a 25-year period using a 2 percent discount rate.

TABLE 10

Estimated Life-Cycle Cost per Pound of Pollutant Removed

CSO Basin	Basin Solution	Total Phosphorus ($/lbs)	Fecal Coliform ($/Billions of CFU)	TSS ($/lbs)	Total Zinc ($/lbs)	Dissolved Zinc ($/lbs)	PCBs ($/gram)
14 & 15[1]	Storage Only	$165,445	$114	$1,830	$4,136,135		$103,403,387
14 & 15[a]	Storage + Green	$37,610	$125	$345	$90,264	$214,915	$19,622,692
14 & 15[a]	Green Only	$10,075	$56	$90	$21,903	$51,668	$5,166,770
20	Storage Only	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]	NA [d]
23	Regulator Upsize	$7,324	$5	$78	$122,062		$4,577,315
24, 25, & 26[b]	Storage Only	$11,008	$8	$120	$196,778		$10,899,955
24, 25, & 26[b]	Storage + Green	$14,180	$12	$153	$110,148	$387,294	$10,531,676
33	Storage Only	$38,127	$28	$440	$737,331		$20,094,106
34	Storage Only	$17,155	$12	$185	$300,208		$674,877
34	Storage + Green	$15,968	$16	$164	$83,717	$246,368	$915,379
34	Storage + Centralized Infiltration	$19,770	$17	$205	$125,652	$403,882	$1,015,872
41	Storage Only	$36,266	$22	$342	$725,328		$18,133,208

[a] CSO Basins 14 and 15 may be controlled with a joint facility.
[b] CSO Basins 24, 25, and 26 may be controlled with a joint facility.
[c] No additional dissolved zinc removal expected for Storage Only and Regulator Upsize basin solutions.
[d] No life-cycle cost available for Storage Only basin solution in CSO Basin 20.

Conclusions

The life-cycle cost per pound of pollutant removed varies by basin solution, with the Storage Only basin solutions generally the most expensive, and the Green Only basin solutions the least expensive on a per pound removed basis, as shown in Table 11 and Figure 16. This trend is most apparent in the total zinc pollutant removal amounts, with the Storage + Green basin solution an average of 9 percent the cost per pound of the Storage Only basin solution, and the Green Only basin solution only 5 percent the cost per pound of the Storage Only basin solution. The higher total zinc concentration in stormwater, along with the 100 percent removal amount resulting from infiltration, contributes to this trend. Fecal coliform shows the opposite relationship, with Storage + Green and Green Only basin solutions being slightly more expensive on a cost per billion colony-forming unit (CFU) removed basis. This is because of the low fecal coliform concentration in stormwater, along with the fact that nearly all of the fecal coliform is removed at the RPWRF.

TABLE 11

Average Cost per Pound Pollutant Removed by Basin Solution

Basin Solution	Total Phosphorus ($/lbs/yr)	Fecal Coliform ($/Billions of CFU/yr)	TSS ($/lbs/yr)	Total Zinc ($/lbs/yr)	Dissolved Zinc ($/lbs/yr)	PCBs ($/gram/yr)
Storage Only	$44,704	$31	$495	$1,003,100	$235,958	$26,355,218
Regulator Upsize	$19,342	$12	$187	$378,704	NA	$12,382,223
Storage + Green & Storage + Centralized Infiltration	$19,737	$34	$198	$91,963	NA	$8,785,564
Green Only	$12,008	$32	$119	$38,478	$273,520	$6,911,495

The Regulator Upsize basin solutions are also very cost-effective, because of the small amount of infrastructure required to bring the basin into control. These types of projects can be a cost-effective way to remove pollutants in CSO basins with smaller CSO discharge volumes. For example, the Regulator Upsize basin solution for CSO Basin 7 has a life cycle cost per pound total phosphorus removed of $14,400 per pound. The Storage Only basin solution for CSO Basins 14 and 15 have a similarly small annual CSO volume reduction, but have a cost per pound total phosphorus removed of $165,400 per pound.

Recommendations

Although the life-cycle cost per pound of pollutant removed is a useful tool to evaluate the cost-effectiveness of a water quality project, it should be used in combination with other evaluation methods, such as a multi-objective decision analysis. This type of an analysis takes into account non-monetary benefits while also considering the total life-cycle cost of the alternative. A decision on what projects to recommend in the Integrated Plan should not be made solely on the life-cycle cost per pound of pollutant removed numbers presented in this memorandum.

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Figures

Appendices

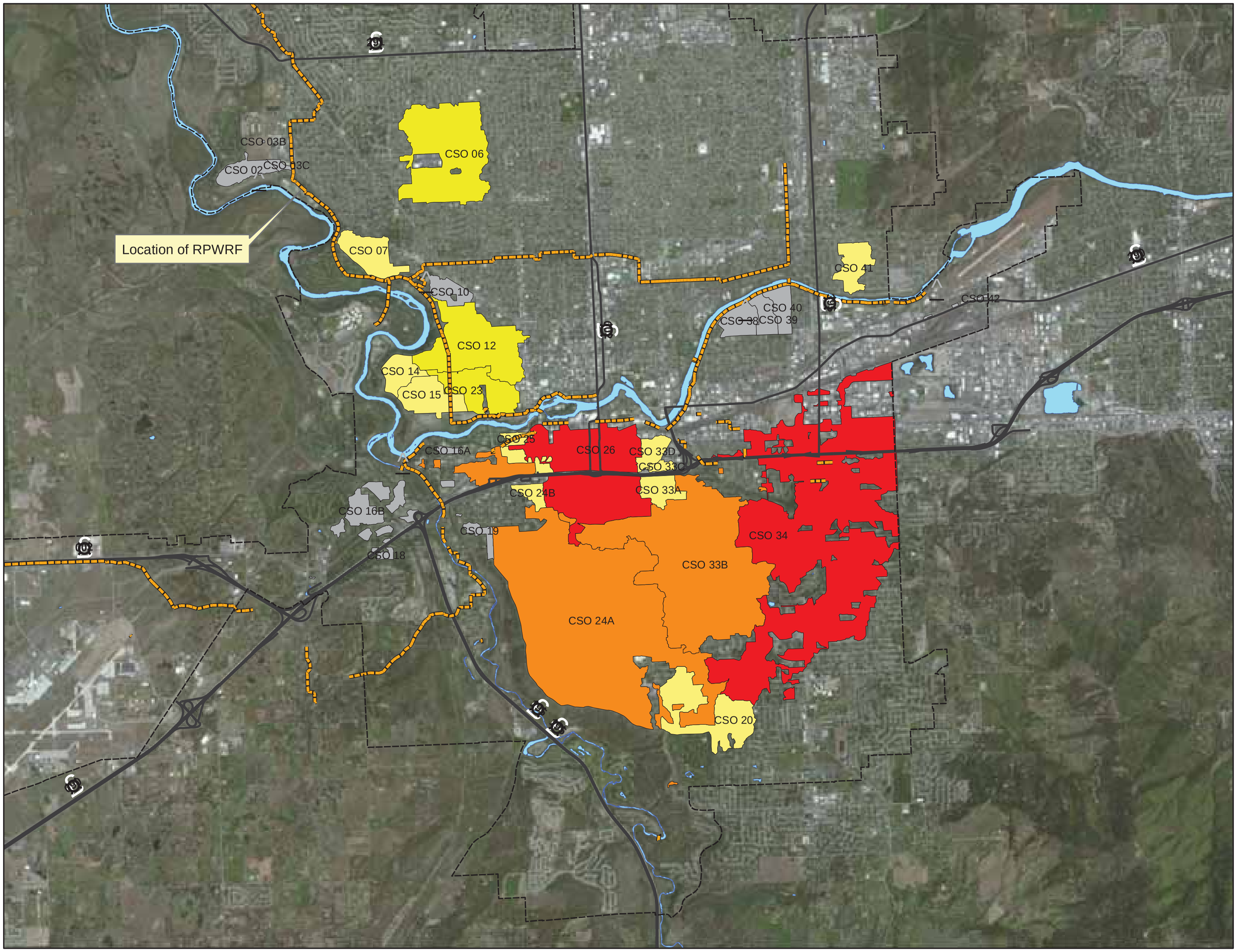

Figure 1
Combined Sewer System Overview
Integrated Plan
City of Spokane

CH2MHILL

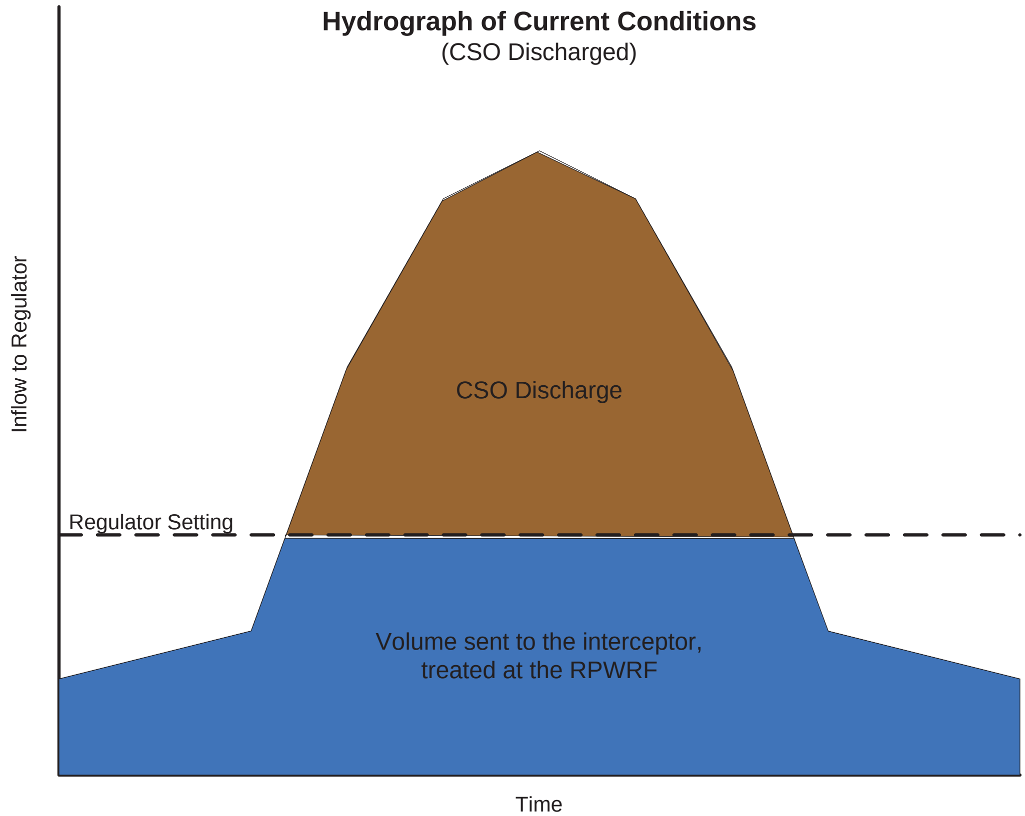

Figure 2
Hydrograph Illustrating Current Pollutant Removal Mechanisms

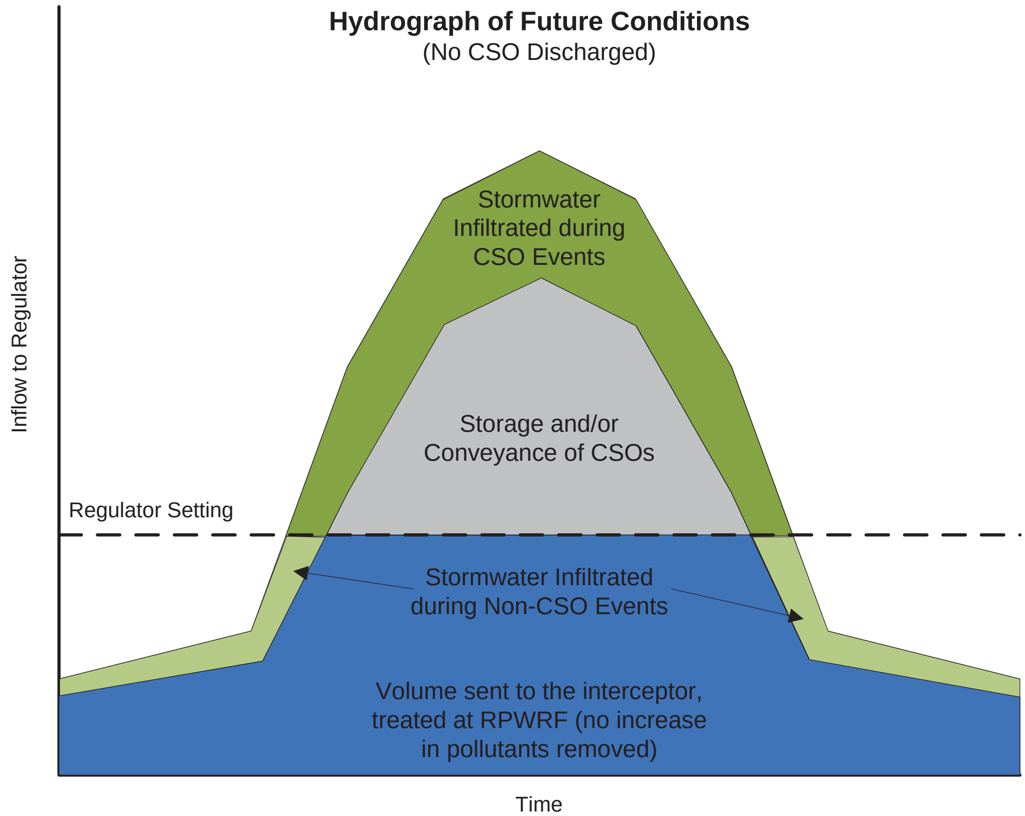

Figure 3
Hydrograph Illustrating Future Pollutant Removal Mechanisms

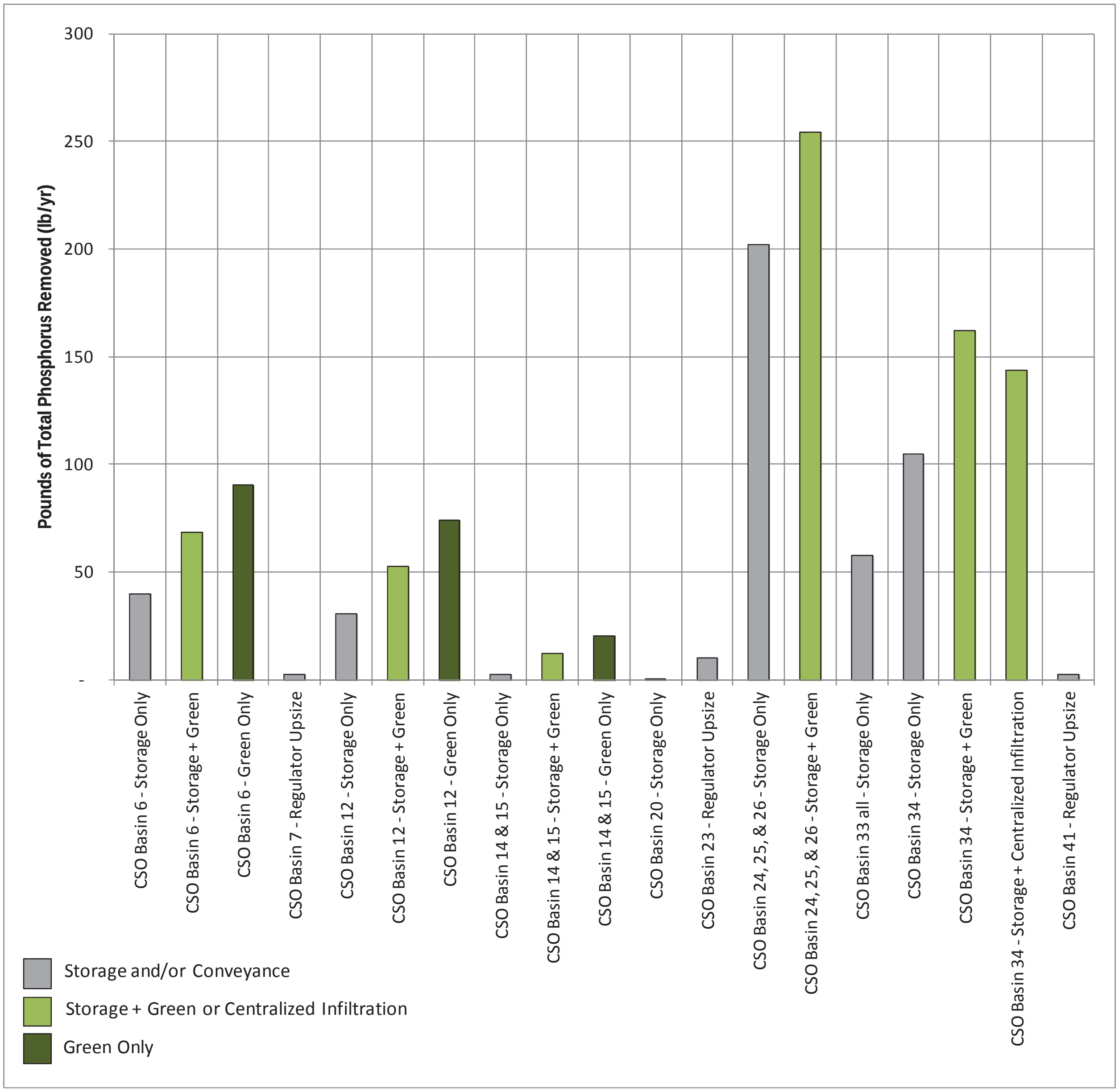

Figure 4
Average Annual Total Phosphorus Removal Amounts

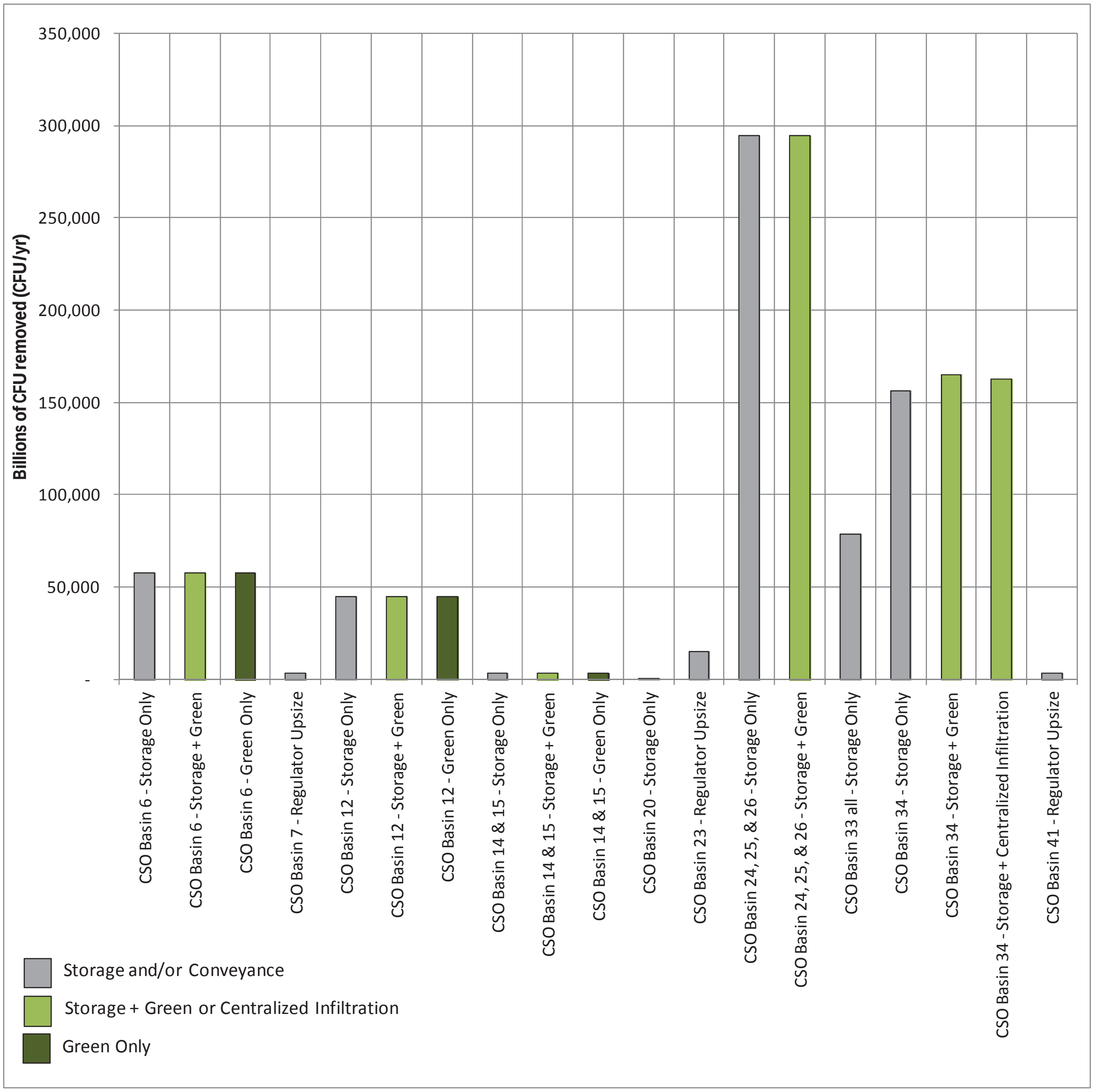

Figure 5
Average Annual Fecal Coliform Removal Amounts

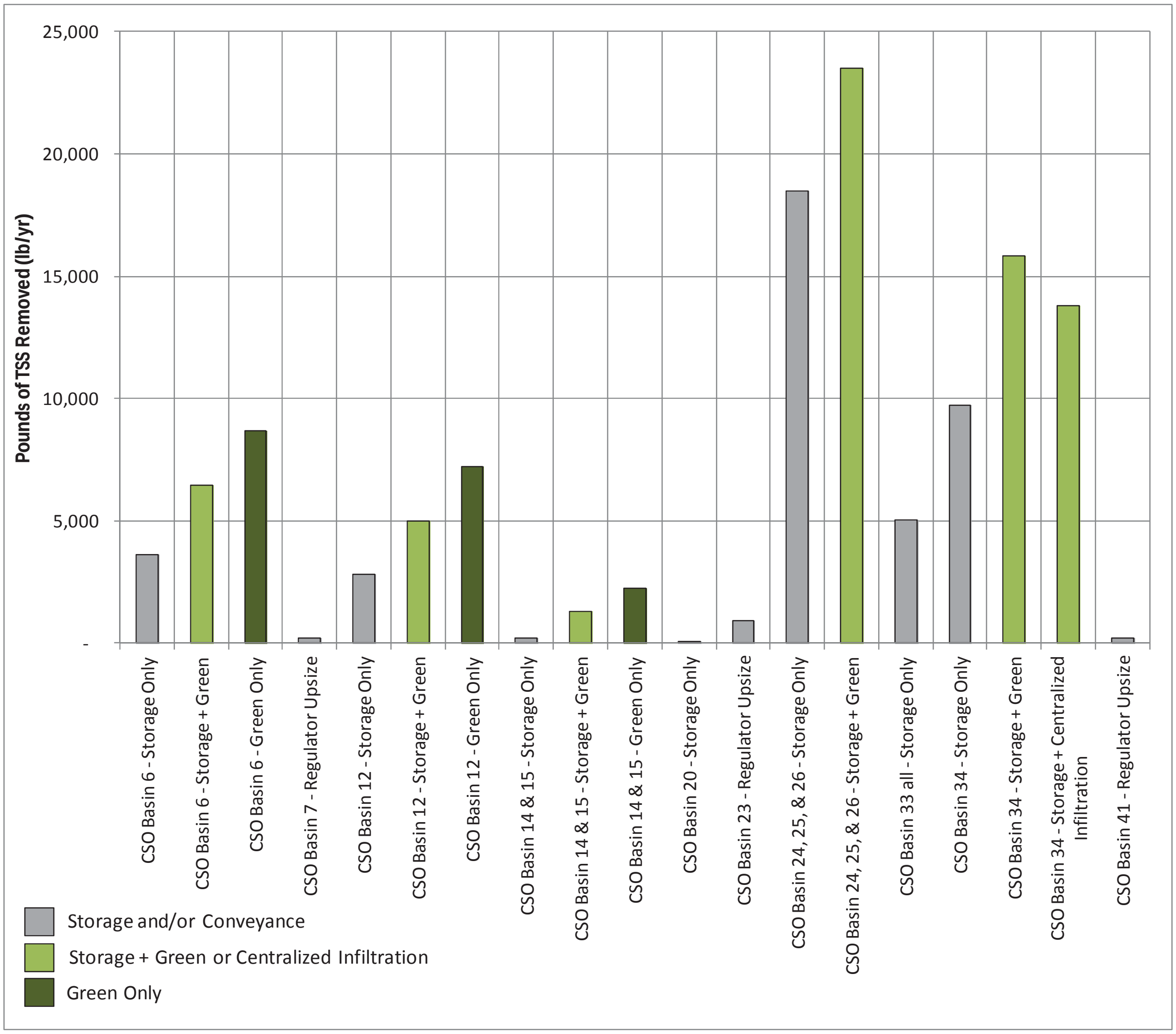

Figure 6
Average Annual TSS Removal Amounts

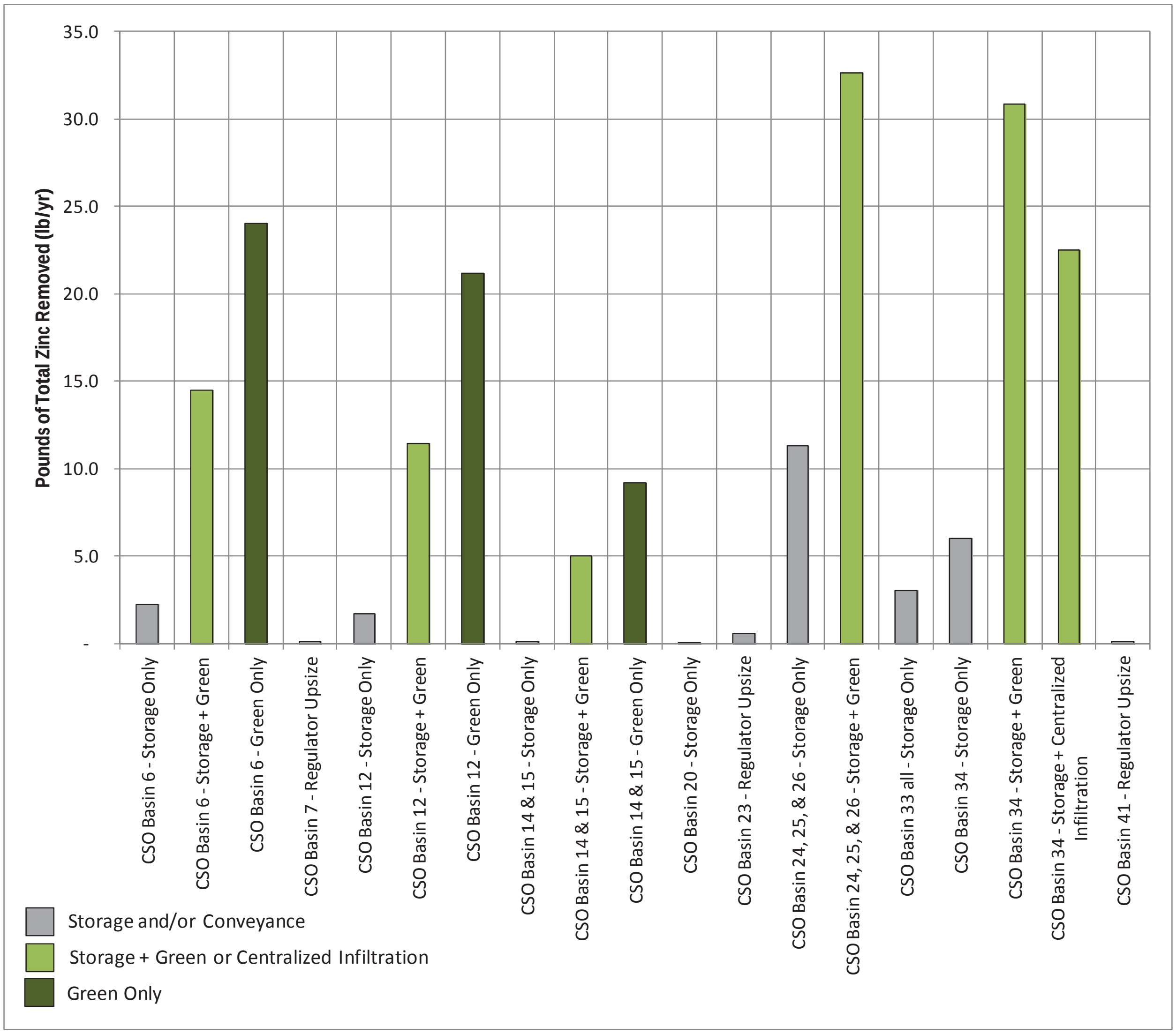

Figure 7
Average Annual Total Zinc Removal Amounts

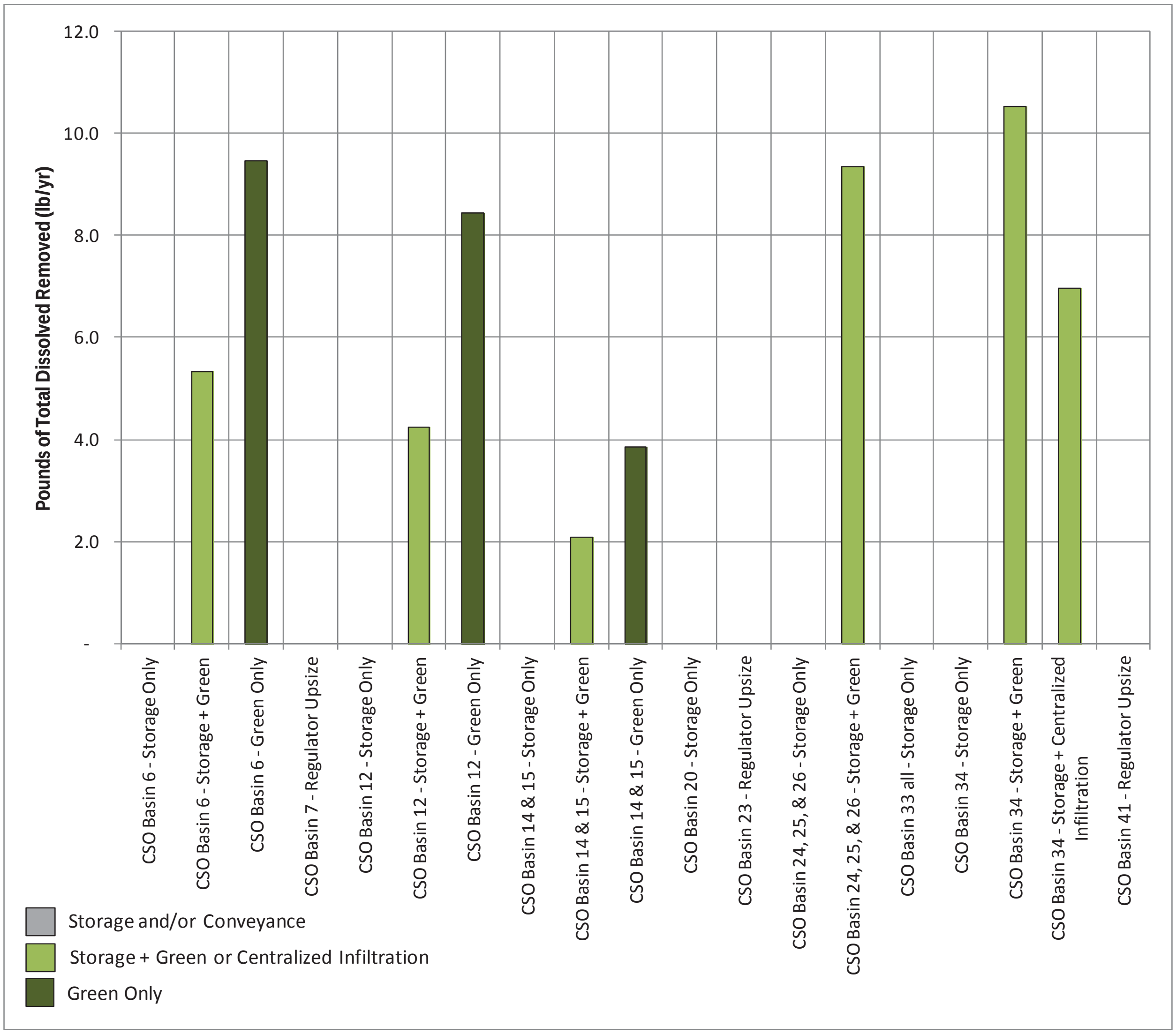

Figure 8
Average Annual Dissolved Zinc Removal Amounts

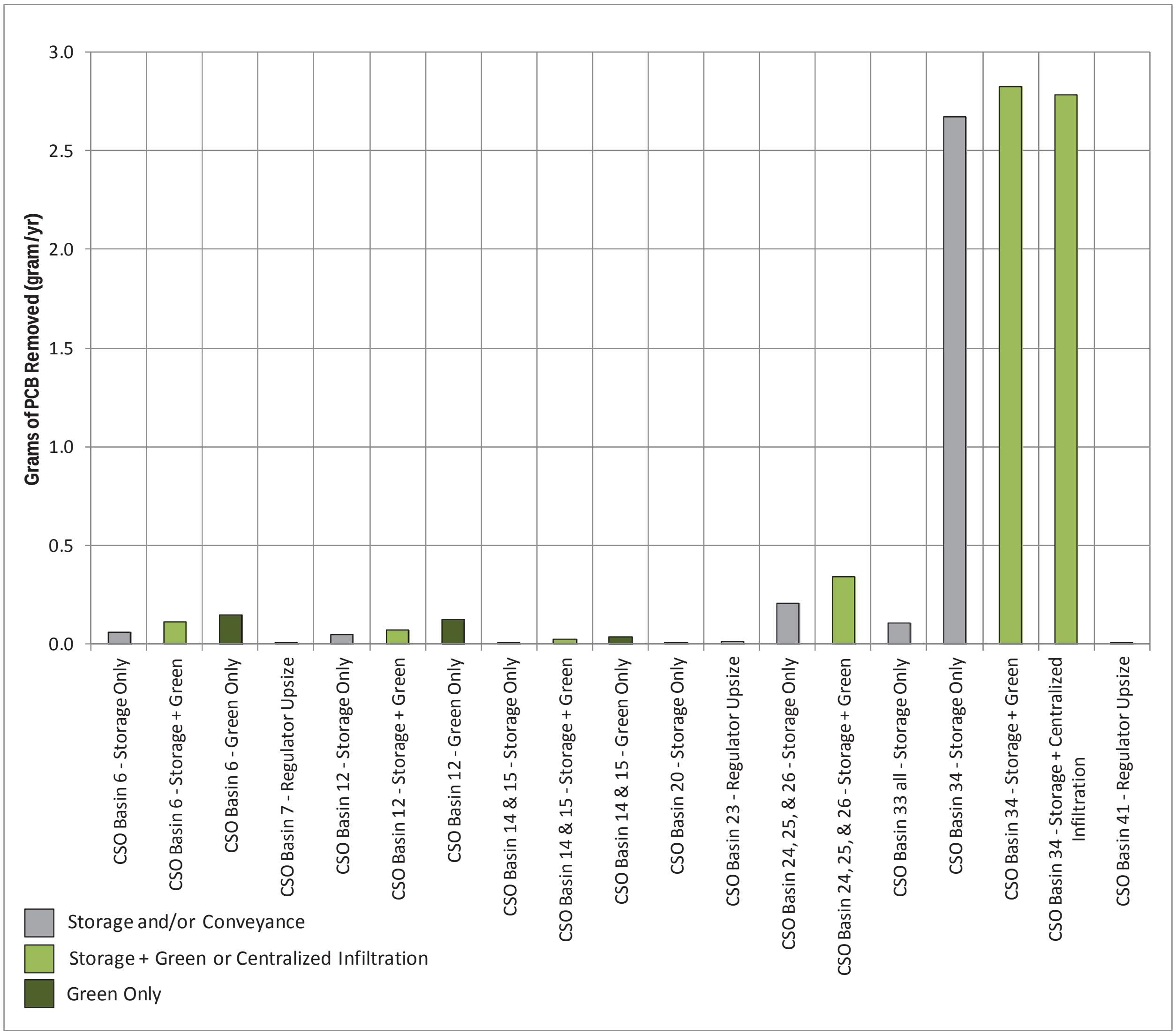

Figure 9
Average Annual PCB Removal Amounts

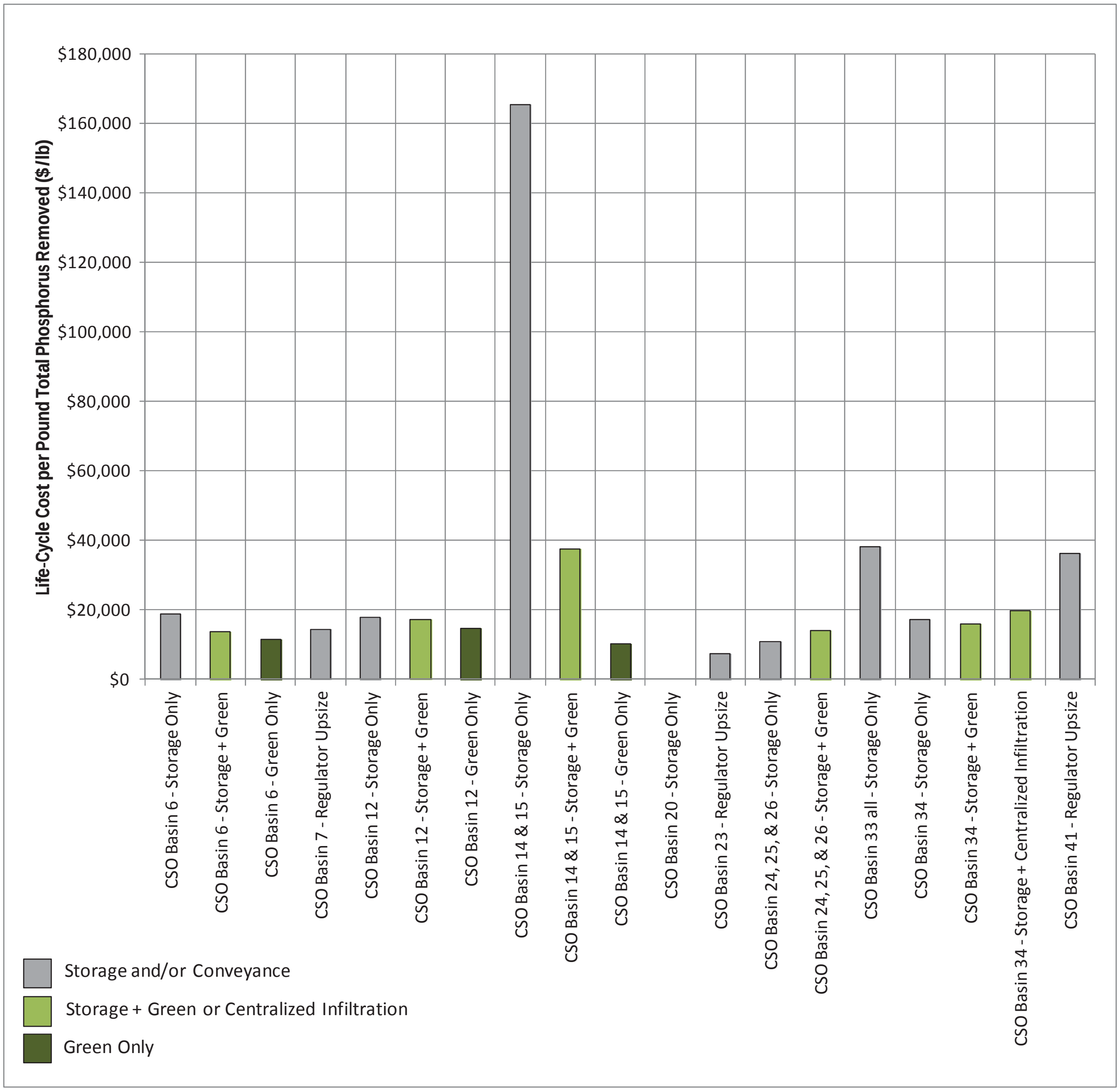

Figure 10
Life-Cycle Cost per Pound of Total Phosphorus Removed

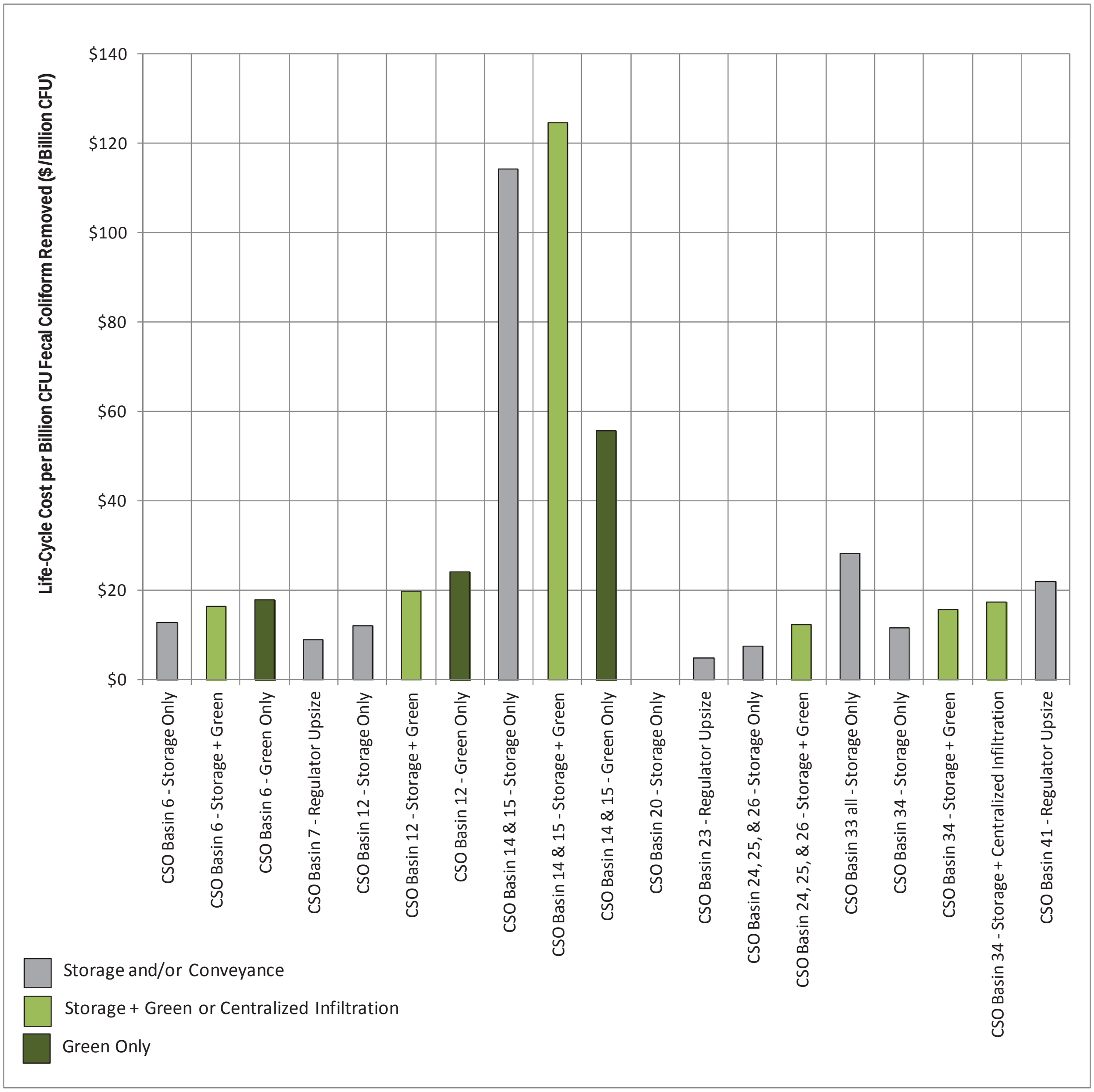

Figure 11
Life-Cycle Cost per Billion CFU of Fecal Coliform Removed

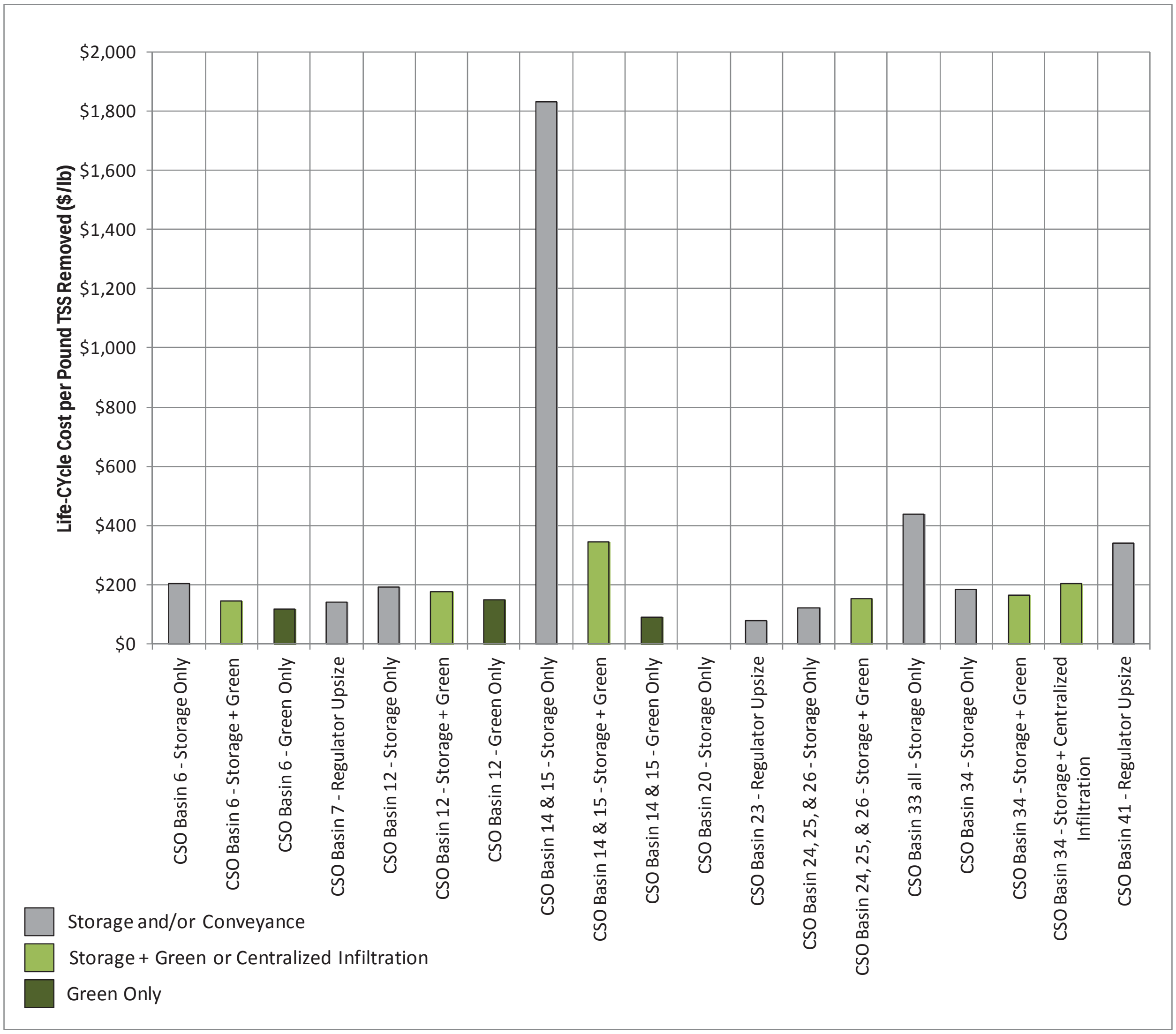

Figure 12
Life-Cycle Cost per Pound of TSS Removed

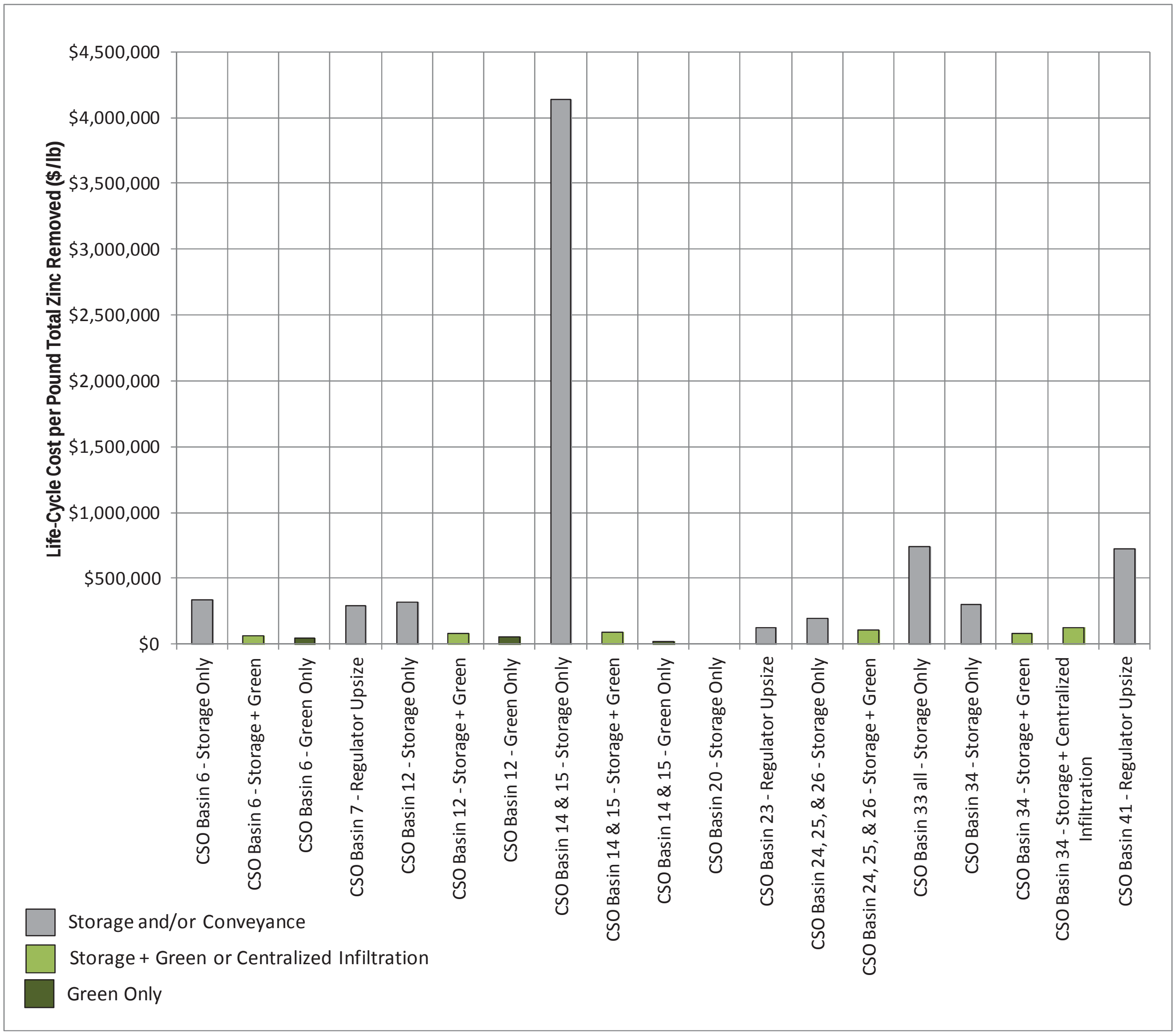

Figure 13
Life-Cycle Cost per Pound of Total Zinc Removed

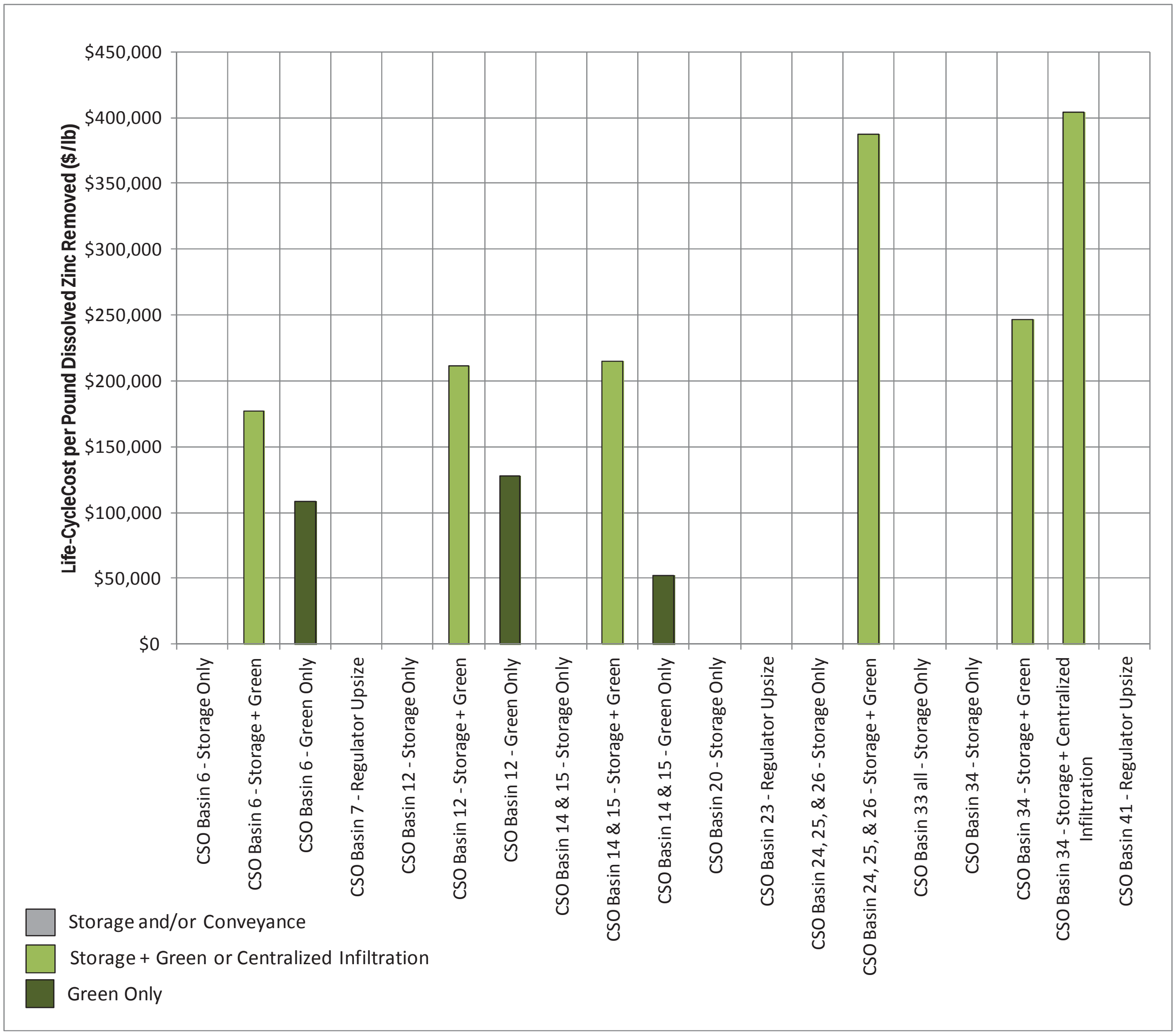

Figure 14
Life-Cycle Cost per Pound of Dissolved Zinc Removed

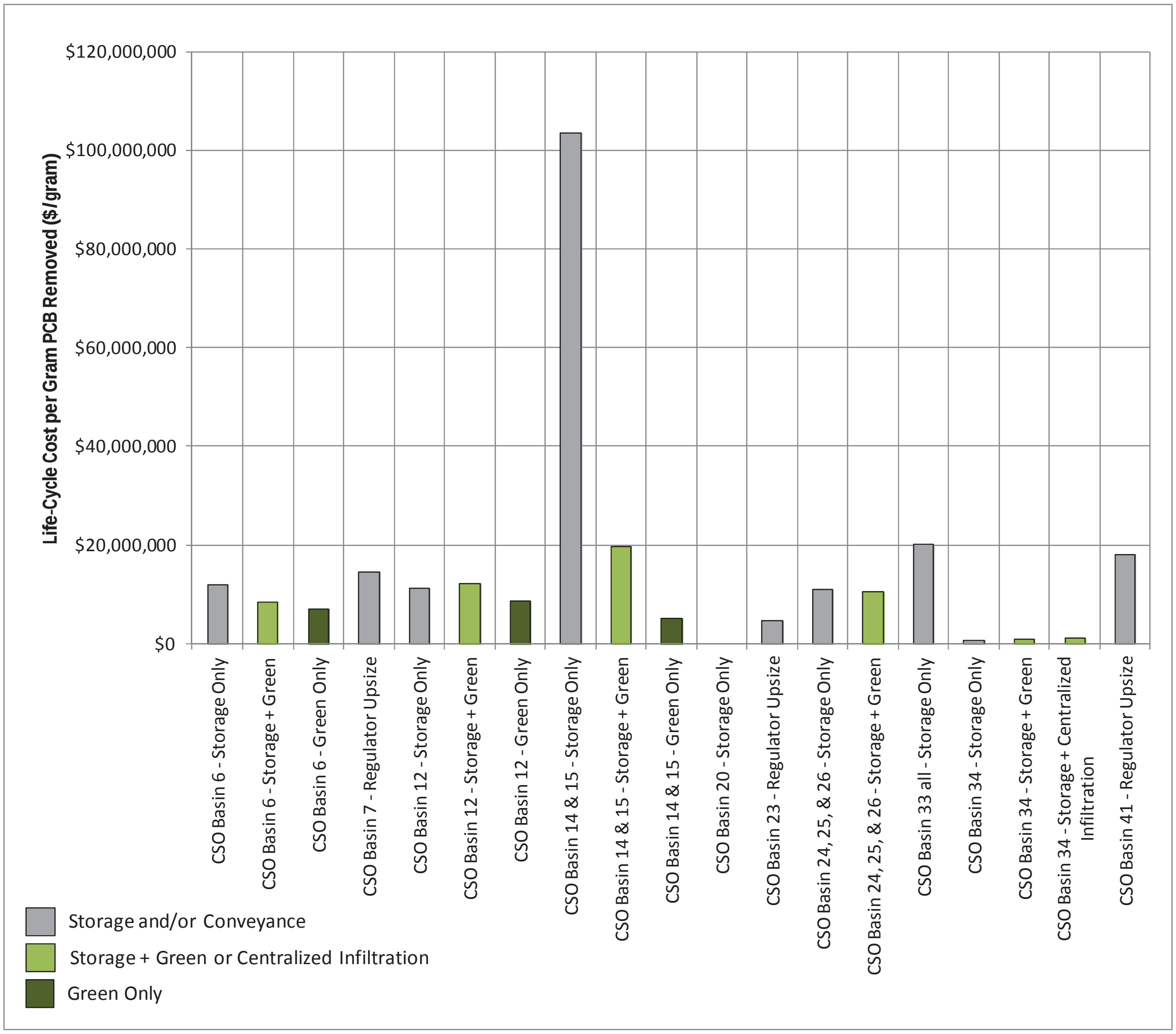

Figure 15
Life-Cycle Cost per Gram of PCB Removed

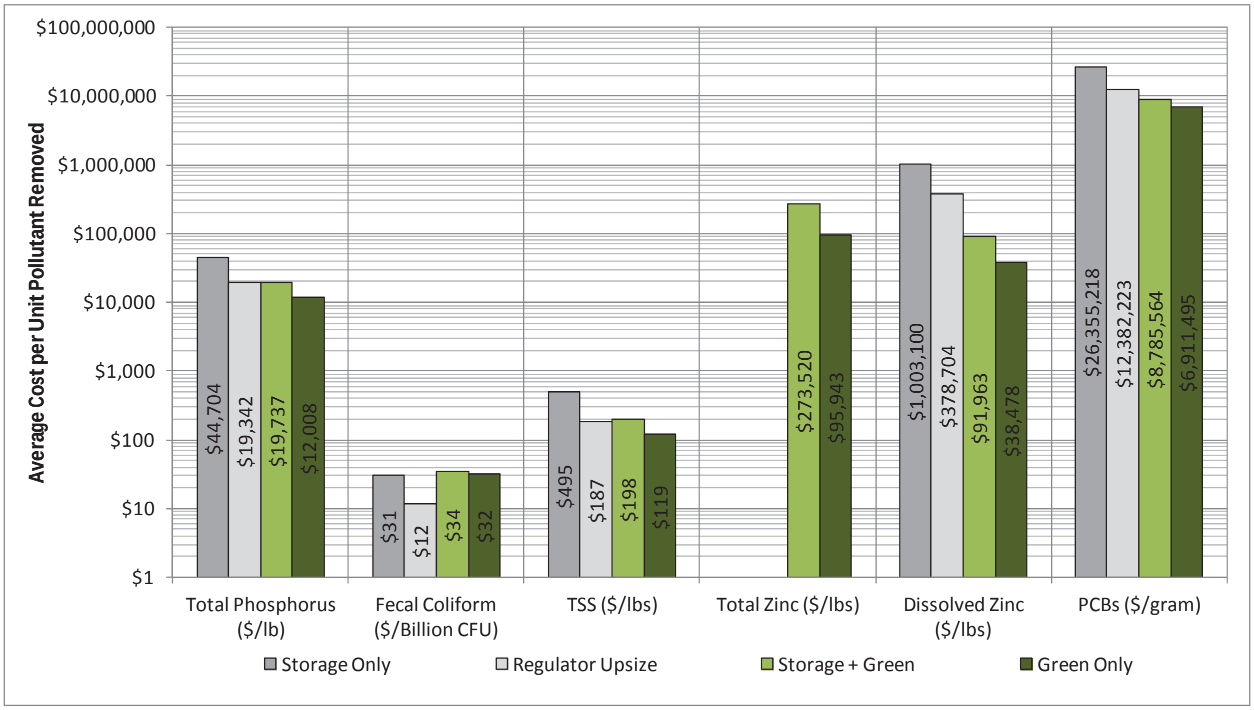

Figure 16
Average Cost per Pound Pollutant Removed by Basin Solution

Appendix A
CSO Volumes and Frequencies by Season

City of Spokane Integrated Plan
Historical CSO Analysis
Memo Appendix A Table

Greyed out rows indicate controlled CSO basin with no additional CSO reduction projects planned.

	Critical Season (March through October)				Non-Critical Season (November through February)				Full Year			
CSO Basin	Current CSO Volume (MG/yr)	Future CSO Volume (MG/yr)	Current CSO Frequency (#/yr)	Future CSO Frequency (#/yr)	Current CSO Volume (MG/yr)	Future CSO Volume (MG/yr)	Current CSO Frequency (#/yr)	Future CSO Frequency (#/yr)	Current CSO Volume (MG/yr)	Future CSO Volume (MG/yr)	Current CSO Frequency (#/yr)	Future CSO Frequency (#/yr)
2	-	-	-	-	-	-	-	-	-	-	-	-
6	2.73	0.45	15.67	0.58	1.73	0.12	9.83	0.33	4.47	0.58	25.50	0.92
7	0.22	0.07	6.58	0.67	0.07	0.01	4.00	0.25	0.29	0.07	10.58	0.92
10	0.01	0.01	0.08	0.08	-	-	-	-	0.01	0.01	0.08	0.08
12	1.88	0.19	17.58	0.50	1.42	0.10	9.58	0.42	3.31	0.30	27.17	0.92
14/15	0.20	0.04	10.64	0.64	0.12	0.03	7.91	0.27	0.31	0.07	22.00	1.82
16B	0.01	0.01	0.17	0.17	-	-	-	-	0.01	0.01	0.17	0.17
19	0.00005	0.00005	0.17	0.17	0.0001	0.0001	0.25	0.25	0.0002	0.0002	0.42	0.42
20	0.03	-	0.44	-	-	-	-	-	0.03	-	0.44	-
22B	0.02	0.02	1.00	0.75	0.003	0.003	0.25	0.17	0.02	0.02	1.25	0.92
23	0.62	0.05	10.75	0.42	0.49	0.04	5.67	0.50	1.11	0.09	16.42	0.92
24/25	4.36	0.84	19.33	0.33	3.33	0.61	10.17	0.58	7.68	1.44	42.00	0.92
26	9.37	1.26	15.83	0.50	6.27	0.81	7.58	0.42	15.64	2.07	23.42	1.83
33A-C	4.55	0.83	7.50	0.50	1.25	0.05	3.17	0.08	5.80	0.88	26.00	0.92
33D	0.24	0.03	14.75	0.25	0.18	0.03	7.50	0.25	0.42	0.06		
34	6.51	0.88	10.67	0.33	6.16	1.27	7.42	0.58	12.67	2.15	18.08	0.92
38	0.01	0.01	0.08	0.08	-	-	-	-	0.01	0.01	0.08	0.08
41	0.26	0.10	7.67	0.67	0.07	0.01	3.42	0.25	0.33	0.11	11.08	0.92
42	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	31.03	4.80	138.91	6.64	21.09	3.09	76.74	4.36	52.12	7.89	224.69	12.65

Appendix B
Drywell and Swale Sizing and Siting

City of Spokane
CSO Plan Amendment
Quantifying the Amount of Drywells and Swales

Purpose

The purpose of this document is to summarize the technical approach of quantifying the amount of swales and drywells to implement in Combined Sewer Overflow (CSO) basins for the City of Spokane's CSO Plan Amendment. The result of this approach will be estimates for the number of drywells needed and lineal feet of swale needed. The exact locations of the drywells and swales are not identified, only the required amount of treatment facilities is estimated. This allows for quick, planning level cost estimates and a flexible approach that can be customized basin by basin if needed.

Background

CH2M HILL created a shapefile (CSO_GIcombined_PotentiallyFeasible20130808) that identified what areas of the City's CSO basins are technically suitable for infiltration using either drywells or swales. The area identified in this analysis is called the "technically feasible area for infiltration", and represents the area that, at a high-level, appears to be suitable for infiltration by drywells or swales. The technically feasible area was then reduced by a 50% factor to account for uncertainties and other limitations, to come up with an area called the "practical feasible area for infiltration", and represents the area in the basin that can cost-effectively be infiltrated. The 50% factor was based on experience on the Seattle Public Utilities Green Stormwater Infrastructure program. AECOM modeled each CSO basin with the practical feasible area disconnected from the combined sewer system (CSS), and estimated the reduction in storage volume due to infiltration. The two infiltration technologies being considered for use are drywells and swales (which have drywells as overflows).

Approach

The following is a summary of the approach to quantify the amounts of drywells and swales. Key assumptions are underlined and italicized.

I. **Drywells versus Swales**: On a basin-by-basin level, determine how much area of the practically feasible area for infiltration to divert to swales and how much area to divert to drywells. The analysis to determine technically feasible areas broke down areas into three categories; not feasible for infiltration, feasible for swales only, or feasible for swales or drywells. Because drywells are easier to maintain and are cheaper, <u>*in areas where either swales or drywells are feasible, the priority will be to implement drywells*</u>. Drywells may actually be feasible in other areas, but because they would require additional pretreatment they were not considered in this analysis.
    a. Calculate the percentage of the technically feasible area for infiltration that is suitable for:
        i. Swales only

ii. Swales or drywells (however, as mentioned above, this is the percentage of area that will be diverted to drywells.)

For example, in CSO Basin 12, approximately 36% of the technically feasible area for infiltration is suitable only for swales, and 64% is suitable for both drywells or swales.

b. Apply this same percentage breakdown to the practically feasible area. For example, in CSO Basin 12, the practically feasible area is 143 acres. Therefore, 36% of 143 acres will be diverted to swales, and 64% of 143 acres will be sent to drywells.

c. *Using the curve number spreadsheet and percent connectivities developed for the Cochran stormwater basin, estimate the acres of connected area for the areas identified for drywells and swales above*.

II. **Number of Drywells**: Estimate the number of drywells needed to infiltrate the area identified for infiltration via drywells in step 1.

a. Estimate the tributary area for one drywell

   i. Estimating the peak runoff

      1. *Use a 10-year recurrence interval, 24-hour duration storm event*. 1.8" rain depth, based on Spokane Regional Stormwater Manual (SRSM)
      2. *Use SCS Type II storm shape* (matches design storm shape for CSO basin control volumes and SRSM design storm for swales)
      3. *Composite curve number calculated based on impervious areas and land use within CSO basin (assumed to be evenly distributed*)
         a. CN sources: SRSM & Civil Engineering Reference Manual 12th ed.
      4. Time of concentration calculated iteratively for some example drywells, typically came out to less than 5 minutes

   ii. Drywell capacity assumptions

      1. *Capacity of one drywell is 1 cfs* (typical design capacity used for drywell designs in Spokane)
      2. *No storage in the drywell*

   iii. Calculating the maximum tributary area to one drywell

      1. Use SCS Method within HEC-HMS to estimate the tributary area for one drywell. Do this by varying the basin area until the peak flow generated by the storm event is equal to 1 cfs

   iv. Calculating the typical tributary area to one drywell

      1. *Multiply the maximum tributary area by 0.8 to account for practical limitations that will prevent each drywell from receiving it's maximum tributary area*
      2. RESULTS: Analysis of drywells in several basins has resulted in an adjusted tributary area per drywell of 0.56 acres.

b. Divide the practical feasible area to drywells (calculated in step 1) by the typical tributary area of one drywell. This will result in an approximation of the number of drywells required to infiltrate the desired tributary area.

III. **Lineal Feet of Swales**: Estimate the lineal feet of swales needed to infiltrate the area identified for infiltration via swales in step 1.

a. *Identify sizing equation*
   i. [Volume] = 1133 x [Hydraulically connected impervious area to be treated] This is Equation 6-1c from the SRSM. This equation is used instead of equation 6-1d, which is used in areas with poor infiltration, because the identification of feasible areas for infiltration, along with the 50% reduction factor, have removed areas with poor infiltration rates from consideration.

b. Identify *characteristics of a typical swale to be implemented*
   i. 12 ft planter top width
   ii. 6” max ponding depth (SRSM)
   iii. 2 ft flat bottom
   iv. 1 ft flat area next to sidewalk
   v. 3H:1V side slopes (City of Spokane Standard Plans)
   vi. 18” total depth to bottom of curb (6” ponding + 12” freeboard)
   vii. 1.75 ft^2 cross-sectional area
   viii. Contains drywell for overflow

c. Calculate the hydraulically connected impervious area in the practical feasible area that is to be diverted to swales.

d. Calculate the volume of swale needed.

e. Divide the volume of swale needed by the cross-sectional area of the typical swale.

f. Estimate the number of drywell needed for swale overflows.
   i. The typical block is 300 feet long by 40 feet wide, which results in a tributary area of approximately 0.28 acres. As indicated in Step II above, the typical drywell has a capacity for 0.56 acres, which indicates that *one drywell per 300 feet of swale should be sufficient for planning purposes*.

APPENDIX C

Cochran Basin Stormwater Alternatives Analysis

FINAL TECHNICAL MEMORANDUM CH2MHILL®

Cochran Basin Stormwater Alternatives Analysis

PREPARED FOR:	City of Spokane
COPY TO:	Jennifer Price/SEA File
PREPARED BY:	Doug Busko, PE/SPK Amy Carlson, PE/SEA Santtu Winter, PE/SEA
REVIEWED BY:	Pete Sturtevant, PE/SEA
DATE:	January 31, 2014
PROJECT NAME:	City of Spokane Integrated Plan
PROJECT NUMBER:	382918.T7.02.07

Purpose

The purpose of this technical memorandum is to present a summary of:

- The watershed data for Cochran Basin
- The hydrologic and pollutant loading calculations on an annual basis, as well as for the water quality storm (i.e., the 6-month, 24-hour storm) in Cochran Basin
- A set of conceptual alternatives for treating the water quality storm flowing from the basin
- The planning level costs for each treatment alternative
- The Multi-Objective Decision Analysis (MODA) that was performed on the set of treatment alternatives
- A recommendation for which stormwater treatment alternative merits further planning and design effort

Summary

Four conceptual alternatives for the treatment and disposal of runoff from Cochran Basin were developed, all located near the basin's current outfall into the Spokane River. Details of the four alternatives were developed to a level sufficient to estimate material quantities and project costs. Operations and maintenance costs over a 25-year time horizon were also calculated for each alternative. A scoring of subjective project elements was performed for each alternative and the result paired with the alternative's cost; the value-cost data points of the four alternatives were then plotted on a single graph. The alternative with the highest value/cost ratio was Alternative 2 (Biofiltration in Disc Golf Course), but Alternative 3 (Biofiltration West of Meenach Bridge), which features a nearly equal value for approximately half the cost, was selected as the Preferred Alternative. The analysis concludes with a recommendation for additional technical studies to be performed at the Alternative 3 location.

Introduction

The Cochran Basin is the largest stormwater basin in the City of Spokane's urban storm drain system. Due to the volume of annual stormwater runoff and accompanying pollutants it discharges to the

Spokane River, it was identified early in the Integrated Planning process as a potential basin in which to focus resources for water quality treatment improvements. A stormwater alternatives analysis was conducted to develop the conceptual alternatives, estimate the costs for each, and score them on the same basis as the other options contained in the Integrated Plan, so that the value and cost of the Cochran Basin preferred alternative could be objectively compared to the other potential projects considered in the Integrated Plan.

Project Goals

The goals of the Cochran Basin alternatives analysis are to:

1. Identify a preferred conceptual alternative for the collection and treatment of the stormwater runoff from Cochran Basin
2. Quantify the amount of pollutants removed on an annual basis from the Spokane River through implementation of the preferred conceptual alternative
3. Develop the cost, on a net present value basis, to construct the preferred conceptual alternative and to operate and maintain it for a period of 25 years
4. Provide a conceptual stormwater option for consideration in the Integrated Plan that is currently being prepared for the City

Regulatory Framework

Spokane Regional Stormwater Manual

The *Spokane Regional Stormwater Manual* (SRSM) (Spokane County, City of Spokane, and City of Spokane Valley, 2008) is the primary regulatory document that guides the collection, treatment, and disposal of stormwater in the City of Spokane. It has been approved as equivalent to the *Stormwater Management Manual for Eastern Washington* by the Washington State Department of Ecology (Ecology) (Ecology, 2004). The SRSM stipulates that stormwater treatment facilities must be sized to treat either the water quality (WQ) storm volume or the WQ peak flow rate, depending on whether the treatment facility employs a volume-based or a flow-based process.

Currently, there are no regulations in place that require the City to collect and treat the runoff from Cochran basin; however, stormwater regulations continue to evolve and are likely becoming more stringent in the future. This alternatives analysis is part of an initial effort to anticipate these changes and take preparatory steps to address them, as a means of achieving the Integrated Plan's objective of a Cleaner River Faster.

Phase II Eastern Washington Municipal National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit

The City of Spokane received a Phase II Eastern Washington Municipal NPDES and State Waste Discharge General Permit from Ecology in 2007, which allows it to discharge stormwater into surface waters or ground waters of Washington State. The permit was modified in 2009 by Ecology, and reissued in unmodified form in 2012; it expires on July 31, 2014. The updated 2014-2019 permit will become effective on August 1, 2014. This updated permit includes two significant changes. First, the permit requires permittees to begin implementing low impact development (LID) stormwater management techniques in new development and redevelopment projects. Permittees must have LID regulations in place by December 31, 2017. Second, the permit features new requirements for permittees to work cooperatively to implement monitoring programs to evaluate the effectiveness of their stormwater management programs, to improve the programs and help guide future permit requirements.

Shoreline Management Act

Because there are conceptual alternatives included in this analysis that include treatment and disposal in the vicinity of the Spokane River, the requirements of the City's Shoreline Master Program, which locally implements the State's Shoreline Management Act, must be considered, including applicable setbacks of any improvements from the river.

Integrated Planning Framework

The City of Spokane is proposing to implement an integrated strategy to achieve its goal of a Cleaner River Faster. The City is proceeding with a planning process to integrate all of the City's clean water investments, including those for stormwater, for combined sewer overflows (CSOs), and for municipal wastewater treatment at the City's Riverside Park Water Reclamation Facility (RPWRF). The City prepared an Integrated Plan (IP) consistent with the U.S. Environmental Protection Agency's (USEPA's) Integrated Planning Approach Framework to summarize its Integrated Strategy, which was the result of the City's integrated planning process. The IP describes the City's proposed portfolio of clean water investments across its range of provided services, and identifies opportunities to improve other assets (such as water lines and roadway conditions) with the implementation of the IP projects. The City of Spokane worked collaboratively with Ecology throughout the process to develop this Integrated Strategy and to develop an integration plan and funding approach for the IP elements.

In its Draft Integrated Planning Approach Framework document, USEPA notes that:

> Integrated planning will assist municipalities on their critical paths to achieving the human health and water quality objectives of the Clean Water Act (CWA) by identifying efficiencies in implementing the sometimes overlapping and competing requirements that arise from distinct wastewater and stormwater programs, including how best to make capital investments. (USEPA, 2012; page 1)

The principles set forth in the guidance require that an IP:

- Maintain existing regulatory standards that protect the public health and water quality
- Balance various CWA requirements in a manner that addresses the most pressing public health and environmental protection issues first
- Does not relieve the City of the requirement to comply to applicable rules

The responsibility to develop an IP rests with the City, but the plan must be approved by USEPA and Ecology.

Description of Cochran Basin and its Runoff Characteristics

Physical Description

Cochran Basin is a stormwater basin within the City's municipal separate stormwater system (MS4) and is located wholly within the corporate limits of the City of Spokane. The approximate boundaries of the basin are Market Street on the east, Alberta Street on the west, Francis Avenue on the north, and Montgomery Avenue on the south. Total basin area is approximately 5,328 acres, of which 57 percent is residential property, 17 percent is impervious City right-of-way, 8 percent is commercial property, 2 percent is industrial property, 1 percent is open space, and the remaining 15 percent is miscellaneous impervious surfaces outside of City right-of-way. Overall, the basin is approximately 68 percent impervious. Approximately 839 acres, or 16 percent, of the basin actually drains to the MS4 (CH2M HILL, 2013a). See Appendix A for a map of the basin.

Stormwater from the basin originally was directed into a combined sewer system and discharged to the Spokane River. In the 1980s and early 1990s, a separate stormwater system was constructed throughout the basin by the City. The outfall for this system discharges to the Spokane River just west of the TJ Meenach Bridge, through the shared Cochran/CSO 10 Outfall (note that, although CSO 10 overflows to the Cochran Outfall, the Cochran Basin separated storm system does not convey sanitary sewage). Currently, there are no major stormwater facilities in the basin that treat the runoff or divert it from the Cochran Basin.

Precipitation, Runoff, and Pollutant Loading

The precipitation, runoff, and pollutant loading characteristics of Cochran Basin were presented previously (CH2M HILL, 2013a) and are summarized in Tables 1 and 2.

TABLE 1
Physical Data and Calculated Runoff for Cochran Basin

Basin Area (acres)	5,328
Impervious City Right-of-way Contributing Runoff to Cochran Basin (acres)	497
Average Annual Precipitation (inches)	17.25
Average Annual Runoff Volume (million gallons [MG])	296.46
Average Annual Runoff Volume (cubic feet [ft^3])	39,634,000

TABLE 2.
Average Annual Pollutant Loading in Cochran Basin

Total Phosphorus (lb/year)	1,806
Total Suspended Solids (TSS) (lb/year)	554,190
Total Zinc (lb/year)	535
Dissolved Zinc (lb/year)	65
Fecal Coliform (billions of colony-forming units [CFU] per year)	2,245
Polychlorinated biphenyls (PCBs) (grams/year)	5.9

The WQ storm is defined as the 6-month, 24-hr storm; in the City of Spokane, this storm is equivalent to 1.0 inch of precipitation. The volume of the WQ storm discharged from Cochran Basin was calculated in the same manner as the annual runoff volume, with a resulting value of 55.4 acre-feet (2,413,000 ft^3, or 18.1 MG). For purposes of conveyance and treatment sizing, the peak flow rate for the WQ storm was calculated using the SCS Method; the peak flow of the WQ storm is 260 cubic feet per second (cfs).

Approximately 91 percent of the total annual discharge from Cochran Basin would be captured and treated by using the WQ storm to size the treatment facilities. Therefore, for a treatment facility that does not discharge the treated effluent to the Spokane River (e.g., the treated effluent is infiltrated), 91 percent of each pollutant would be removed from the Spokane River, compared to present day conditions. The annual pollution removal results are summarized in Table 3.

TABLE 3
Annual Pollutant Removal in Cochran Basin for Facilities Sized Using the Water Quality Storm

Total Phosphorus (lb)	1,644
TSS (lb)	504,313
Total Zinc (lb)	487
Dissolved Zinc (lb)	59
Fecal Coliform (billions of CFU)	2,043
PCBs (grams)	5.4

Description of Alternatives

This section describes the major components of the various conceptual alternatives that were developed for the analysis, including the conveyance, storage, treatment, and disposal infrastructure required for each alternative. Conceptual layouts for each alternative are presented in Appendix B.

Alternative 1 – Media Filtration in Disc Golf Course

Under Alternative 1, shown in Appendix B, a diversion manhole (DM) would be constructed in TJ Meenach Drive just south of its intersection with NW Boulevard, on the existing storm line that discharges into the Spokane River via the Cochran/CSO 10 Outfall. This DM would have a weir in its invert, set at an elevation to divert flow up to 260 cfs, the WQ storm peak flow rate, to a new pipeline flowing to the west. Flow in excess of 260 cfs would pass over the weir and continue to the Cochran/CSO 10 Outfall.

The flow diverted to the west would be conveyed via Cleveland Avenue in a new 72-inch storm drain, to a 3.2-acre initial treatment basin located within Downriver Golf Course. The initial treatment basin would be a below-grade, concrete-lined facility, that would serve to remove floatables, sediment, and other debris from the stormwater. Flow would proceed to a 225,000-gallon buried detention vault in the disc golf course located between Downriver Drive and the river. The purpose of the detention tank is to reduce the peak flow to a maximum of 3 cfs. The stormwater would then continue via buried storm drain to a concrete vault fitted with approximately 320 stormwater filter cartridges, each capable of treating 1.5 gallons of stormwater per minute. The cartridges can be filled with a variety of media, including leaf compost, perlite, or zeolite, depending on the pollutants that are targeted for removal. The treated stormwater would then flow to an infiltration drainfield located on the disc golf course. The detention vault, media filtration vault, and drainfield would all be subsurface facilities, allowing disc golf activities to occur directly over them.

Alternative 2 – Biofiltration Channel in Disc Golf Course

Under Alternative 2, shown in Appendix B, a DM would be constructed in or near the intersection of Nettleton Street and Cleveland Avenue, on the existing storm line that discharges into the Spokane River via the Cochran/CSO 10 Outfall. This DM would have a weir in its invert, set at an elevation to divert flow up to 260 cfs, the WQ storm peak flow rate, to a new pipeline that would flow into the City park located on the southeast corner of NW Boulevard and TJ Meenach Drive. Flow in excess of 260 cfs would pass over the weir and continue on down to the Cochran/CSO 10 Outfall via the existing storm drain in TJ Meenach Drive.

The flow diverted to the park would first enter a concrete distribution tank, which would split the flow into four streams by means of four 36-inch discharge pipes. Each discharge pipe would connect to a continuous deflection separator (CDS), which would remove floatables and sediment from the stormwater. Each of the CDS units would be sized to treat a peak flow of 65 cfs. The four 36-inch discharge pipes from the four CDS units would connect to a 225,000-gallon buried detention vault. The purpose of the detention tank (which is a feature common to Alternatives 2, 3, and 4) is to reduce the peak flow to 3 cfs. Consequently, the conveyance facilities downstream of the detention tank can be significantly smaller than the conveyance facilities needed under Alternative 1.

All new stormwater facilities in the park would be subsurface, and the park's uses and amenities would not change. A gravel maintenance driveway from the Grace Avenue cul de sac would be constructed to provide access to the new facilities.

From the detention vault, the initially treated stormwater would then flow west in a new 18-inch pipe, along Cleveland Avenue, Columbia Circle, and Downriver Drive to the disc golf course described in Alternative 1. There, the stormwater would daylight into a shallow biofiltration channel for final treatment. The channel would be trapezoidal, with a minimum length of 600 feet and a bottom width of 10 feet; maximum velocity would be 1 foot per second, and maximum flow depth would be less than 6 inches. Various types of vegetative cover can be considered for the channel, including turf, native grasses, or other types of landscaping; the channel would be integrated with the disc golf course and is also intended to serve as an aesthetic enhancement. Biofiltration channels are approved by Ecology as a permanent best management practice. The treated stormwater would then flow to an infiltration drainfield located on the disc golf course, as described in Alternative 1.

Alternative 3 – Biofiltration Channel West of TJ Meenach Bridge

Alternative 3 features the same diversion, pretreatment, and detention configuration as Alternative 2, where the WQ storm is first directed to the park at the southeast corner of NW Boulevard and TJ Meenach Drive for initial treatment and reduction of peak flow rate to 3 cfs. From there, the initially treated stormwater would be directed down TJ Meenach Drive in an 18-inch pipe to the recreation area just west of TJ Meenach Bridge. Similar to Alternative 2, the stormwater would daylight into a biofiltration channel for final treatment and disposal in a drainfield. See Appendix B for the layout of Alternative 3.

This alignment would require two short auger borings to facilitate pipe installation, one under a fill slope adjacent to TJ Meenach Drive and the other at the north end of the bridge under the intersection of TJ Meenach Drive and Pettet Drive.

Alternative 4 – Biofiltration Channel East of TJ Meenach Bridge

Alternative 4, shown in Appendix B, also features the same initial treatment and detention configuration as Alternative 2, with these processes occurring in the park at the southeast corner of NW Boulevard and TJ Meenach Drive. Similar to Alternative 3, the initially treated stormwater would flow in an 18-inch pipe down TJ Meenach Drive; however, instead of the initially treated stormwater flowing to the west side of Meenach Bridge, it would be directed to an open area directly east of the bridge and the Centennial Trail parking lot. The stormwater would then daylight into a biofiltration channel, similar to that described in Alternative 2, for final treatment. It would then be conveyed to a drainfield for infiltration. This alignment would also feature two short auger bores: one under the aforementioned fill slope adjacent to TJ Meenach Drive and the other under Pettet Drive.

Other Alternatives

In addition to Alternatives 1 through 4, other potential solutions for treating runoff within Cochran Basin were studied, two by the City of Spokane and one by CH2M HILL. These approaches are briefly described below.

Distributed Stormwater Treatment. The City studied the possibility of constructing bioinfiltration swales in each block of arterials and residential streets within wellhead protection areas, and catch basin/drywell combinations on residential streets outside of wellhead protection areas. While this approach would maximize the street-by-street benefits of being able to concurrently upgrade water mains, curbs, and sidewalks, it was deemed to be prohibitively expensive; conceptual estimates of just the stormwater elements of the upgrades were in excess of $200 million. This alternative was eliminated from further consideration due to its high cost.

Regional Stormwater Treatment. The City also studied the potential of using larger parcels of City-owned property in a regional approach for treatment and disposal. Under this plan, stormwater would be collected within subbasins of the Cochran Basin and routed to golf courses (including Esmeralda Golf Course and Downriver Golf Course) and parks. Stormwater would be treated in the golf courses and parks by means of bioinfiltration, and infiltrated onsite. A conceptual cost analysis of this approach, which would require installation of many miles of storm drain as well as the treatment facilities, concluded that the cost would be in excess of $75 million. Due to the high cost, this alternative was eliminated from consideration.

Bioinfiltration Ponds at Downriver Golf Course and the Disc Golf Course. Early in this analysis, CH2M HILL studied the potential to use Downriver Golf Course for treating and infiltrating the WQ storm volume of 55.4 acre-feet that flows off of Cochran Basin. The SRSM requires bioinfiltration ponds to be sized to flood to a maximum depth of 6 inches; thus, to treat the WQ storm would require at least 110.8 acres of bioinfiltration ponds. The scenario where the ponds could be permitted to flood to a depth of 1 foot was also considered; the required minimum area with such an approach would be at least 55.4 acres. Neither one of these solutions is feasible because these facilities could not be sited on Downriver Golf Course. As a final exercise, the area of the disc golf course was considered for construction of bioinfiltration ponds, but the analysis revealed that not enough land is available in the area between Downriver Drive and the river to construct bioinfiltration facilities.

Cost

The capital costs of constructing Alternatives 1 through 4 were calculated by CH2M HILL using *Engineering News Record* construction cost data from April 2013. In addition to the direct facility construction costs, the capital costs include:

- Mobilization, bonds, and insurance
- Traffic control during construction
- Erosion control during construction
- Washington state sales tax
- Permit fees (estimated)
- Utility conflict allowance
- Soft costs (e.g., planning, design, etc.) , as 25 percent of the estimated construction cost
- A 30 percent overall contingency on the sum of the construction cost and soft costs

See Appendix C for the detailed capital cost estimates for Alternatives 1 through 4.

In addition to the capital costs, the 25-year operation and maintenance (O&M) costs were calculated for each alternative. The net present value (NPV) of the capital cost and 25-year O&M costs were then calculated, using a discount rate of 2 percent. See Appendix D for the O&M and NPV cost calculations for Alternatives 1 through 4. The capital, O&M, and NPV costs are summarized below in Table 4.

TABLE 4
Summary of Costs for Alternatives 1 through 4

Alternative	Capital Cost (MM$, April 2013 data)	Annual O&M ($)	NPV (MM$)
1 – Media Filtration at Disc GC	33.1	71,200	28.0
2 – Biofiltration Channel at Disc GC	20.5	72,200	17.9
3 – Biofiltration Channel W. of TJ Meenach Br.	11.1	52,000	10.0
4 – Biofiltration Channel E. of TJ Meenach Br.	10.9	52,200	9.8

Multi-Objective Decision Analysis of Alternatives

To support the decision-making process and make objective comparisons between the alternatives, a Multi-Objective Decision Analysis (MODA) routine was used. Twelve decision criteria across four broad performance objectives were formulated by City staff and CH2M HILL (CH2M HILL, 2013b). The performance categories are:

- System Benefits and Risks
- Environmental Outcomes – Cleaner Water
- Integrated Benefits
- Operations & Maintenance Considerations

Each alternative was assessed on the twelve performance objectives, with scores of 1 to 5 (low to high) assigned to each objective for a particular alternative; City staff and CH2M HILL collaborated on the scoring process during two separate work sessions.

The MODA spreadsheet then combined the performance scoring with the NPV for each alternative, in a value-cost (X-Y) plot of performance vs. cost for the group of options. The resulting graph provides a direct visual comparison of the alternatives, with the alternatives located furthest left (lowest cost) and highest (greatest benefit) on the chart being the most attractive solutions for investment.

See Appendix E for the MODA score sheets and the value-cost tradeoff graph.

Conclusions and Recommendations

The MODA indicates that Alternative 2 achieves the greatest overall “value” score, with Alternatives 3 and 4 following very closely. Alternative 1 provides the lowest value score. Significant factors that contribute to the high value scores for Alternative 2 include:

- Potential economic benefit that may be gained through enhancement of the Disc Golf Course
- Reduced functional risk, due to the relative simplicity of constructing and maintaining a biofiltration channel
- No open-air impoundments of stormwater greater than 6 inches deep
- Zero impacts to Downriver Golf Course

Factors that contribute to the positive value scores for Alternatives 3 and 4 include:

- Less disruption to the neighborhood during construction

- Reduced functional risk, due to the relative simplicity of constructing and maintaining a biofiltration channel
- No open-air impoundments of stormwater greater than 6 inches deep
- Zero impacts to Downriver Golf Course
- Opportunities to enhance either a nearby existing river access area (Alternative 3) or the adjacent Centennial Trail parking lot (Alternative 4)

The drawback of Alternative 2 relative to Alternatives 3 and 4 is its significantly higher capital cost (85 percent greater than Alternative 3, and 88 percent higher than Alternative 4), as well as its much higher annual O&M cost compared to the others. It is unlikely that the primary differentiator for Alternative 2, the potential economic benefit that may be realized through reconstruction of the Disc Golf Course around the biofiltration facilities, would outweigh the substantial investment required to construct the facilities. Therefore, Alternative 2 should be eliminated from further study.

Alternatives 3 and 4 are very similar in their capital and O&M costs and many of their value scores. However, Alternative 4 is located adjacent to a group of springs that emanate from the hillside directly to the north of the proposed facility site. Additionally, there are known fish spawning beds in the Spokane River directly adjacent to the site. Although there is no information available that indicates Alternative 3 has either of these constraints, additional geotechnical exploration and environmental investigation needs to be performed in the Meenach West location to gain a more complete understanding of the feasibility of siting the treatment facilities there. Therefore, the final recommendation of this analysis is to tentatively move forward with Alternative 3 as the preferred alternative, with an additional recommendation to perform a thorough site investigation as early as possible.

References

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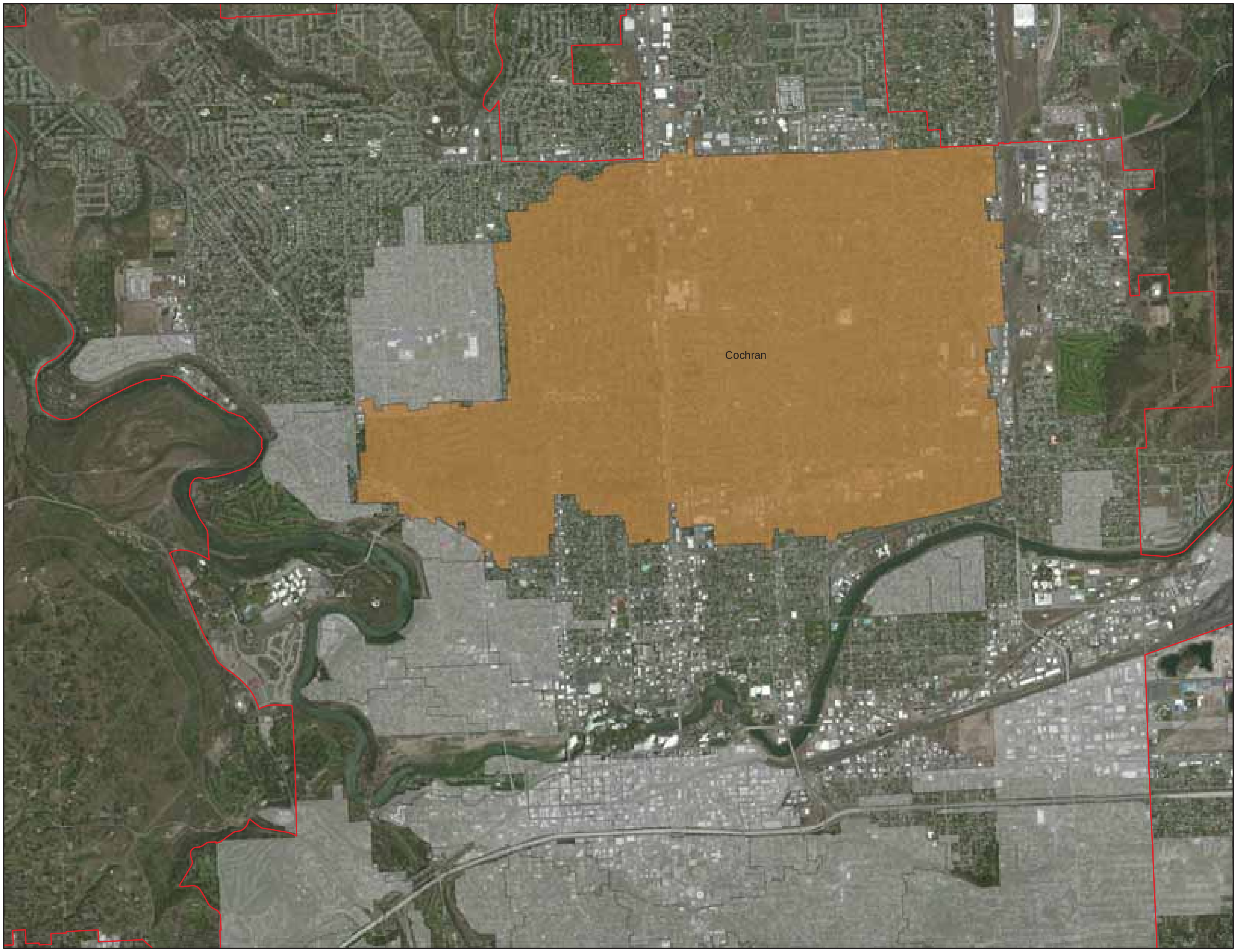
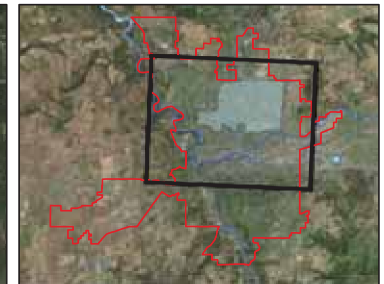
APPENDIX A

Figure 1 – Map of Cochran Basin





Legend

City of Spokane Boundary

Cochran

CSO Basins

0 2,350 4,700 Feet

Figure 1. Cochran Basin Overview
Integrated Plan
City of Spokane

CH2MHILL

APPENDIX B

Figures 2 through 5 – Conceptual Layouts of Alternatives 1 through 4

ALTERNATIVE 1

- CONVEY WQ STORM (Q=260 CFS) VIA NEW 72" PIPE FROM TJ MEENACH DR. TO DOWNRIVER GC
- PRETREATMENT IN SEDIMENTATION BASIN
- 225,000 GALLON DETENTION VAULT TO REDUCE PEAK OUTFLOW TO 3 CFS
- TREAT 3 CFS IN MEDIA FILTRATION VAULT IN DISC GOLF COURSE
- INFILTRATE TREATED STORMWATER IN DRAINFELD ADJACENT TO SPOKANE RIVER
- 5100 LF OF CONVEYANCE PIPE
- 22 MANHOLES

ALTERNATIVE 1
MEDIA FILTRATION IN DISC GOLF COURSE

CH2MHILL.

ALTERNATIVE 2

- PRETREAT WQ STORM (Q=260 CFS) IN PARK AT NW BLVD & TJ MEENACH
- 225,000 GALLON DETENTION VAULT TO REDUCE PEAK OUTFLOW TO 3 CFS
- NEW 16" PIPE TO DISC GOLF COURSE
- WQ TREATMENT IN BIOFILTRATION CHANNEL
- INFILTRATE TREATED STORMWATER IN DRAINFIELD ADJACENT TO SPOKANE RIVER
- 7200 LF OF CONVEYANCE PIPE
- 32 MANHOLES

ALTERNATIVE 2
BIOFILTRATION CHANNEL IN DISC GOLF COURSE

CH2MHILL.

ALTERNATIVE 3

- PRETREAT WQ STORM (Q=260 CFS) IN PARK AT NW BLVD & TJ MEENACH
- 225,000 GALLON DETENTION VAULT TO REDUCE PEAK OUTFLOW TO 3 CFS
- NEW 18" PIPE ALONG TJ MEENACH DRIVE
- WQ TREATMENT IN BIOFILTRATION CHANNEL
- INFILTRATE TREATED STORMWATER IN DRAINFIELD ADJACENT TO SPOKANE RIVER
- 1740 LF OF CONVEYANCE PIPE (INCLUDING 500 LF OF BORING)
- 13 MANHOLES

ALTERNATIVE 3 BIOFILTRATION CHANNEL WEST OF TJ MEENACH BRIDGE

CH2MHILL

ALTERNATIVE 4

- PRETREAT WQ STORM (Q=260 CFS) IN PARK AT NW BLVD & TJ MEENACH
- 225,000 GALLON DETENTION VAULT TO REDUCE PEAK OUTFLOW TO 3 CFS
- NEW 18" PIPE ALONG TJ MEENACH DRIVE
- WQ TREATMENT IN BIOFILTRATION CHANNEL
- INFILTRATE TREATED STORMWATER IN DRAINFIELD ADJACENT TO SPOKANE RIVER
- 1660 LF OF CONVEYANCE PIPE (INCLUDING 460 LF OF BORING)
- 14 MANHOLES

ALTERNATIVE 4
BIOFILTRATION CHANNEL EAST OF TJ MEENACH BRIDGE

CH2MHILL

APPENDIX D

Cost per Pound Pollutant Removed for Next Level of Treatment Alternatives in the Integrated Clean Water Plan

Cost per Unit Pollutant Removed for Next Level of Treatment Alternatives in the Integrated Plan

PREPARED FOR:	City of Spokane
COPY TO:	Jennifer Price/SEA File
PREPARED BY:	Santtu Winter/SEA
REVIEWED BY:	Dave Reynolds/SEA
DATE:	February 28, 2014
PROJECT NAME:	City of Spokane Integrated Plan
PROJECT NUMBER:	382918.T7.02.09

Purpose

The purpose of this technical memorandum is to document the analysis performed to estimate the life-cycle cost per unit of pollutant removed for two alternatives involving the next level of treatment (NLT) for the City of Spokane's (City's) Integrated Plan, and to compare the results with combined sewer overflow (CSO) reduction projects and stormwater projects included in the Integrated Plan. These two alternatives are summarized as follows:

- Upsize the NLT from a capacity of 50 million gallons per day (mgd) to a capacity of 85 mgd (upsize NLT)
- Operate the NLT membrane filters during the non-critical season (non-critical season membrane filtration)

Summary

The life-cycle cost per unit of pollutant removed was calculated by estimating the life-cycle pollutant removal amounts and life-cycle costs. A comparison of the life-cycle cost per unit of pollutant removed indicated that upsizing the NLT from 50 mgd (10 membrane trains) to 85 mgd (16 membrane trains) results in a higher life-cycle cost per unit of pollutant removed than the Cochran stormwater project. Both 50 and 85 mgd refer to nominal, firm capacities and actual capacity is higher than this. The 85-mgd membrane alternative has a peak capacity of 125 mgd and eliminates discharge of secondary effluent during the critical season. The 50 mgd membrane alternative discharges a small percentage of secondary treated effluent.

The non-critical season membrane filtration results in the lowest life-cycle cost per unit of pollutant removed for all pollutants except fecal coliform. All pollutants except fecal coliform are measured in pounds. Fecal coliform are measured by the number of colony-forming units (CFUs) per unit of volume, typically 100 milliliters. CSO reduction projects have a slightly lower cost per unit of pollutant removed. However, it should be noted that the life-cycle cost per unit of pollutant removed for phosphorus is not directly comparable between the non-critical season membrane filtration and the upsize NLT alternatives, because they remove phosphorus during different seasons.

This memorandum provides technical background and results to support the development of the Integrated Plan. No recommendations are contained in this memorandum; see the Integrated Plan for recommendations based on the analysis described in this memorandum.

Introduction

The City is in the process of completing an Integrated Plan that evaluates all of the City's required Clean Water Act (CWA) and National Pollutant Discharge Elimination System (NPDES) permit requirements, and prioritizes them based on water quality and human health benefits. The integrated planning process was created by the United States Environmental Protection Agency (USEPA) to "assist municipalities on their critical paths to achieving the human health and water quality objectives of the CWA by identifying efficiencies in implementing requirements that arise from distinct wastewater and stormwater programs, including how best to make capital investments" (USEPA, 2012). Integrated plans may include NPDES requirements for separate sanitary sewer systems, combined sewer systems, municipal separate storm sewer systems, and at wastewater treatment plants.

One of the City's NPDES permit requirements is to implement additional phosphorus removal, called NLT. The NPDES permit requires the NLT to be constructed and operational by March 1, 2018, capable of meeting the final effluent limits stated in the permit. The NPDES permit currently states that these limits are effective March 1, 2021, but doesn't state what limits will be in effect March 1, 2018. The NPDES permit is scheduled to be renewed in 2016 and it is likely that the limits for March 1, 2018 will be established in that permit. The final limits for carbonaceous biochemical oxygen demand (CBOD) and phosphorus require NLT to operate during the "critical season" from March 1 through October 31. The final limits for CBOD and phosphorus do not require NLT to operate during the "non-critical season" from November 1 through the end of February.

As described in the Riverside Park Water Reclamation Facility (RPWRF) NLT Engineering Report/Wastewater Facilities Plan Amendment No. 3 (Wastewater Facilities Plan Amendment No. 3) (CH2M HILL, 2013a), the NLT is expected to consist of membrane filtration with a 50-mgd capacity[1]. The 50-mgd description is a nominal capacity used to describe the alternative that includes 10 membrane trains and allowance for 10 percent recycle from the membranes. Fifty mgd refers to the approximate average firm and net capacity. Firm capacity is the capacity with one membrane train not processing flow for deconcentrating solids, and one membrane train out of service for maintenance. The actual capacity of the NLT is greater than 50 mgd, and depends on the operating flux and how many membrane trains are in service. The Wastewater Facilities Plan Amendment No. 3 describes these capacities in detail in Section 5.3.2.1.

Peak flows to the RPWRF frequently exceed 50 mgd; however, through flow equalization discharge of secondary effluent that does not get treated by the NLT only occurs on one to 15 percent of days (based on an analysis of data from 2002 through 2011). When flows exceed the capacity of the NLT, they will be diverted into two clarifiers that are used for equalization storage: primary clarifier #5 (0.9 million gallons [MG]), and secondary clarifier #5 (2 MG). If the flow to the RPWRF continues to exceed the capacity of the NLT and all of the equalization storage is filled, secondary effluent that is not treated by the NLT would be discharged. (See Figures 2 and 3 for examples of the use of equalization storage during a storm event for 50 mgd and 85 mgd capacity, respectively.)

[1] Membrane filtration provides the removal of phosphorus and polychlorinated biphenyls (PCBs) and only the costs for these facilities are used in this analysis.

Membranes with 50-mgd capacity were found to be cost-effective and they provide net environmental benefits compared to 100-mgd peak flow capacity conventional filters. Conventional filters also can meet the City NPDES permit effluent limits, but would discharge substantially more phosphorus than membranes. Conventional filters are cost-effective compared to the 85 mgd nominal capacity (125 mgd peak capacity) of membranes, and would eliminate discharge of secondary effluent during the critical season. However, constructing the NLT with membranes at a higher capacity would result in larger pollutant removal amounts by reducing the amount of secondary effluent discharged. Because of this, a 16 membrane train NLT alternative was developed to be evaluated and compared with other water quality projects, including CSO reduction projects and stormwater projects, being planned by the City of Spokane as part of the Integrated Plan. The City is also pursuing a strategy of identifying and eliminating sources of infiltration and inflow to reduce the amount of flow sent to the RPWRF during wet weather events, thus reducing the amount of secondary effluent discharged during the critical season.

The upsize NLT alternative consists of increasing the capacity of the NLT to 85 mgd (16 membrane trains). As described above for the 50-mgd alternative, 85 mgd is the nominal, firm capacity used to describe the alternative. The actual NLT capacity of the 85-mgd alternative is greater than 85 mgd, and varies depending on the operating flux and how many membrane trains are in service. This alternative has a peak capacity of 125 mgd and eliminates discharge of secondary effluent in the critical season.

The non-critical season membrane filtration alternative was developed for the Integrated Plan because it may result in a significant amount of pollutant removal at a low cost per unit pollutant removed. This opportunity will be evaluated and compared with other water quality projects being planned by the City as part of their Integrated Plan.

Upsize NLT from 50 mgd to 85 mgd

The first step in calculating the life-cycle cost per unit of pollutant removed for the upsize NLT alternative was to estimate the additional pounds of pollutants that would be removed during the critical season by upsizing the NLT, as presented in Table 1. Additional pollutant is removed by treating an average of about 1 percent more of the total wastewater by eliminating secondary effluent not receiving NLT. This was estimated for the pollutants of concern that were selected for the analysis in the Integrated Plan (CH2M HILL, 2013b). The pollutant removal amounts were estimated by modifying existing analysis completed for the Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013a). The additional pollutant removal amounts are based on the average removal amounts for a time period of 10 years (2002-2011).

In order to develop an accurate life-cycle cost per unit of pollutant removed, the life-cycle pollutant removal amounts were calculated based on the average annual pollutant removal amounts. These were calculated based on a 25-year life-cycle, using a 2 percent discount rate, which matches the parameters used to develop the life-cycle cost estimates in the Integrated Plan. Details on the annual and life-cycle pollutant removal amounts for the upsize NLT alternative are included in Appendix A.

TABLE 1
Pollutant Removal Amounts for Upsizing NLT from 50 mgd to 85 mgd [a]

Pollutant	Annual Pollutant Removal with 50 mgd of NLT	Annual Pollutant Removal with 85 mgd of NLT	Annual Pollutant Removal Due to Upsizing the NLT	Life-Cycle Pollutant Removal Due to Upsizing the NLT [b]
Total Phosphorus	35,622	35,967	345 lbs/yr (1.0% increase)	4,897 lbs
Fecal Coliform	4,693	4,738	45 Billion CFU/yr (1.0% increase)	643 CFU
Total Suspended Solids	716,883	723,739	6,855 lbs/yr (1.0% increase	97,348 lbs
Total Zinc	237	238	1.4 lbs/yr (0.6% increase)	20 lbs
Dissolved Zinc	0	0	0 lbs/yr	0 lbs
PCBs	14.4	14.5	0.1 grams/yr (0.9% increase)	1.9 grams

[a] Additional pollutant removal was achieved only during the critical season. In this alternative, NLT would not be operated during the non-critical season.

[b] 25-year life-cycle pollutant removal amount using a 2% discount rate, which matches the parameters used for the life-cycle cost analysis.

Life-cycle cost estimates were completed as part of the Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013a) for both the 50-mgd and 85-mgd NLT capacities. These life-cycle costs were modified to be based on a 25-year life-cycle cost using a 2 percent discount rate to match the parameters used for other water quality projects included in the Integrated Plan, and were used to calculate the life-cycle cost per unit of pollutant removed as a result of upsizing the NLT, as presented in Table 2. These values were calculated by taking the life-cycle cost of the alternative and dividing it by the life-cycle pounds of pollutant removed during the 25-year life-cycle analysis period. The life-cycle cost estimates for the NLT at 50 mgd and 85 mgd, and the life-cycle cost of upsizing, are summarized as follows:

- 50-mgd of NLT: $127 million (M)
- 85-mgd of NLT: $163M
- Upsize NLT from 50 mgd to 85 mgd: $36M

TABLE 2
Life-Cycle Cost per unit of Pollutant Removed for Upsizing NLT from 50 mgd to 85 mgd [a]

Pollutant	Upsize NLT from 50 mgd to 85 mgd	Percent Increase from NLT with 50-mgd Capacity
Total Phosphorus ($/lb)	$7,294	3,100%
Fecal Coliform ($/Billion CFU)	$55,517	3,100%
Total Suspended Solids ($/lb)	$367	3,100%
Total Zinc ($/lb)	$1,744,311	4,900%
Dissolved Zinc ($/lb)	NA [b]	NA [b]
PCBs ($/gram)	$19,116,872	3,300%

[a] Additional pollutant removal was achieved only during the critical season. In this alternative, NLT would not be operated during the non-critical season.

[b] No dissolved zinc removal expected.

Non-critical Season Membrane Filtration

This section describes the process of estimating the life-cycle cost per unit of pollutant removed for the non-critical season membrane filtration alternative.

These calculations are based on operating the membrane filters with alum added and with chemically enhanced primary treatment (CEPT) included upstream of the membrane filters during the non-critical season. Because there is no NPDES permit requirement to operate NLT during the non-critical season, neither the addition of alum nor CEPT are required during the non-critical season. Because the addition of both of these options add operating cost, and may have an impact on the life-cycle of the filtration membranes, the City may choose to operate the membrane filters during the non-critical season without one or both of these treatment components. Doing so would result in lower pollutant removal amounts for some pollutants. Additional evaluation would be required in order to estimate the pollutant removal amounts and life-cycle costs of operating the membrane filters during the non-critical season without the addition of alum and/or CEPT.

Pollutant Removal Amounts

The first step in calculating the pollutant removal amounts for the non-critical season membrane filtration alternative was to estimate the volume of secondary effluent treated by the membrane filters during the non-critical season. This was accomplished by taking the typical non-critical season influent flow to the RPWRF of 34.3 mgd (estimated for 2018 conditions), and multiplying by the number of days in the non-critical season (120 days). This volume (4,116 MG/yr) was then adjusted to account for secondary effluent that is not treated by the membrane filters. Based on an analysis of the operation of the NLT with critical season flows, it is estimated that approximately 0.7 percent of secondary effluent will not be treated by NLT in a typical year (with the percentage ranging from 0.1% to 2%). This same percentage was applied to the volume of flow sent to the RPWRF during the non-critical season, resulting in a total volume of 4,087 MG/yr of secondary effluent treated by the NLT during the non-critical season.

The next step was to estimate the additional pollutant removal amounts resulting from treating the volume calculated above with the membrane filters. Under current conditions, flow during the non-critical season undergoes secondary treatment; thus, the additional pollutant removal is the difference between the secondary effluent concentrations and the membrane filtration effluent concentrations. Table 3 summarizes these effluent concentrations and quantifies the difference between the two. Table 4 presents the additional pollutant load reductions resulting from operating the membrane filters during the non-critical season. Details on these calculations are contained in Appendix B.

TABLE 3

Estimated Secondary and Membrane Filtration Effluent Concentrations During the Non-Critical Season

Pollutant	Concentration in Secondary Effluent [a]	Concentration in Membrane Filtration Effluent [b]	Difference in Concentration
Total Phosphorus	2.5 mg/L	0.018 mg/L	2.48 mg/L
Fecal Coliform	15 CFU/100 mL	1 CFU/100 mL	14 CFU/100 mL
Total Suspended Solids	10 mg/L	0.3 mg/L	9.7 mg/L
Total Zinc	49.5 ug/L	37.0 ug/L	12.5. ug/L
Dissolved Zinc	37.0 ug/L	37.0 ug/L	0.0 ug/L
PCBs	0.6 ng/L	0.17 ng/L	0.43 ng/L

[a] Concentrations for secondary effluent total phosphorus, total suspended solids, total zinc, and PCBs are based on 90th percentile concentrations as presented in Table 5-7 of the RPWRF Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013a).

Concentration for secondary effluent fecal coliform based on discussions with CH2M HILL staff with experience in the operation and performance of the RPWRF (Reynolds, 2013) and RPWRF Discharge Monitoring Reports for November and December 2012.

Concentration for secondary effluent dissolved zinc assumed to be equal to the NLT effluent dissolved zinc concentration.

[b] Concentrations for membrane filtration effluent for total phosphorus, total suspended solids, total zinc, and PCBs are based on 90th percentile concentrations as presented in Table 5-7 of the RPWRF Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013a).

Concentration for membrane filtration effluent fecal coliform based on discussions with CH2M HILL staff with experience in the operation and performance of the RPWRF (Reynolds, 2013), and Spokane County Regional Water Reclamation Facility (SCRWRF) Discharge Monitoring Reports for 2012 and 2013.

Concentration for membrane filtration effluent dissolved zinc based on the assumption that the membrane filters remove all zinc except the dissolved component.

TABLE 4

Additional Pollutant Load Removed Due to Operating Membrane Filters during the Non-Critical Season

Pollutant	Additional Annual Pollutant Load Removed	Additional Life-Cycle Pollutant Load Removed [a]
Total Phosphorus	84,659 lbs/yr	1,202,198 lbs
Fecal Coliform	2,166 Billion CFU/yr	30,759 Billion CFU
Total Suspended Solids	330,859 lbs/yr	4,698,358 lbs
Total Zinc	426 lbs/yr	6,055 lbs
Dissolved Zinc	0 lbs/yr	0 lbs
PCBs	6.7 grams/yr	94.5 grams

[a] 25-year life-cycle pollutant removal amount using a 2% discount rate, which matches the parameters used for the life-cycle cost analysis.

Life-cycle Cost Estimate

A life-cycle cost estimate was also prepared for operating the membrane filters during the non-critical season. This estimate was based on the work done for the Wastewater Facility Plan No. 3 (CH2M HILL, 2013a), which calculated the capital, operations and maintenance (O&M), and replacement costs for membrane filtration at a 50-mgd capacity. The operation of membrane filters during the non-critical season does not require additional facilities. The capital costs are assumed to be sunk costs and are not included in this economic analysis because those costs would be incurred regardless of whether or not the membrane filters are operated during the non-critical season. In addition, replacement costs were assumed to remain unchanged because the difference in membrane life when operated 8 months per year versus all year is not known. As such, the life-cycle cost for this alternative includes only annual O&M costs.

The O&M cost is made up of five components: labor, electricity, chemicals, preventive maintenance and repair materials, and solids handling. Table 5 presents the estimated annual O&M cost for operating the membrane filters during the non-critical season.

TABLE 5
Additional Annual[a] O&M Cost Due to Operating the NLT during the Non-Critical Season

O&M Component	Additional Annual O&M Cost	Description
Labor	$0	The City of Spokane does not expect to hire additional staff in order to operate the membrane filters during the non-critical season.
Electricity	$69,000	Additional electrical demand resulting from operating the membrane filters during the non-critical season.
Chemicals	$679,000	Chemical addition of alum, sodium hydroxide, and polymer for the membrane filters and CEPT.
Preventive Maintenance and Repair Materials	$102,000	Some additional preventive maintenance and repairs may be needed.
Solids Handling	$101,000	Additional solids produced by operating the membrane filters during the non-critical season.
Total	$951,000	
Additional Annual Life-Cycle Cost	$15,460,000	Using 2% discount rate over a 25-year life-cycle.

[a] Annual O&M cost for 2018. O&M cost estimated to increase by 0.3% to 2.9% per year.

Life-cycle Cost per unit Pollutant Removed

Table 6 presents the estimated life-cycle cost per unit of pollutant removed for the operation of the membrane filters during the non-critical season.

TABLE 6
Life-Cycle Cost per unit of Pollutant Removed for the Non-Critical Season Membrane Filtration Alternative

Pollutant	NLT During the Non-Critical Season
Total Phosphorus ($/lb)	$13
Fecal Coliform ($/Billion CFU)	$503
Total Suspended Solids ($/lb)	$3
Total Zinc ($/lb)	$2,553
Dissolved Zinc ($/lb)	NA[a]
PCBs ($/gram)	$163,645

[a] No dissolved zinc removal expected.

Conclusions

Figure 1 and Table 7 present the life-cycle cost per unit of pollutant removed for operating the membrane filters during the non-critical season, upsizing the NLT from 50 mgd to 85 mgd, typical CSO projects, and the Cochran stormwater project. As shown in Figure 1, operating the membrane filters during the non-critical season results in the lowest life-cycle cost per unit of pollutant removed for all pollutants except fecal coliform, for which the CSO reduction projects have a slightly lower cost per unit. The cause for the low life-cycle cost per unit of pollutant removed for operating the membrane filters during the non-critical season is that a large volume of combined sewage is treated. Specifically, operating the membrane during the non-critical season would treat on average 4,087 MG/yr, whereas CSO reduction projects are expected to reduce CSO discharges by approximately 40 MG/yr. The Cochran stormwater project is expected to reduce stormwater discharges by approximately 250 MG/yr.

Figure 1 also indicates that upsizing the NLT from 50 mgd to 85 mgd results in a higher life-cycle cost per unit of pollutant removed than both the Cochran stormwater project and operating the NLT during the non-critical season, for most pollutants. Although constructing the NLT at an 85-mgd capacity would remove additional pollutants compared to constructing the NLT at a 50-mgd capacity, the 70 percent increase in capacity only results in a 1 percent increase in pollutants removed. Figures 2 and 3 present hydrographs of the NLT during a storm event, illustrating how the NLT would operate with equalization storage in both the 50-mgd and 85-mgd alternatives. Note that in Figures 2 and 3, although the 85-mgd alternative provides NLT treatment to 100 percent of the flow that is conveyed to the RPWRF, the 50-mgd alternative treats 96 percent of the flow by the NLT.

TABLE 7
Comparison of the Life-Cycle Cost per unit of Pollutant Removed

Pollutant	NLT During the Non-Critical Season	Upsize NLT from 50-mgd to 85-mgd	CSO Reduction Projects[a]	Cochran Stormwater Project
Critical Season Total Phosphorus ($/lb)	NA[c]	$7,294	$64,291	$1,585
Non-Critical Season Total Phosphorus ($/lb)	$13	NA[d]	$150,707	$1,148
Fecal Coliform ($/Billion CFU)	$503	$55,517	$31	$536
Total Suspended Solids ($/lb)	$3	$367	$493	$2
Total Zinc ($/lb)	$2,553	$1,744,311	$809,697	$2,248
Dissolved Zinc ($/lb)	NA[b]	NA[b]	NA[b]	$18,554
PCBs ($/gram)	$163,345	$19,116,872	$6,544,653	$201,122

[a] Life-cycle cost per unit pollutant removed for CSO projects recommended in the 2013 CSO Plan Amendment.
[b] No dissolved zinc removal expected.
[c] No critical season total phosphorus removed.
[c] No non-critical season total phosphorus removed.

Recommendations

This memorandum only provides technical background and results to support the development of the Integrated Plan. No recommendations are contained in this memorandum. See the Integrated Plan for recommendations based on the analysis described in this memorandum.

References

CH2M HILL. 2013a. Ecology Draft Riverside Park Water Reclamation Facility NLT Engineering Report/Wastewater Facilities Plan Amendment No. 3. Prepared for the City of Spokane. December.

CH2M HILL. 2013b. Recommended Pollutants for Consideration in Integrated Plan Preparation. Prepared for the City of Spokane. March 30.

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United States Environmental Protection Agency (USEPA). 2012. Integrated Municipal Stormwater and Wastewater Planning Approach Framework. May.

Figures

Appendices

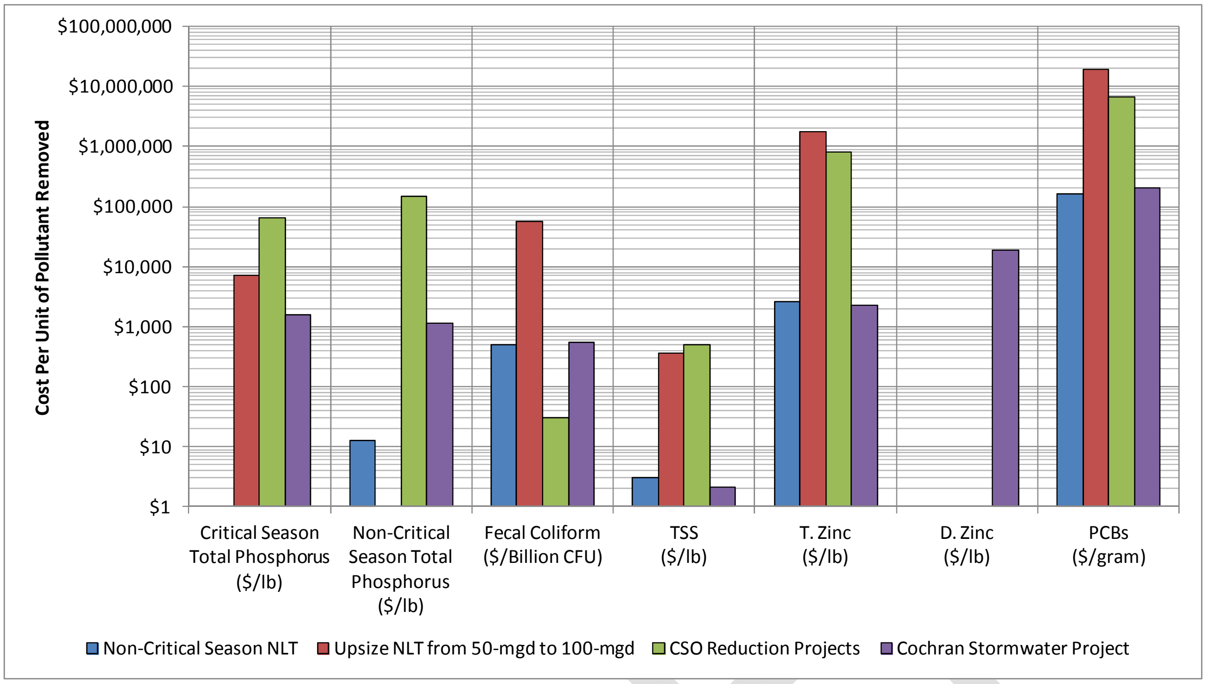

Figure 1
Comparison of the Life-Cycle Cost per unit Pollutant Removed for Various Water Quality Projects

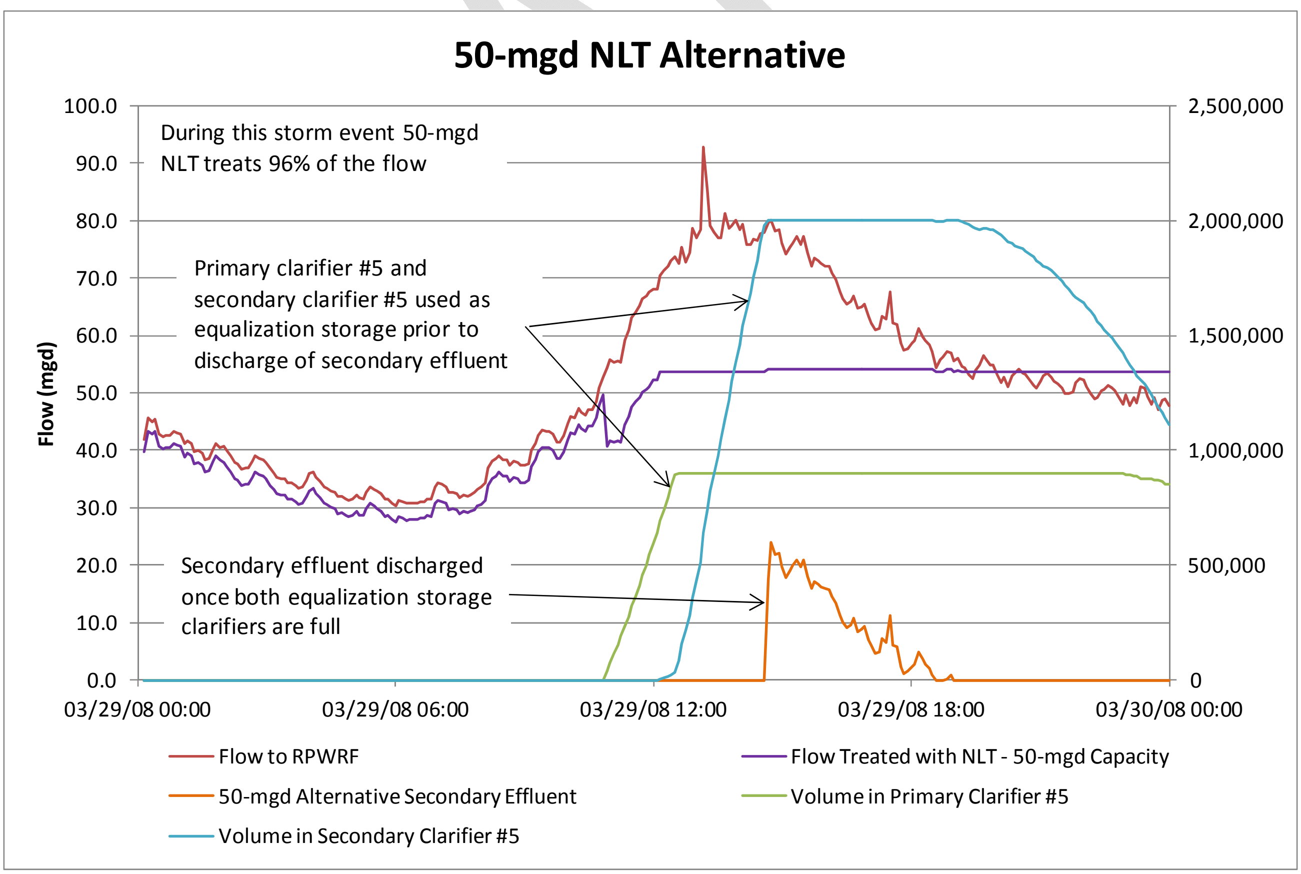

Figure 2
Estimated Performance of the NLT with a 50-mgd Capacity during a Storm Event

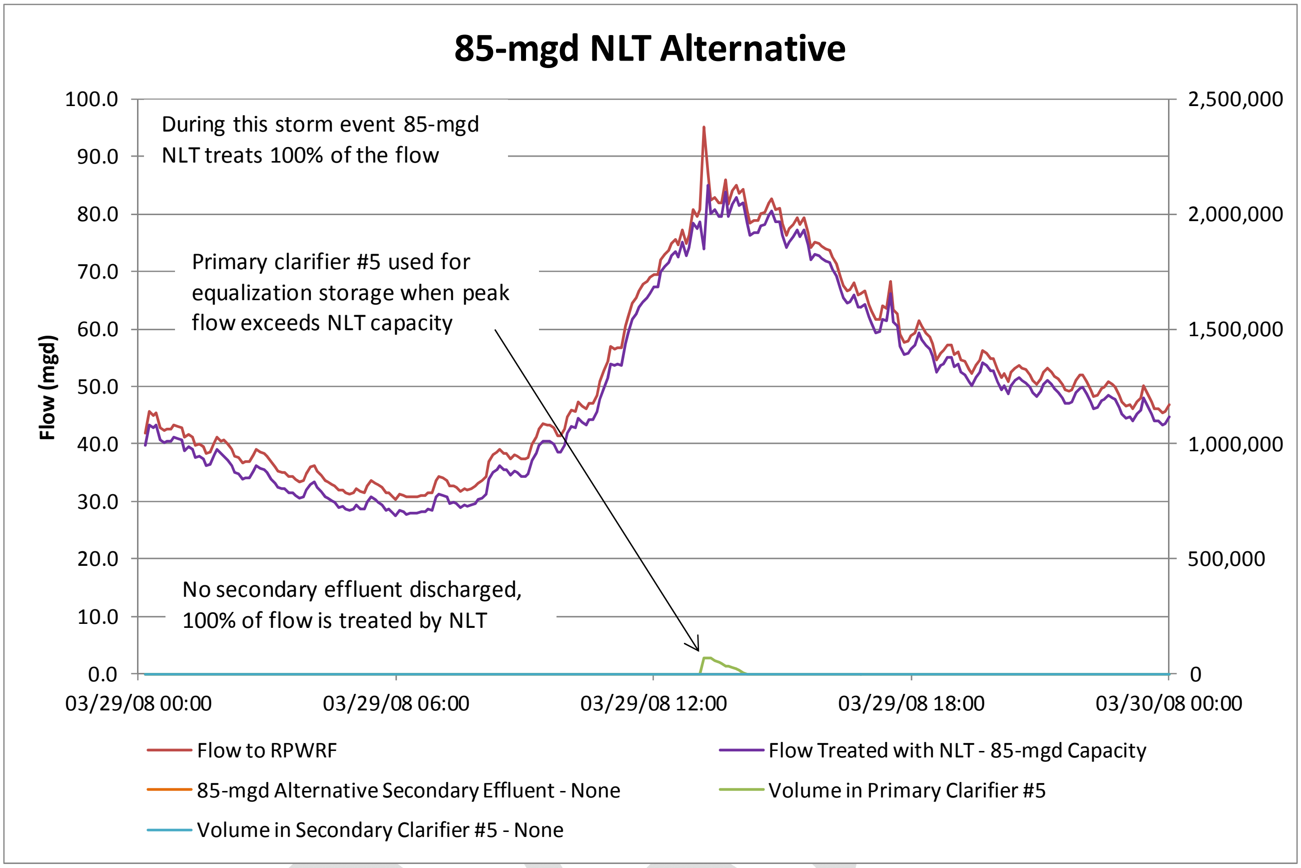

Figure 3
Estimated Performance of the NLT with a 85-mgd Capacity during a Storm Event

Appendix A
Upsize NLT Pollutant Removal Calculations

City of Spokane
Integrated Plan
Calculation of Additional Pollutants Removed through Upsizing NLT from 50 mgd to 85 mgd

Conversions

mg/L to lbs/MG	8.3454
100 mL to MG	37,854,000

Pollutant Concentrations

Source: RPWRF Wastewater Facilities Plan Amendment No. 3, Table 5-7. Fecal Coliform is based on SCRWRF and RPWRF DMRs. No Dissolved Zinc assumed for NLT effluent.

Pollutant	Critical Season Effluent Concentrations				Non-Critical Season Effluent Concentrations
	NLT Effluent	Secondary Effluent	Difference	Treated CSO Effluent	Treated CSO Effluent (1)
Total Phosphorus (mg/L)	0.018	0.5	0.482	1.4	3.4
Fecal Coliform (CFU/100mL)	1	15	14	51	87
TSS (mg/L)	0.3	10	9.7	41	65
Total Zinc (ug/L)	37	40.2	3.2	78	100
Dissolved Zinc (ug/L)	37.0	37.0	0.0	37	37
PCBs (ng/L)	0.17	0.6	0.43	2.8	4.4

(1) Without CEPT

Average Ratio of Treated CSO to Secondary Effluent (used for Treated CSO fecal concentration)	3.38	5.78
Min Ratio	1.94	2.49
Max Ratio	4.67	7.33

Average Annual Secondary Effluent and Treated CSO Volumes (based on analysis of 2002-2011)

Sources:

50-mgd volumes from https://deliver.ch2m.com/projects/382918/T3-Consulting/_layouts/xlviewer.aspx?id=/projects/382918/T3-Consulting/T306Design%20Flow/AKART/RPWRF_Analysis_Spreadsheet/Spreadsheets/RPWRF_NLT_Analysis_Summary.xlsx&Source=https%3A%2F%2Fdeliver%2Ech2m%2Ecom%2Fprojects%2F382918%2FT3%2DConsulting%2FT306Design%2520Flow%2FForms%2FAllItems%2Easpx%3FRootFolder%3D%252Fprojects%252F382918%252FT3%252DConsulting%252FT306Design%2520Flow%252FAKART%252FRPWRF%255FAnalysis%255FSpreadsheet%252FSpreadsheets&DefaultItemOpen=1&DefaultItemOpen=1

85-mgd volumes from https://deliver.ch2m.com/projects/382918/T7/_layouts/xlviewer.aspx?id=/projects/382918/T7/T702IntegPlan/T7.02.09_Integrated_Plan/NLT_Alternatives/50-mgd_versus_85-mgd/100-mgd_RPWRF_Analysis/Summary_100mgd_Membranes.xlsx&Source=https%3A%2F%2Fdeliver%2Ech2m%2Ecom%2Fprojects%2F382918%2FT7%2FT702IntegPlan%2FForms%2FAllItems%2Easpx%3FRootFolder%3D%252Fprojects%252F382918%252FT7%252FT702IntegPlan%252FT7%252E02%252E09%255FIntegrated%255FPlan%252FNLT%255FAlternatives%252F50%252Dmgd%255Fversus%255F85%252Dmgd%252F100%252Dmgd%255FRPWRF%255FAnalysis%26FolderCTID%3D0x012000A028989319B1F1479AF645110BD1A981%26View%3D%7BA77A67F4%2DC8AB%2D4F3B%2DB9EC%2D4271978B1B20%7D%26InitialTabId%3DRibbon%252EDocument%26VisibilityContext%3DWSSTabPersistence&DefaultItemOpen=1&DefaultItemOpen=1

Component	Critical Season Secondary Effluent (MG)	Critical Season Treated CSO (MG)	Non-Critical Season Treated CSO (MG)
NLT at 50 mgd	91.88	0.53	0.17
NLT at 85 mgd	-	1.46	0.66
Difference in Volume Treated at 85 mgd	91.88	(0.93)	(0.49)
% Change from NLT at 50 mgd	1.04%		

Average Additional Annual Pollutant Removal Amounts

Pollutant	Critical Season Secondary Effluent	Critical Season Treated CSO	Non-Critical Season Treated CSO	Total	% Increase Compared to 50-mgd NLT		
Total Phosphorus (lbs/yr)	370	(11)	(14)	345	1.0%	35,967	
Fecal Coliform (billions of CFU/yr)	49	(2)	(2)	45	1.0%	4,739	
TSS (lbs/yr)	7,438	(317)	(265)	6,855	1.0%	723,739	
Total Zinc (lbs/yr)	2.5	(0.6)	(0.4)	1.4	0.6%	238	
Dissolved Zinc (lbs/yr)	-	-	-	-	#DIV/0!	-	No dissolved zinc treatn
PCBs (grams/yr)	0.15	(0.01)	(0.01)	0.13	0.9%	14.5	

Life-Cycle Pollutant Removal

Discount Rate 2%

			Present Worth of Pollutant Removal					
Year	**Year No.**	**Present Worth Factor**	**Total Phosphorus (lbs)**	**Fecal Coliform (Billions of CFU)**	**TSS (lbs)**	**Total Zinc (lbs)**	**Dissolved Zinc (lbs)**	**PCBs (grams)**
		Total ->	4,897	643	97,348	20	-	1.87
2013	0	1.00	-	-	-	-	-	-
2014	1	0.98	-	-	-	-	-	-
2015	2	0.96	-	-	-	-	-	-
2016	3	0.94	-	-	-	-	-	-
2017	4	0.92	-	-	-	-	-	-
2018	5	0.91	-	-	-	-	-	-
2019	6	0.89	306	40.2	6,087	1.3	-	0.12
2020	7	0.87	300	39.4	5,968	1.3	-	0.11
2021	8	0.85	294	38.7	5,851	1.2	-	0.11
2022	9	0.84	289	37.9	5,736	1.2	-	0.11
2023	10	0.82	283	37.2	5,624	1.2	-	0.11
2024	11	0.80	277	36.4	5,513	1.2	-	0.11
2025	12	0.79	272	35.7	5,405	1.1	-	0.10
2026	13	0.77	267	35.0	5,299	1.1	-	0.10
2027	14	0.76	261	34.3	5,195	1.1	-	0.10
2028	15	0.74	256	33.7	5,094	1.1	-	0.10
2029	16	0.73	251	33.0	4,994	1.1	-	0.10
2030	17	0.71	246	32.4	4,896	1.0	-	0.09
2031	18	0.70	241	31.7	4,800	1.0	-	0.09
2032	19	0.69	237	31.1	4,706	1.0	-	0.09
2033	20	0.67	232	30.5	4,613	1.0	-	0.09
2034	21	0.66	228	29.9	4,523	1.0	-	0.09
2035	22	0.65	223	29.3	4,434	0.9	-	0.09
2036	23	0.63	219	28.7	4,347	0.9	-	0.08
2037	24	0.62	214	28.2	4,262	0.9	-	0.08

Appendix B
Non-Critical Season Membrane Filtration Pollutant Removal Calculations

City of Spokane
Integrated Plan
Calculation of Additional Pollutants Removed through Non-Critical Season Membrane Filtration

Volumes

Non-Critical Season Influent Flow	34.3	mgd, average 2018 non-critical season flow, from "Design Flows and Waste Loads" TM. Includes 6.5 mgd removed by SCRWRF
Non-Critical Season Start	11/1/2018	
Non-Critical Season End	3/1/2019	
Days in Non-Critical Season	120	
Non-Critical Volume	4,116	MG/yr
Non-Critical Season NLT Bypass	0.7%	Based on critical season NLT bypass from 2002-2011
Non-Critical Season Volume Treated	4,087	MG/yr

Conversions

mg/L to lbs/MG	8.3454
100 mL to MG	37,854,000

Effluent Concentrations

Pollutant	Non-Critical Season NLT[1]	Non-Critical Season Secondary Effluent[2]	Difference
Total Phosphorus(mg/L)	0.018	2.50	2.48
Fecal Coliform (CFU/100 mL)	1	15	14
TSS (mg/L)	0.3	10	9.7
Total Zinc (ug/L)	37	49.5	12.5
Dissolved Zinc (ug/L)	37.0	37.0	0.0
PCBs (ng/L)	0.17	0.6	0.43

[a] Concentrations for secondary effluent Total Phosphorus, Total Suspended Solids, Total Zinc, and PCBs are based on 90th percentile concentrations as presented in Table 5-7 of the RPWRF Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013a).

Concentration for secondary effluent Fecal Coliform based on discussions with CH2M HILL staff with experience of the operation and performance of the RPWRF (Reynolds, 2013) and RPWRF Discharge Monitoring Reports for November and December 2012.

Concentration for secondary effluent Dissolved Zinc based on a ratio of dissolved zinc to total zinc of 0.9, which was estimated based on effluent sampling data from the Spokane AWRP (Washington State Department of Ecology, 1998).

[b] Concentrations for NLT effluent for Total Phosphorus, Total Suspended Solids, Total Zinc, and PCBs are based on 90th percentile concentrations as presented in Table 5-7 of the RPWRF Wastewater Facilities Plan Amendment No. 3 (CH2M HILL, 2013a).

Concentration for NLT effluent Fecal Coliform based on discussions with CH2M HILL staff with experience of the operation and performance of the RPWRF (Reynolds, 2013), and Spokane County Regional Water Reclamation Facility (SCRWRF) Discharge Monitoring Reports for 2012 and 2013.

Concentration for NLT effluent Dissolved Zinc based on secondary effluent Dissolved Zinc concentration. No additional Dissolved Zinc removal is anticipated with the operation of NLT during the non-critical season.

Additional Annual Pollutant Removal

Pollutant	Additional Pollutants Removed
Total Phosphorus(lbs/yr)	84,659
Fecal Coliform (Billions of CFU/yr)	2,166
TSS (lbs/yr)	330,859
Total Zinc (lbs/yr)	426
Dissolved Zinc (lbs/yr)	-
PCBs (lbs/yr)	0.014667
PCBs (grams/yr)	6.653

Life-Cycle Pollutant Removal

Discount Rate	2%		Present Worth of Pollutant Removal					
Year	Year No.	Present Worth Factor	Total Phosphorus (lbs)	Fecal Coliform (Billions of CFU)	TSS (lbs)	Total Zinc (lbs)	Dissolved Zinc (lbs)	PCBs (grams)
		Total ->	1,202,198	30,759	4,698,358	6,055	-	94.5
2013	0							
2014	1							
2015	2							
2016	3							
2017	4							
2018	5							
2019	6	0.89	75,175	1,923	293,794	379	-	5.9
2020	7	0.87	73,701	1,886	288,033	371	-	5.8
2021	8	0.85	72,256	1,849	282,385	364	-	5.7
2022	9	0.84	70,839	1,812	276,848	357	-	5.6
2023	10	0.82	69,450	1,777	271,420	350	-	5.5
2024	11	0.80	68,088	1,742	266,098	343	-	5.4
2025	12	0.79	66,753	1,708	260,880	336	-	5.2
2026	13	0.77	65,444	1,674	255,765	330	-	5.1
2027	14	0.76	64,161	1,642	250,750	323	-	5.0
2028	15	0.74	62,903	1,609	245,833	317	-	4.9
2029	16	0.73	61,670	1,578	241,013	311	-	4.8
2030	17	0.71	60,460	1,547	236,287	304	-	4.8
2031	18	0.70	59,275	1,517	231,654	299	-	4.7
2032	19	0.69	58,113	1,487	227,112	293	-	4.6
2033	20	0.67	56,973	1,458	222,659	287	-	4.5
2034	21	0.66	55,856	1,429	218,293	281	-	4.4
2035	22	0.65	54,761	1,401	214,013	276	-	4.3
2036	23	0.63	53,687	1,374	209,816	270	-	4.2
2037	24	0.62	52,634	1,347	205,702	265	-	4.1

APPENDIX E

Decision Making Framework for City of Spokane Combined Sewer Overflow Planning and Integrated Planning

Decision-Making Framework for City of Spokane Combined Sewer Overflow Planning and Integrated Planning

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REVIEWED BY	Jennifer Price/SEA Roger Flint/SPK
DATE:	January 14, 2014
PROJECT NAME:	Riverside Park Water Reclamation Facility City of Spokane Integrated Planning
PROJECT NUMBER:	382918.T7.02.08

Purpose

The purpose of this memorandum is to document the methods and results of an evaluation of system-wide alternatives as part of the City's Integrated Planning process. The framework uses the principles of multi-objective decision analysis (MODA) to provide insight about environmental and social factors and life-cycle costs relevant for decision making. This memorandum documents the framework and the process used in its development.

Summary

This memorandum presents the results of a MODA process used in the City's Integrated Planning for the City's clean water investments – combined sewer overflow (CSO) plan, stormwater, and Next Level of Treatment (NLT) at the Riverside Park Water Reclamation Facility (RPWRF). Background information on the MODA process is also presented. Decision criteria and relative value weights used in this evaluation were agreed to in two workshops attended by CH2M HILL and City staff, and then used to evaluate both basin solutions and system-wide alternatives. Two sensitivity analyses were also conducted to evaluate the effects of focusing on economic development and infrastructure systems, as well as a focus on reducing polychlorinated biphenyl (PCB) concentrations. Non-monetary value-to-cost evaluations were also conducted for each of the main pollutants of concern.

The system-wide alternatives evaluated for the Integrated Plan are as follows.

- 1a: combined sewer overflow (CSO) Plan – tank sizes revised from 2005, all gray storage, no green infrastructure.
- 1b: CSO Plan + Green – use green infrastructure instead of storage in CSO Basins 14 and 15. In CSO Basins 6 and 12, allows for the long-term implementation of green infrastructure projects as the City implements its integrated strategy and build smaller storage tanks that together control to regulatory requirements, same size tanks in all other CSO basins.
- 2a: CSO Plan + Cochran – 1a plus an end-of-pipe stormwater treatment project in the Cochran stormwater basin. The technology used is biofiltration.

- 2b: CSO Plan + using Next Level of Treatment (NLT) during the non-critical (winter) season – 1a plus use of NLT all year instead of just during the critical (summer) season.
- 3: CSO Plan + Green + Cochran + winter NLT –1a plus green in CSO Basins 14 and 15 (no green in CSO Basins 6 and 12) plus the long-term implementation of green infrastructure plus the Cochran project in 2a, plus the NLT usage in 2b.

Based on the MODA evaluation, Alternative 3 is the preferred alternative for the Integrated Plan. Recommended projects are discussed in more detail in the Integrated Plan.

Introduction

During development of the Integrated Plan, evaluations were conducted at different project stages. It was important to have a clear understanding of terminology and the types of evaluations that were conducted. The evaluations that were performed during development of the Integrated Plan are described in Figure 1. This figure includes an example of each evaluation type, and documents the methods that were used for each evaluation conducted.

Figure 1 refers to non-monetary evaluations that were conducted for basin solutions and Integrated Plan alternatives. MODA was used to conduct these evaluations.

The MODA Process

MODA is a quantitative technique for making decisions that involve multiple financial, environmental, and social objectives. MODA proceeds through a series of defined steps, which are illustrated in Figure 2 and described in this section. The steps include:

- Establish the decision goal
- Identify and specify decision criteria
- Develop performance measures (measurement scales) to measure how well alternatives meet each decision criterion
- Assign scores for each decision criterion under each alternative
- Assign weights to the decision criteria
- Calculate total value scores and conduct sensitivity analysis

Decision Goal

The decision goal is the overall purpose of the evaluation. For the Integrated Plan, the decision goal was as follows: “Decide upon the best mix of combined sewer overflow (CSO) and other water quality projects that will remove as many pollutants as rapidly as possible with the highest environmental and public benefit at the lowest long-term life-cycle cost.”

Decision Criteria

Decision criteria are the important non-monetary aspects of a decision that answer a simple question: “What are the important issues relevant to making a decision?” The terms values, objectives, and criteria are often used almost interchangeably in decision analysis; in the Integrated Plan, we use the term “Decision Criteria.” The decision criteria for the Integrated Plan have been developed in a “hierarchy” in which a series of sub-criteria are used to characterize a particular criterion more completely.

During a workshop held on March 20, 2013, CH2M HILL presented a draft set of decision criteria that included a hierarchical structure with five main criteria and a total of 13 sub-criteria. The group engaged in a discussion about the criteria/sub-criteria and made a series of modifications. Subsequent to the workshop, additional work was conducted to refine specifically how project water quality improvements would be evaluated. The resulting decision criteria are shown in Table 1.

TABLE 1
Decision Criteria

1. Evaluate System Benefits and Risks
1.1 Reduce Functional Risk
1.2 Reduce Regulatory Risk
1.3 Increase Adaptability
2. Environmental Outcomes – Cleaner Water
2.1 Reduce Human Exposures
2.2 Reduce Aquatic Life Exposures
2.3 Improve Aesthetics
2.4 Protect Aquifer
3. Integrated Benefits
3.1 Minimize Potential Community Impacts During Construction
3.2 Increase Opportunity for Economic Development
3.3 Create Lasting Public Benefit from Improvement to Other City Infrastructure Systems
4. Operations & Maintenance Considerations
4.1 Beneficial Operations & Maintenance
4.2 Safety and Security to Staff, Public, and Assets
5. Cost (minimize net present value of capital, operations, maintenance and replacement)
5.1 Low Cost (net present value of capital, operations, maintenance and replacement)

Measurement Scales

Measurement scales are required to determine how well alternatives perform against the decision criteria. Scales may be quantitative or qualitative, depending on the objective and the availability of data for each measure. After scoring alternatives, the scores are arithmetically transformed to a scale of zero-to-one. For example, in a hypothetical scale measuring pollutants reduced in a particular alternative ranging from 1,000 lb to 4,000 lb, a score of 4,000 lb would rate a one on the transformed scale, 1,000 would rate a zero, and 2,500 would rate a 0.5. This zero-to-one scale implies a linear relationship between pounds and value. This means that increasing pounds reduced from 1,000 to 2,500 is as important as increasing pounds reduced from 2,500 to 4,000. The two incremental changes are of equivalent value. Scales can also be nonlinear when changes along the scale have different degrees of importance.

The measurement scales that were used in the Integrated Plan evaluations are shown in Table 2.

TABLE 2
Measurement Scales

Decision Criteria	Best Outcome	Worst Outcome
1. System Benefits and Risks		
1.1 Reduce Functional Risk	System is not particularly complex, it has well-understood operations and maintenance requirements, City staff have experience operating the process, and the system has been demonstrated at more than three similar-scale facilities in North America.	The system is complex, it has challenging operations and maintenance elements that must be managed carefully, City staff have no experience operating the process, and the system has been demonstrated at less than three similar- scale facilities in North America.
1.2 Reduce Regulatory Risk	System uses technologies and designs that have predictable and well-understood impacts on CSO frequency, and are highly effective at reducing CSO frequency.	System uses technologies and designs that have unpredictable and not well-understood impacts on CSO frequency.

TABLE 2
Measurement Scales

Decision Criteria	Best Outcome	Worst Outcome
1.3 Increase Adaptability	System is inherently less vulnerable to risks from natural hazards (e.g., earthquakes, floods) and changes in standards, and has an inherent ability to respond to future changes in flows and loads greater than 25% of design capacity.	Significant engineering systems required to mitigate inherent vulnerabilities of the system, and system is not able to adapt significantly to future changes in flows or loads.
2. Environmental Outcomes – Cleaner Water		
2.1 Reduce Human Exposures	Weighted annual average reduction in indicator pollutant quantities that may affect human health (pollutants and weights include: fecal coliform bacteria [20], total suspended solids [10], total phosphorus [15], PCBs [100])	
2.2 Reduce Aquatic Life Exposures	Weighted annual average reduction in indicator pollutant quantities that may affect aquatic life (pollutants and weights include: total suspended solids [60], total phosphorus [40], total zinc [100])	
2.3 Improve Aesthetics	Mechanism to control solids, floatables, or odors applied to more than 80% of combined sewage or stormwater by volume (e.g., screening, advanced treatment, stormwater constructed wetlands)	Mechanism to control solids, floatables, or odors applied to <10% of combined sewage or stormwater by volume
2.4 Protect Aquifer	Facilities not likely to result in substantial change in risk to the aquifer	Facilities likely to increase the risk to the aquifer
3. Integrated Benefits		
3.1 Minimize Potential Community Impacts During Construction	Construction likely to result in impacts to the community ***substantially less*** than those associated with development of the City's CSO reduction project in Basins 38-39-40.	Construction likely to result in impacts to the community ***substantially greater*** than those associated with development of the City's CSO reduction project in Basins 38-39-40.
3.2 Increase Opportunity for Economic Development	Facilities include features highly likely to serve as a catalyst for local economic development	Facilities not likely to result in any substantive economic development
3.3 Create Lasting Public Benefit from Improvement to Other City Infrastructure Systems	Facilities will provide a lasting public benefit by improving other infrastructure systems, and/or the completed project alleviates current concerns of local residents (odor, noise, visual).	Facilities will not improve other infrastructure systems and impacts from the facility would require significant mitigation to be acceptable to the community.
4. Operations and Maintenance Considerations		
4.1 Beneficial Operations & Maintenance	The facilities require no operating staff or can be remotely operated. Peak staff times require <1 operator. The facility can be shut down with minimal staff time. Cleanup work is automated or can be scheduled to be integrated with other staff duties. The facilities only require annual preventive maintenance. The processes have minimal mechanical/instrumentation components. The equipment is reliable in intermittent use.	The facilities require operator attention during the event. Peak staff times require two or more operators. The facility requires significant effort for shutdown. Cleanup work is generally manual with two or more personnel required for more than one day. Most procedures of shutdown need to be conducted immediately. The facilities require monthly maintenance. The processes have an increasing level of mechanical or instrumentation components. Equipment is prone to failure with intermittent use.
4.2 Safety and Security to Staff, Public, and Assets	The facilities do not have right-of-way access requirements or constrained confined space entry. No traffic control procedures are required during operations and maintenance. The site and City assets are secure from tampering or risk is low.	The facilities have right-of-way access requirements or extreme confined space entry during routine operation and/or maintenance procedures. Traffic control procedures are required during routine operations and maintenance procedures. Work is in a densely populated environment. Site and City assets are vulnerable to tampering.
5. Low Cost (minimize net present value of capital, operations, maintenance and replacement)[a]		

[a] Will be measured in dollars and is not weighted: the total value from the non-monetary decision criteria will be compared to cost in a benefit-cost type of comparison as shown in Figure 4.

Alternatives

As shown in Figure 1, the alternatives evaluated include a set of basin solutions for stormwater and CSOs. After identifying the preferred set of basin solutions, a broader set of system-wide alternatives was evaluated. The alternatives selected were as follows:

- 1a: combined sewer overflow (CSO) Plan – tank sizes revised from 2005, all gray storage, no green infrastructure.
- 1b: CSO Plan + Green – use green infrastructure instead of storage in CSO Basins 14 and 15. In CSO Basins 6 and 12, allows for the long-term implementation of green infrastructure projects as the City implements its Integrated strategy and build smaller storage tanks that together control to regulatory requirements, same size tanks in all other CSO basins.
- 2a: CSO Plan + Cochran – 1a plus an end-of-pipe stormwater treatment project in the Cochran stormwater basin. The technology used is biofiltration.
- 2b: CSO Plan + using Next Level of Treatment (NLT) during the non-critical (winter) season – 1a plus use of NLT all year instead of just during the critical (summer) season.
- 3: CSO Plan + Green + Cochran + winter NLT –1a plus green in CSO Basins 14 and 15 (no green in CSO Basins 6 and 12) plus the long-term implementation of green infrastructure plus the Cochran project in 2a, plus the NLT usage in 2b.

Relative Value Weights

Introduction. Based on the value system of the decision maker(s), some decision criteria may be more or less important than other decision criteria. Different stakeholders faced with the same problem may have different underlying value systems and, therefore, may have a different sense of what is most important in the given problem. This leads to the concept of "weighting" objectives, resulting in relative value weights. Assigning relative value weights to decision criteria is a subjective exercise based on the values of the stakeholder(s).

Weighting Workshop. A weighting workshop was held on April 11, 2013, with members of the project Technical Team and with members of the Strategy Team, separately. In this workshop, a CH2M HILL decision facilitator presented updated decision criteria and measurement scales, including introducing the environmental outcome criteria that are aimed at improving water quality and meeting the regulatory criteria. At this time, it was noted that the cleaner waters/water quality scale was still in development; thus, the weighting for this criterion would need to be adjusted.

Information was presented about the appropriate perspective for assigning relative value weights, and the group was led through an exercise to assign weights to each decision criterion. Each participant assigned a relative value weight for each criterion, and then the group discussed and came to consensus on the relative weights. It was explained how a weighting sensitivity analysis can be conducted to explore the effects that different subjective preferences about decision criteria weights might have on the relative ranking of different projects.

For the environmental outcome criteria, the group discussed several critical aspects, including impacts of prioritizing aquifer health without changing the project goal to be about improving the aquifer. The Integrated Plan projects should not degrade the aquifer, but it was agreed that they should not be intended to improve the aquifer water quality beyond the indirect benefits from improving water quality in the river.

In addition, the group discussed how to weight the impacts to aquatic life and human health, including how to weight short-term acute impacts compared to long-term chronic impacts. After the workshop, the CH2M HILL team conducted additional research and analysis on these environmental outcome criteria, and incorporated the results of that research into the MODA model.

For the community outcomes, it was generally agreed that short-term disruptions to the community were not as critical compared to the long-term benefits expected from these projects, and they were weighted accordingly. The Strategy Team agreed to change the name of the overall category to Integrated Benefits.

For the operations and maintenance (O&M) considerations, the group discussed the relative importance of public safety compared to O&M considerations. It was agreed that public safety should outweigh O&M considerations, because many of the O&M issues will be captured in the life-cycle costing of projects.

The group then discussed the relative weightings of the overall decision criteria. The relative weightings reflect the project goals in that the purpose of the Integrated Plan is the environmental outcomes, which were rated as the highest priority. The next priority is making sure that the projects meet their intended outcomes, so system benefits and risks were weighted relatively high as well.

Post-workshop Adjustment to the Water Quality Exposure Criteria. Subsequent to the April 11 workshop, CH2M HILL staff further developed the proposed methodology for evaluating the water quality benefits resulting from proposed projects. That methodology is outlined in the Water Quality Scoring Technical Memorandum. A summary of that methodology follows.

The pollutants that were evaluated for the water quality measure include the following:

- Fecal coliform bacteria (colony forming units/year)
- PCBs (kilograms [kg]/year)
- Total phosphorus (kg/year)
- Total zinc (kg/year)
- Total suspended solids (TSS) (kg/year)

Note that total zinc is used for the purposes of the numerical calculations of water quality impact in the MODA evaluation. Dissolved zinc was used in the documentation for the Integrated Plan when the link is made between pollutant discharge and meeting applicable regulatory criteria; specifically, water quality standards. Total zinc is used in the MODA evaluation because of its value as an indicator parameter and because it is easier to measure than dissolved zinc.

The water quality benefits associated with a project were measured by comparing the estimated annual pollutants removed by each alternative. The rationale for this approach is that any demonstrable reduction in a pollutant's load, even one that may equate to minimal changes in water quality, is an improvement over no reduction at all. This is particularly true for highly persistent pollutants (such as PCBs) that accumulate in sediment and aquatic biota and where continued loading adds to their potential to cause adverse effects. Thus, for each project, there would be a measure that estimates the quantity of pollutants removed for those pollutants that the Integrated Plan is focused on removing.

To translate the pollutant load reduction percentages to potential benefits, each pollutant has been linked to potential effects on human health and aquatic life, with a qualitative weighting factor. These weights were developed on the basis of the real and perceived severity and reversibility of a pollutant's adverse health and ecological effects. For example, PCBs, which persist, bioaccumulate, and can cause both cancer and non-cancer effects, many of which are not reversible, were weighted more heavily than fecal coliform, which does not persist, does not accumulate, has largely reversible health effects, and only sickens a small portion of people exposed to the bacteria.

The qualitative weighting factors used for each pollutant are shown in Table 3. The relative weights of human health versus aquatic life and the relative weights of different pollutants were developed by CH2M HILL and are intended to be representative of the actual or perceived effect of exposure reduction potential likely from CSO or stormwater projects. The initial weights were modified slightly by the Technical Team. For human health, the highest exposure reduction potential (PCBs) was assigned a weight of 100, and the others scaled proportionately. A similar approach was taken for aquatic life.

The last column of Table 3 shows the weights converted to percentages. Those percentages were applied to the normalized pollutant reduction potential for each pollutant and summed to result in total human health and aquatic life water quality scores for each project and system-wide alternative.

TABLE 3
Pollutant Weights for Water Quality Measure

	Weight	Percent
Human Health Receptors		
Fecal coliform	40	22%
TSS	10	6%
Total phosphorus	30	17%
PCBs	100	56%
Total		100%
Aquatic Life Receptors		
TSS	60	30%
Total phosphorus	40	20%
Total zinc	100	50%
Total		100%

Note: Totals may not add because of rounding.

The relative value weights used in the MODA evaluations are shown in Table 4, including the relative value weights for two sensitivity analyses. For the first sensitivity analysis the relative weights of sub-criteria 3.2 and 3.3 were adjusted to evaluate the potential effects of placing greater value on impacts associated with economic development and infrastructure improvements. The second sensitivity analysis evaluated the potential impact of only considering PCBs for the water quality criteria.

TABLE 4
Revised Relative Value Weights

	Strategy Team (Base Case)	Sensitivity 1 (Econ Dev Emphasis)	Sensitivity 2 (PCB as only WQ Criteria)
1. Evaluate System Benefits and Risks	**30%**	**19%**	**30%**
1.1 Reduce Functional Risk	10%	6%	10%
1.2 Reduce Regulatory Risk	12%	7%	12%
1.3 Increase Adaptability	8%	5%	8%
2. Environmental Outcomes – Cleaner Water	**32%**	**20%**	**32%**
2.1 Reduce Human Exposures	15%	9%	22%
2.3 Reduce Aquatic Life Exposures	7%	4%	N/A
2.4 Improve Aesthetics	4%	3%	4%
2.5 Protect Aquifer	6%	4%	6%
3. Integrated Benefits	**25%**	**53%**	**25%**
3.1 Reduce Potential Community Impacts During Construction	5%	3%	5%
3.2 Increase Opportunity Potential for Economic Development	9%	25%	9%
3.3 Create Lasting Public Benefit from Improvement to Other City Infrastructure Systems	11%	25%	11%
4. Operations & Maintenance Considerations	**13%**	**8%**	**13%**
4.1 Beneficial Operations & Maintenance	6%	4%	6%
4.2 Safety and Security to Staff, Public, and Assets	6%	4%	6%

Note: Cost will be measured in dollars and is not weighted: the total value from the non-monetary decision criteria will be compared to cost in a benefit-cost type of comparison as shown in Figure 4.

Note: Totals may not add because of rounding.

Water Quality Scale

The water quality scores were calculated using the values demonstrated in Table 5.

Part 1 of the table shows the estimated loading reductions by pollutant from each project. Part 2 shows the pollutant loads normalized on a linear 0-1 scale, with a zero representing no load reduction and a 1 representing the maximum load reduction for that pollutant over the three alternatives. Part 3 shows the weighting factors from Table 3. Part 4 shows the human health and aquatic life scores, which are calculated by multiplying the percentages in Part 3 times the weights in Part 4, and by 100 (a scalar to make results easier to interpret), and summing over all pollutants. As shown, the maximum score is 100 and the minimum score is zero. The raw scores are then scaled linearly to the same 1 to 5 scale used to score other decision criteria. This transformation, although not strictly necessary, is conducted for consistency with how other decision criteria are scored.

It should be noted that this example applies to evaluation of basin solutions for the maximum normalized scale endpoint (normalized score of 1), which represents the maximum load reduction for that pollutant within that particular basin. When comparing system-wide alternatives, the maximum possible load reduction will reflect the total load generated within the geographic area spanned by the alternatives.

TABLE 5
MODA Water Quality Scores

Pollutant	1a: CSO Storage	1b: CSO Storage + Green	2a: CSO Storage + Cochran	2b: Storage + Winter NLT	3: Storage+ Green+ Cochran+Winter NLT	Units
1. Reduction in pollutant load						
Fecal coliform	657,438	657,443	659,481	663,924	665,968	cfu/yr
TSS	41,267	47,411	545,580	635,146	1,141,466	lb/yr
Total phosphorus	452	513	2,096	93,124	94,786	lb/yr
PCBs	6,877	7,082	18,877	20,887	32,954	lb/yr
Total Zinc	25	52	512	90	586	lb/yr
2. Normalized reduction (0-1 scale based on percent of maximum)						
Fecal coliform	0.99	0.99	0.99	1.00	1.00	
TSS	0.04	0.04	0.48	0.56	1.00	
Total phosphorus	0.00	0.01	0.02	0.98	1.00	
PCBs	0.21	0.21	0.57	0.63	1.00	
Total Zinc	0.04	0.09	0.87	0.15	1.00	
3. Relative Value Weights for Pollutants						
Human Health Receptors						
Fecal coliform	40	22%				
TSS	10	6%				
Total phosphorus	30	17%				
PCBs	100	56%				
Aquatic Health						
TSS	60	30%				
TP	40	20%				
Total Zinc	100	50%				
4. Value Scores (normalized score x weight x 100)						
Human Health Receptors						
Fecal coliform	21.94	21.94	22.01	22.15	22.22	
TSS	0.20	0.23	2.66	3.09	5.56	
TP	0.08	0.09	0.37	16.37	16.67	

TABLE 5
MODA Water Quality Scores

Pollutant	1a: CSO Storage	1b: CSO Storage + Green	2a: CSO Storage + Cochran	2b: Storage + Winter NLT	3: Storage+ Green+ Cochran+Winter NLT	Units
PCBs	11.59	11.94	31.82	35.21	55.56	
Total	**33.81**	**34.20**	**56.85**	**76.83**	**100.00**	
1-5 Scale to MODA	***2.35***	***2.37***	***3.27***	***4.07***	***5.00***	
Aquatic Health						
TSS	1.08	1.25	14.34	16.69	30.00	
TP	0.10	0.11	0.44	19.65	20.00	
Total Zinc	2.15	4.45	43.69	7.68	50.00	
Total	**3.33**	**5.80**	**58.47**	**44.02**	**100.00**	
1-5 Scale to MODA	***1.13***	***1.23***	***3.34***	***2.76***	***5.00***	

cfu = colony forming units

Scoring Alternatives

Rating or scoring alternatives is the process by which the measurement scales are applied to the alternatives. The system-wide alternatives were initially scored by the CH2M HILL project team with review by the City to determine the extent to which each alternative meets each decision criterion. The scores for each system-wide alternative are shown in Table 6. Scores are on a 1 to 5 scale for all criteria. The rationale provided for each score is shown in Table 7 in Attachment A.

TABLE 6
MODA Non-monetary Value Scores

	SWA 1a	SWA 1b	SWA 2a	SWA 2b	SWA 3
	CSO Storage	CSO Storage + Green	CSO Storage + Cochran	Storage + Winter NLT	Storage+ Green+ Cochran+Winter NLT
1. System Benefits and Risks					
1.1 Reduce Functional Risk	4	3	4	4	4
1.2 Reduce Regulatory Risk	4	3	5	4	5
1.3 Increase Adaptability	2	4	3	3	5
2. Environmental Outcomes - Cleaner Water					
2.1 Reduce Human Exposures	2.4	2.4	3.3	4.1	5.0
2.2 Reduce Aquatic Life Exposures	1.1	1.2	3.3	2.8	5.0
2.3 Improve Aesthetics	2	3	4	3	4
2.4 Protect Aquifer	3	2	3	3	3
3. Integrated Benefits					
3.1 Minimize Potential Community Impacts During Construction	3	2	3	3	3
3.2 Increase Opportunity for Economic Development	1	3	2	1	2
3.3 Create Lasting Public Benefit from Improvement to Other City Infrastructure Systems	2	3	3	2	3
4. Operations & Maintenance Considerations					
4.1 Beneficial Operations & Maintenance	5	3	4	3	3
4.2 Safety and Security to Staff, Public and Assets	3	2	3	3	3

Results

The total value score for each alternative was calculated as a weighted averaging process in which the normalized scores are multiplied by the value weights and summed for each alternative. As indicated above, the scores for each objective were normalized to a 0-1 scale.

The results were multiplied by 100 so that scores would be reported as ranging between 0 and 100 rather than as decimals. Resulting value scores for the Base Case are presented in Table 8. As shown, Alternative 3 has the highest overall value score, followed by Alternative 2a. The two main criteria affecting value scores were Environmental Outcomes and System Benefits and Risks.

TABLE 8
Total Value Scores – Base Case

	Total Value Scores Baseline - Strategy Team Weights				
	SWA 1a	**SWA 1b**	**SWA 2a**	**SWA 2b**	**SWA 3**
Decision Criteria	**1a: CSO Storage**	**1b: CSO Storage + Green**	**2a: CSO Storage + Cochran**	**2b: Storage + Winter NLT**	**3: Storage+ Green+ Cochran+Winter NLT**
Total Score	**42.6**	**42.3**	**60.5**	**51.9**	**72.5**
1. System Benefits and Risks	18.3	17.1	23.4	20.4	27.6
1.1 Reduce Functional Risk	7.2	4.8	7.2	7.2	7.2
1.2 Reduce Regulatory Risk	9.0	6.0	12.0	9.0	12.0
1.3 Increase Adaptability	2.1	6.3	4.2	4.2	8.4
2. Environmental Outcomes - Cleaner Water	9.4	9.2	18.8	19.8	28.2
2.1 Reduce Human Exposures	5.1	5.2	8.7	11.7	15.2
2.2 Reduce Aquatic Life Exposures	0.2	0.4	4.0	3.0	6.9
2.3 Improve Aesthetics	1.0	2.1	3.1	2.1	3.1
2.4 Protect Aquifer	3.0	1.5	3.0	3.0	3.0
3. Integrated Benefits	5.2	11.2	10.2	5.2	10.2
3.1 Minimize Potential Community Impacts During Construction	2.5	1.2	2.5	2.5	2.5
3.2 Increase Opportunity for Economic Development	0.0	4.4	2.2	0.0	2.2
3.3 Create Lasting Public Benefit from Improvement to Other City Infrastructure Systems	2.8	5.5	5.5	2.8	5.5
4. Operations & Maintenance Considerations	9.7	4.8	8.1	6.5	6.5
4.1 Beneficial Operations & Maintenance	6.5	3.2	4.8	3.2	3.2
4.2 Safety and Security to Staff, Public and Assets	3.2	1.6	3.2	3.2	3.2

Figure 3 provides a graphic comparison of the total value scores and Figure 4 shows a comparison of those scores to the life-cycle cost of each alternative.

Sensitivity analyses were conducted to test the sensitivity of the results to changes in weights. Sensitivity analyses gives decision makers an additional opportunity to think carefully about what is most important to them in selecting between alternatives, then acting accordingly. In this case, two sensitivity analyses were compared against the Base case (Strategy Team) weights.

Summary results that show the results for the Base Case and the two sensitivity analyses are presented in Table 9. The first part of this table shows the value scores for both the Base Case and the two sensitivity analyses. The second part of the table presents a color-coded ranking of alternatives for the three cases. As shown in this table, Alternative 3 is the preferred option for both the Base Case and the two sensitivity cases.

TABLE 9
Sensitivity to Changes in Relative Weights

Value Scores					
Total Value Score	**1a: CSO Storage**	**1b: CSO Storage + Green**	**2a: CSO Storage + Cochran**	**2b: Storage + Winter NLT**	**3: Storage+ Green+ Cochran+Winter NLT**
Base - Strategy Team	42.6	42.3	60.5	51.9	72.5
Econ Dev and Other Infr Systems	31.1	45.2	51.7	36.9	59.2
WQ is PCB Only	41.9	41.4	60.5	51.2	72.5
Alternative Rank Based on Value Score					
Rank, Highest Valued Option = 1	**1a: CSO Storage**	**1b: CSO Storage + Green**	**2a: CSO Storage + Cochran**	**2b: Storage + Winter NLT**	**3: Storage+ Green+ Cochran+Winter NLT**
Base - Strategy Team	4	5	2	3	1
Econ Dev and Other Infr Systems	5	3	2	4	1
WQ is PCB Only	4	5	2	3	1

Results from the MODA can be visualized to provide additional insights for decision makers. Figure 3 shows a stacked bar graph that indicates the total value score for the four alternatives considered and includes the components of value for each alternative. Figure 4 shows a scatter diagram comparing total value on the x-axis and total cost on the y-axis. This shows the trade-offs presented between value and cost.

A value-to-cost presentation for removal of individual pollutants is shown in Figure 5 to Figure 8. As shown in Figure 5, the relative costs for removal of additional colony forming units (CFUs) of fecal coliform are similar for each of the alternatives. For PCBs, TSS, and total phosphorus, the relative cost per pound of pollutant removed is significantly less for Alternatives 3, 2a, and 2b, compared with Alternatives 1a and 1b.

Conclusions

Based on the MODA evaluation, Alternative 3 is the preferred alternative for the Integrated Plan.

Recommendations

Recommended projects based on the MODA evaluation are included in the Integrated Plan.

Figures

	Strategies	Techn-ologies	Projects	Basin Solutions	System-wide Alternatives
Description	High-level method of controlling stormwater and/or CSOs	Means of implementing a strategy	Implementing a technology at a specific location	One or more projects in a basin to meet CSO or stormwater goals in a basin	A mix of projects in multiple basins to meet Integrated Plan goals city-wide
Examples	• Gray • Green • Optimization	• Rain gardens • Bio-swale • Storage tank • Storage pipe	• Rain gardens in 10 blocks in the Cochran Basin • 6.7 mg storage tank in CSO Basin X	• Rain gardens in 20 blocks, drywells in 20 blocks, and 2.4 MG of offline storage in CSO Basin Y	• Do nothing • Existing CSO plan • Updated CSO plan • Integrated plan
Evaluation Methods	• Not applicable	• Document cost and pollutant reduction potential of technologies from literature and prior experiences	• Use available data and expertise to identify locations and technologies • Use cost curves for technologies and size estimates • Screening-level non-monetary evaluations	• Use available data and expertise to identify possible basin solutions • Prepare conceptual cost estimates • Non-monetary evaluations	• Use available data and expertise to prioritize basin solutions into system-wide alternatives • Prepare conceptual cost estimates • Non-monetary evaluations

FIGURE 1
Integrated Plan Evaluation Methods

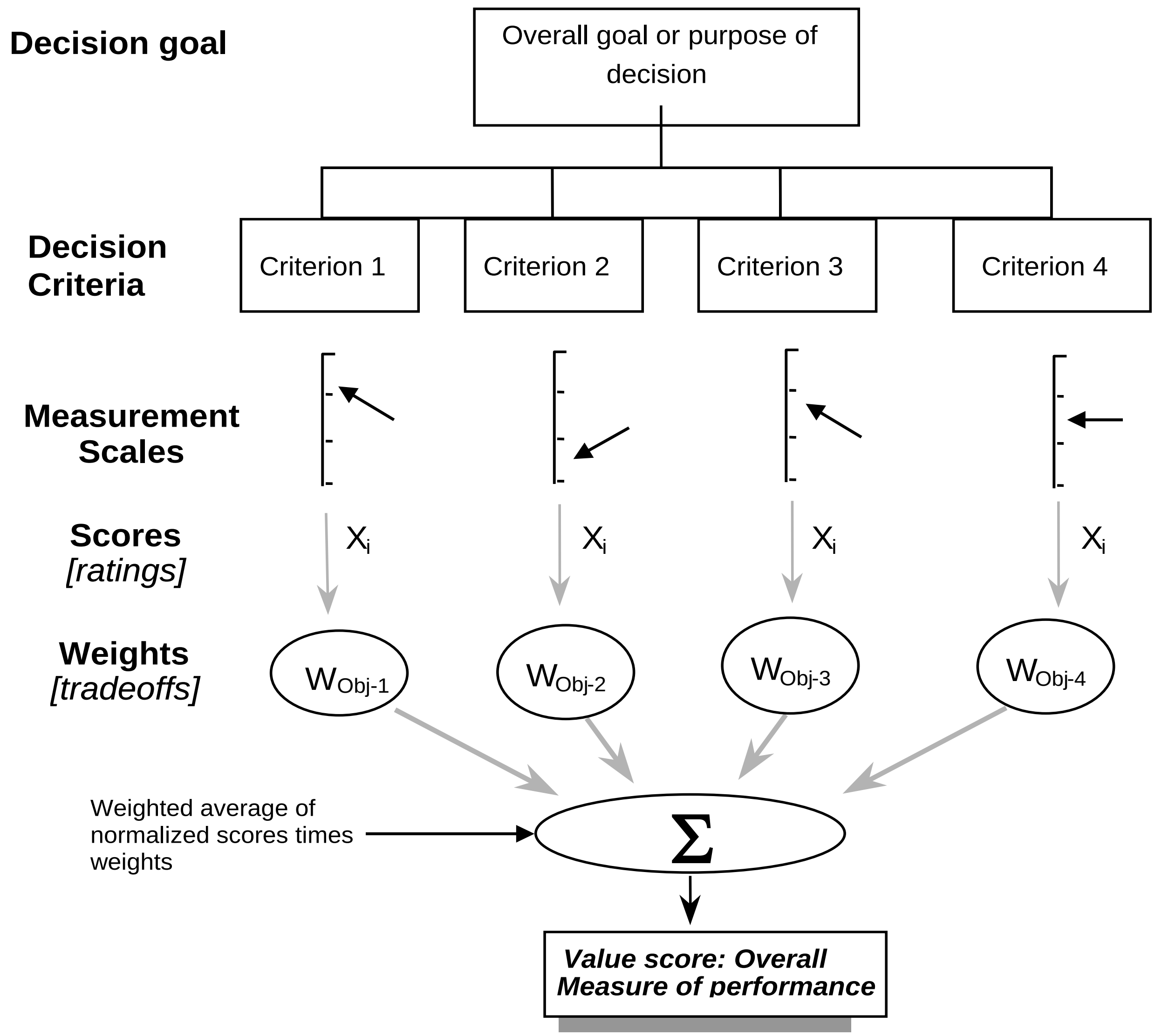

FIGURE 2
Generalized MODA Process

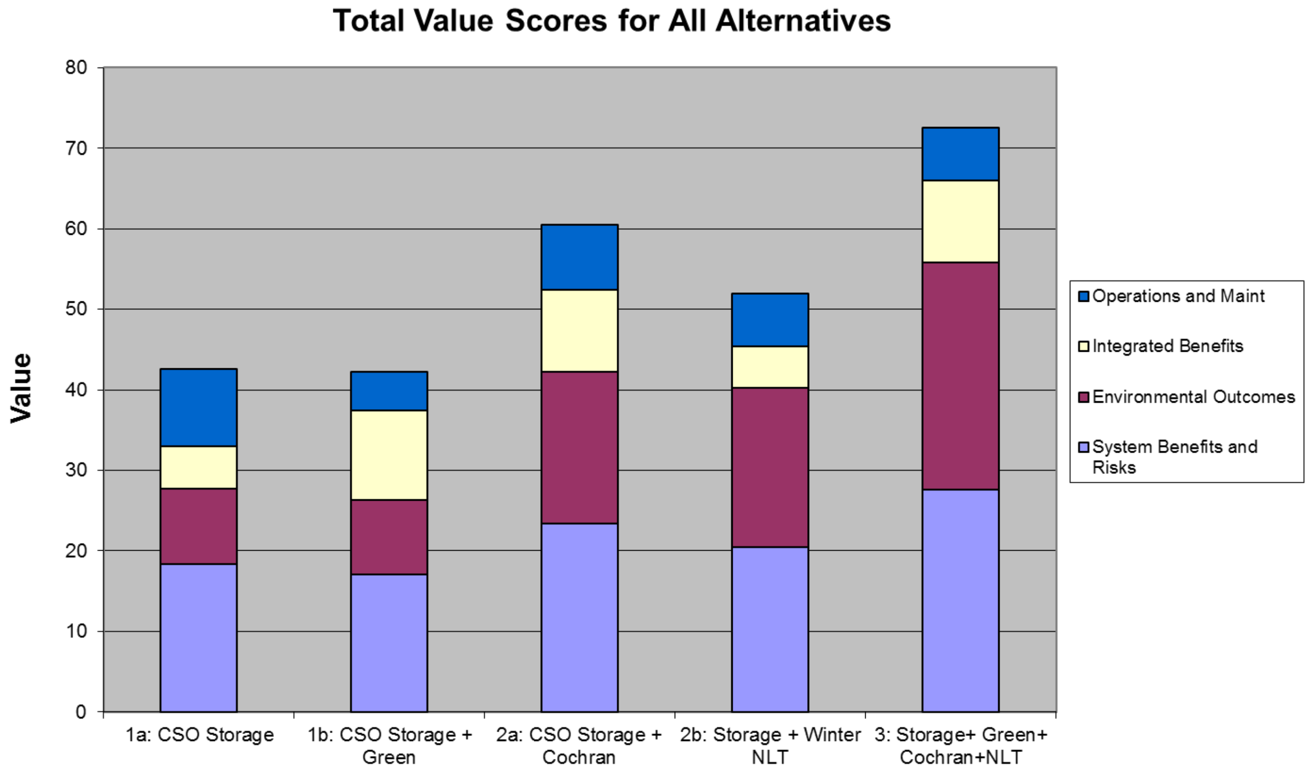

FIGURE 3
Results with Strategy Team (Base Case) Weights

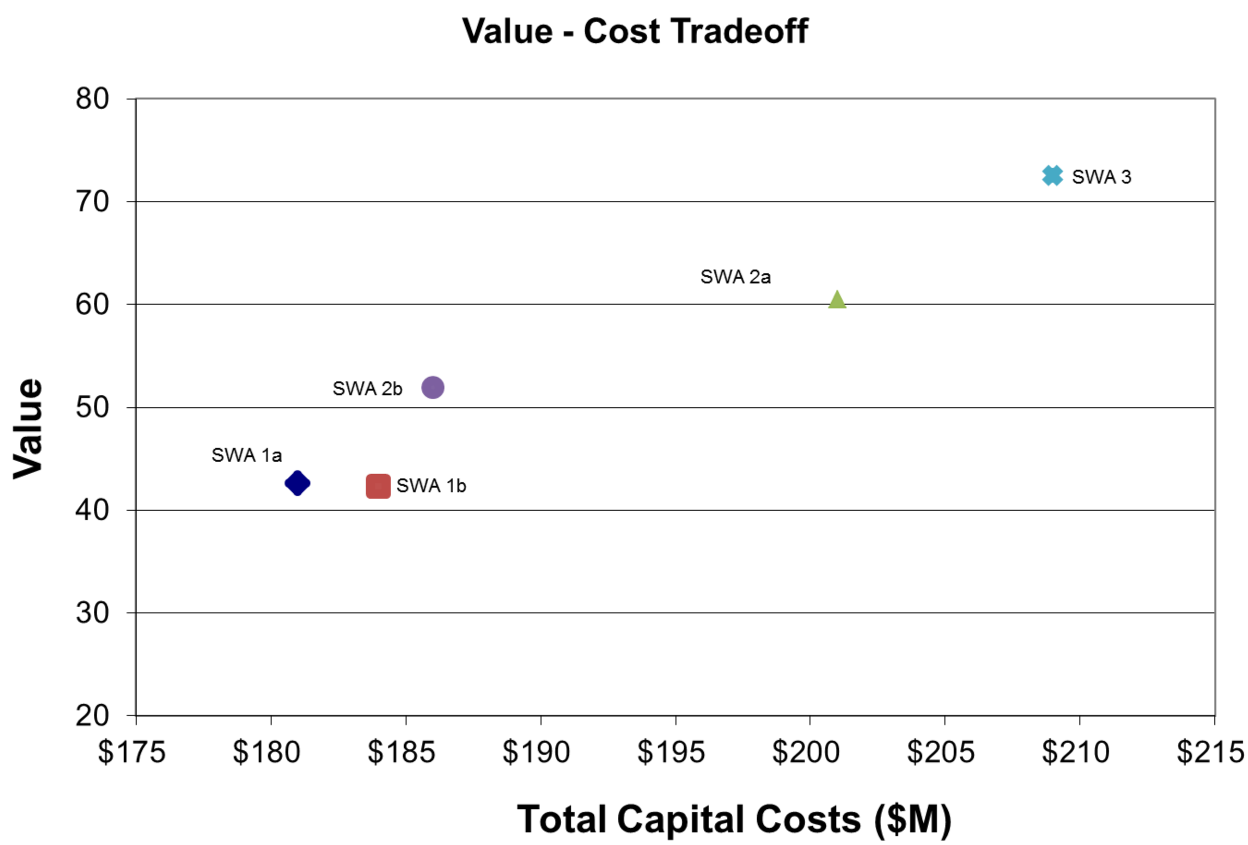

FIGURE 4
Results: Value-Cost Tradeoff for Strategy Team

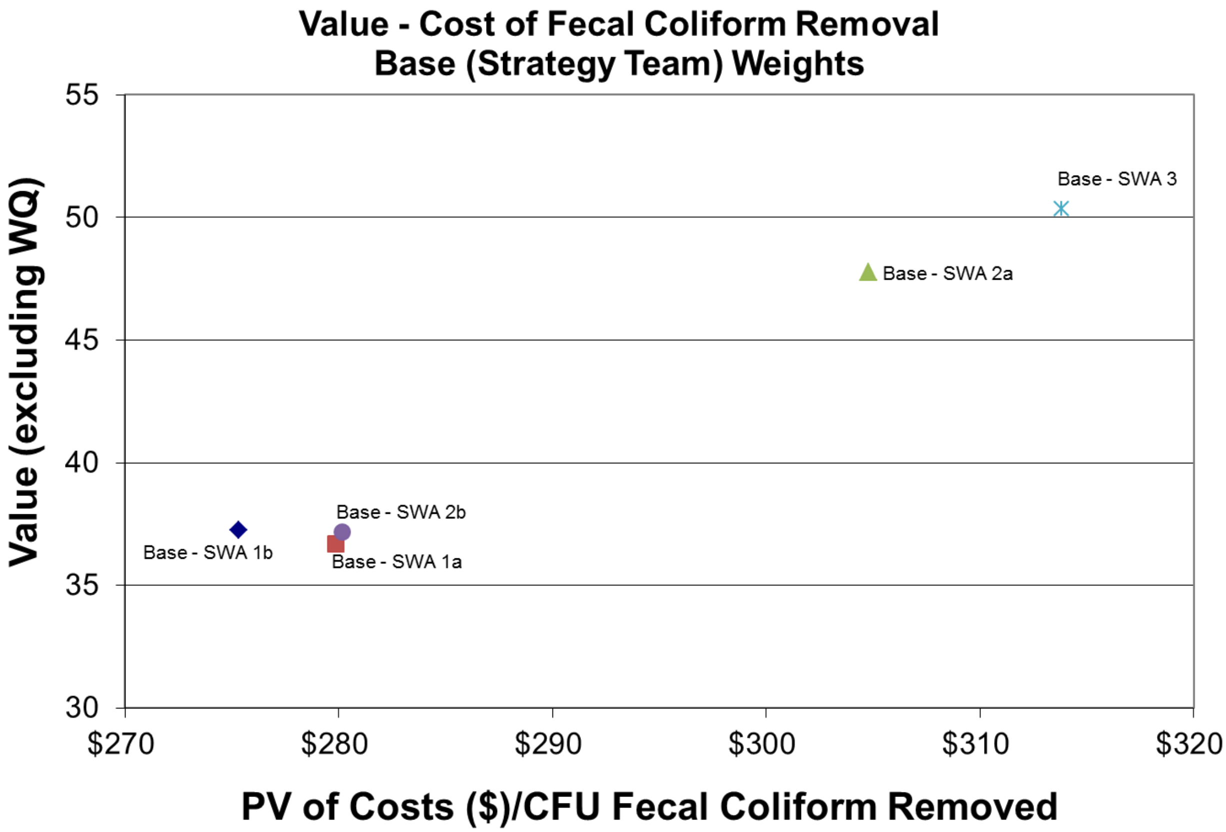

FIGURE 5
Value-Cost Tradeoff for E. Coli

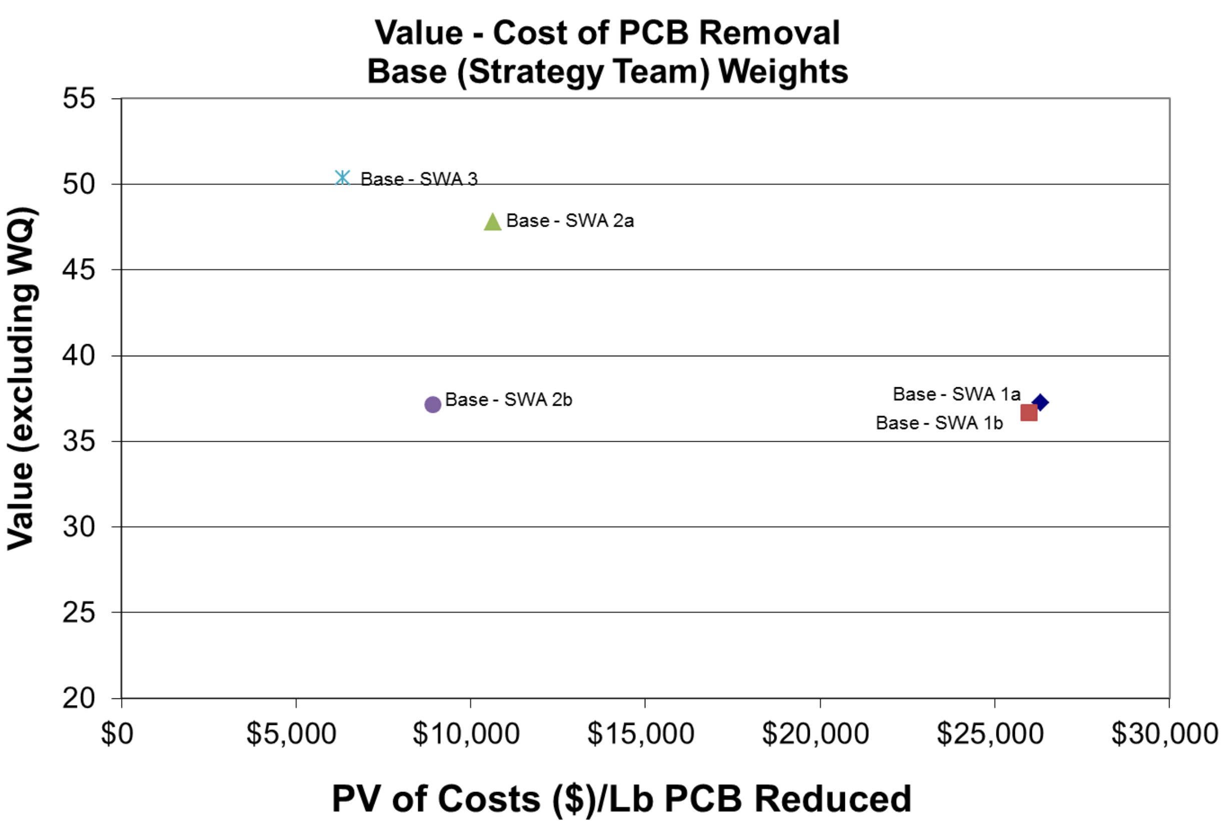

FIGURE 6
Value-Cost Tradeoff for PCB Removal

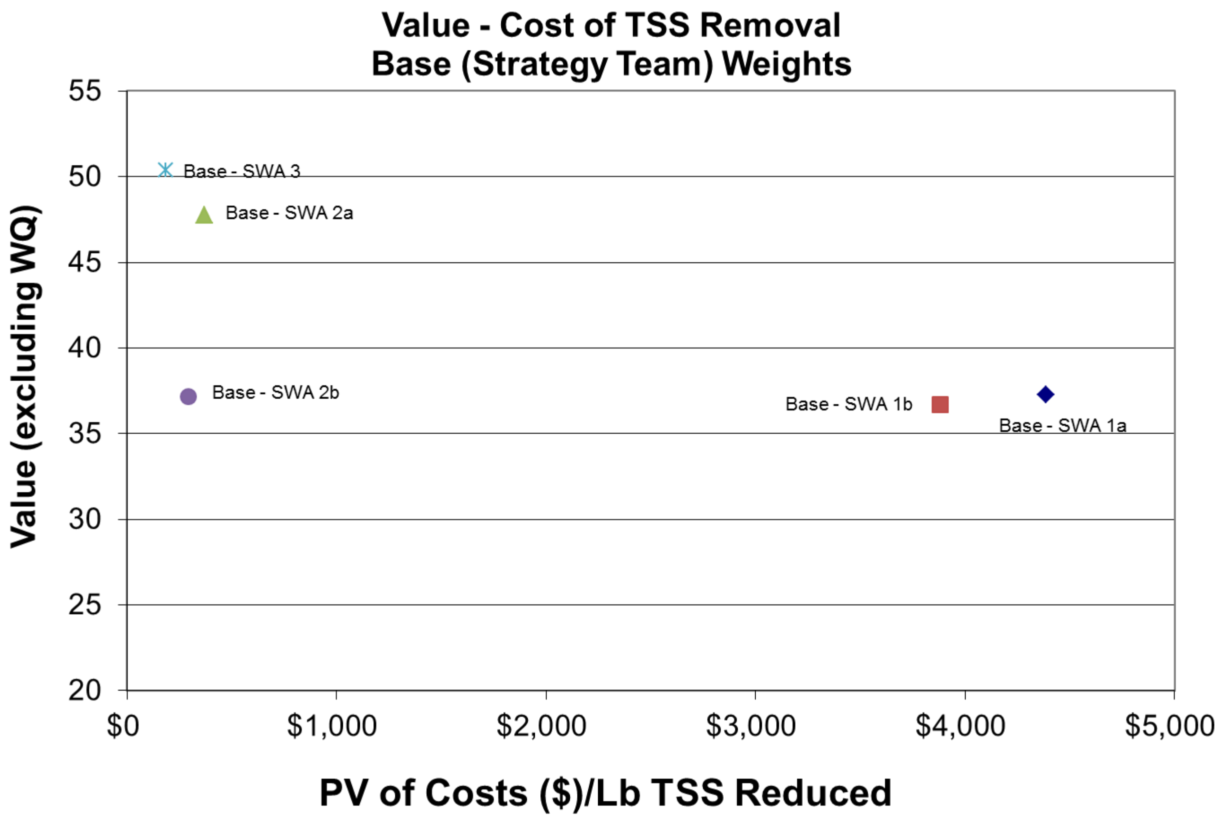

FIGURE 7
Value-Cost Tradeoff for TSS Removal

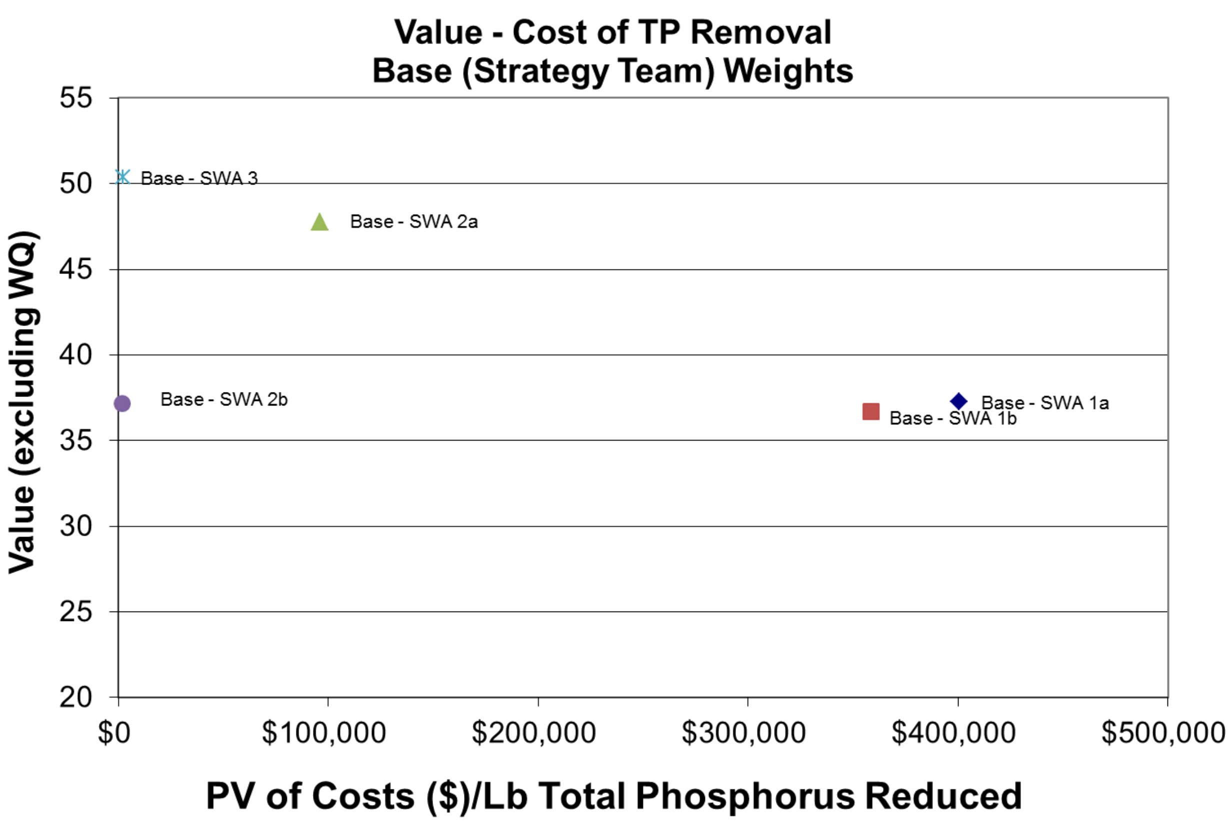

FIGURE 8
Value-Cost Tradeoff for Total Phosphorus Removal

Attachment A
Scoring Rationale

TABLE 7
Scoring Rationale

	Rationale				
	SWA 1a	**SWA 1b**	**SWA 2a**	**SWA 2b**	**SWA 3**
Decision Criteria	**1a: CSO Storage**	**1b: CSO Storage + Green**	**2a: CSO Storage + Cochran**	**2b: Storage + Winter NLT**	**3: Storage+ Green+ Cochran+Winter NLT**
1. System Benefits and Risks					
1.1 Reduce Functional Risk	Storage tanks (technology familiar to City, on City right-of-way and park property)	Storage tanks (technology familiar to City, on City right-of-way and park property); smaller tanks because of green, slightly more risky; green requires more frequent maintenance, risk around whether or not maintenance is done	Storage tanks (technology familiar to City, on City right-of-way and park property) + Cochran infrastructure to maintain, which adds to risk (though City is familiar with type of maintenance required)	Storage tanks (technology familiar to City, on City right-of-way and park property) + NLT infrastructure to maintain, which adds to risk (though City will be familiar with type of maintenance required, will be doing it anyway)	Storage tanks + Cochran infrastructure to maintain, which adds to risk + NLT infrastructure to maintain, which adds to risk + green requires more frequent maintenance, risk around whether or not maintenance is done
1.2 Reduce Regulatory Risk	Controlling CSOs in CSO basins with trusted technology. Assumes control volume sizing is correct.	Smaller CSO tanks in a few CSO basins because of green, more CSO regulatory risk. Assumes control volume sizing is correct.	Controlling CSOs in CSO basins with trusted technology. Assumes control volume sizing is correct. Cochran project anticipates possible future stormwater regulations.	Controlling CSOs in CSO basins with trusted technology. Assumes control volume sizing is correct.	Controlling CSOs in CSO basins with trusted technology. Assumes control volume sizing is correct. Cochran project anticipates possible future stormwater regulations.
1.3 Increase Adaptability	CSO storage tanks resilient to changes in flows/loads. Somewhat challenging to increase tank size if needed for CSO regulations, depending on CSO tank location; fix would benefit that CSO basin, rather than entire system	If need arises in an individual CSO basin, add more green in that CSO basin; infiltration is 100% removal, rather than <100% removal of CSO storage; fix would benefit that CSO basin, rather than entire system	Could upsize/enhance Cochran to increase benefits in Cochran basin, benefits Cochran only, rather than entire system; same adaptability as SWA 1	Could upsize/enhance NLT to increase benefits to entire system, treatment is <100% removal, so not as adaptable in that way compared to SWA 2a	Because SWA 3 contains elements from all of the other SWAs, this alternative provides the best adaptability.
2. Environmental Outcomes - Cleaner Water					
2.1 Reduce Human Exposures	See pollutant reduction calculations	See pollutant reduction calculations	See pollutant reduction calculations	See pollutant reduction calculations	See pollutant reduction calculations
2.2 Reduce Aquatic Life Exposures	See pollutant reduction calculations	See pollutant reduction calculations	See pollutant reduction calculations	See pollutant reduction calculations	See pollutant reduction calculations
2.3 Improve Aesthetics	Could be odor issues with tank	Does not provide additional solids, floatables, or odor benefits compared to stand-alone CSO alt 1	Does not provide additional solids, floatables, or odor benefits compared to stand-alone CSO alt 1	Does not provide additional solids, floatables, or odor benefits compared to stand-alone CSO alt 1	Does not provide additional solids, floatables, or odor benefits compared to stand-alone CSO alt 1
2.4 Protect Aquifer	Storage does o't impact aquifer	Green will infiltrate more, elevated risk to aquifer in certain areas	Storage does not impact aquifer, some additional risk from Cochran infiltration	Storage and NLT does not impact aquifer	Green will infiltrate more, elevated risk to aquifer in certain areas

TABLE 7
Scoring Rationale

	Rationale				
	SWA 1a	SWA 1b	SWA 2a	SWA 2b	SWA 3
Decision Criteria	1a: CSO Storage	1b: CSO Storage + Green	2a: CSO Storage + Cochran	2b: Storage + Winter NLT	3: Storage+ Green+ Cochran+Winter NLT
3. Integrated Benefits					
3.1 Minimize Potential Community Impacts During Construction	Several new tanks and regulator improvements in the neighborhoods	in addition to new tanks and regulator improvements, green infrastructure construction is disruptive on roadways	Several new tanks and regulator improvements in the neighborhoods + construction of Cochran infrastructure (centralized, but proximate to park)	Several new tanks and regulator improvements in the neighborhoods + construction of NLT infrastructure (centralized, outside of neighborhoods)	In addition to new tanks and regulator improvements, green infrastructure construction is disruptive on roadways + construction of Cochran infrastructure + construction of NLT
3.2 Increase Opportunity for Economic Development	Underground storage tanks on public land, minimal indirect opportunities to spur private development	Opportunities for private development proximate to green infrastructure implementation	Limited to no opportunities compared with stand-alone CSO alt 1	Limited to no additional opportunities compared with system-wide alt 1	Limited to no additional opportunities compared with system-wide alt 1
3.3 Create Lasting Public Benefit from Improvement to Other City Infrastructure Systems	Storage tanks, could be some limited opportunities for broader public benefit (viewpoints, parks, etc.) or where conveyance improvements are needed along street right-of-way	Additional opportunities beyond tanks for improvements to other infrastructure system proximate to green infrastructure implementation	limited additional opportunities compared with stand-alone CSO alt 1, because proposed Cochran projects are all end-of-pipe, could be additional opportunities for water access/ parks improvements	Limited to no additional opportunities compared with system-wide alt 1	Additional opportunities beyond tanks for improvements to other infrastructure system proximate to green infrastructure implementation
4. Operations & Maintenance Considerations					
4.1 Beneficial Operations & Maintenance	Known, infrequent O&M requirements	Requires additional, frequent (bi-weekly) O&M, likely additional full-time equivalent employees for green infrastructure	Requires additional, but infrequent O&M at end-of-pipe facility, may not require additional full-time equivalent employees	Full-time operator necessary for NLT, instead of just in critical months, extend to all-year	Requires additional, frequent (bi-weekly) O&M, likely additional full-time equivalent employees for green infrastructure, Cochran, and NLT
4.2 Safety and Security to Staff, Public and Assets	Storage tanks could require confined space, maybe traffic control; can restrict access to facility easily	In addition to storage tanks, more individual assets to maintain, challenging to restrict public access to swales during maintenance, drywells likely do not require confined space entry or traffic control.	In addition to storage tanks, more assets to maintain. Cochran facilities are inside a park, so restricting access is challenging during maintenance, could require confined space entry, and traffic control	In addition to storage facilities, have NLT maintenance. Just like storage facilities, can easily restrict access to site during maintenance	In addition to storage tanks, more individual assets to maintain, challenging to restrict public access to swales during maintenance, drywells likely do not require confined space entry or traffic control. Cochran facilities are inside a park, so restricting access is challenging during maintenance, could require confined space entry, and traffic control

APPENDIX F

Green Infrastructure Case Studies

City of Spokane Integrated Plan – Green Infrastructure Case Studies

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COPY TO:	Jennifer Price/SEA File
PREPARED BY:	Erin Thatcher/SEA
REVIEWED BY	Dustin Atchison/SEA
DATE:	March 6, 2014
PROJECT NAME:	City of Spokane Integrated Plan
PROJECT NUMBER:	382918.T7.02.06

Purpose

The purpose of these case studies is to explore and strategize what types of green infrastructure (GI) practices for stormwater can be integrated with other improvements in the City of Spokane (the City) Public Works service area for lower capital investment and impact on the public from construction. This document presents case studies at two scales: a project-level scale and a combined sewer overflow (CSO) basin-level scale. In addition, where there is public investment in implementing GI, operations and maintenance (O&M) can be a significant component of the life-cycle cost. This memorandum addresses and outlines some options for conducting O&M for GI constructed in the public right-of-way (ROW), on public properties, or on private property where the City has invested in GI through a partnership project.

Why Green Infrastructure?

Green infrastructure (GI), also referred to as green stormwater infrastructure or low impact development (LID), consists of a suite of practices and strategies to reduce the volume of untreated stormwater runoff entering the sewer system. GI seeks to mimic natural hydrologic functions through infiltration, evaporation, and storage rather than a single regulatory purpose (such as temporary storage) to reduce peak flows in the sewer system, which is common of "gray" infrastructure strategies. GI also provides an enhanced opportunity to integrate stormwater benefits with improvements in other areas, such as transportation, bicycle/pedestrian mobility, business revitalization, and urban landscaping.

Summary

Opportunities for GI in Spokane are particularly valuable where overlapping infrastructure needs exist, as demonstrated by two case studies completed for the City of Spokane's *Integrated Plan* (CH2M HILL, 2014). The Euclid Avenue Water Main Replacement Project case study demonstrates the potential for cost savings (additional value provided at a lower cost) from integrating GI into other public works projects. The Cannon Park CSO Basin case study documents a method for identifying opportunities to partner with other entities to achieve multiple community goals at a single location, and for generating planning-level cost/benefit estimates for GI at a basin scale. These goals include stormwater volume reduction for CSO control, pedestrian safety improvements, and pavement condition improvements, among others. As the City moves forward with evaluating these integrated GI opportunities, a variety of strategies for O&M are available, as demonstrated by an increasing number of jurisdictions across the country.

As next steps for implementing GI in Spokane, the project team recommends that the City:

- Continue to pilot GI partnership opportunities as identified in CSO Basin 12 and track refinements to the GI opportunity database (described below), specifically implementation levels and tracking costs.
- Develop a formal desktop feasibility analysis to identify a targeted list of GI opportunities in additional priority basins.
- Initiate City code modifications to support implementation of GI, specifically those with private-public partnerships for O&M.
- Develop supporting GI maintenance standards (e.g., Service Levels) and materials.
- Develop a formal plan for CSO Basins 14 and 15 to implement GI for CSO control. Implement GI for CSO control in other CSO basins as other infrastructure projects are completed.

Introduction

A variety of GI practices were considered for these case studies, including porous pavement, bioretention, vegetated swales, and street tree trenches designed to enhance infiltration. Each GI practice seeks to maximize use of existing ROW space to provide as many benefits as practical. With or without integration with other improvement projects, GI practices have the following environmental, social, and economic benefits:

- Reduced stormwater volume entering the sewer system
- Recharged groundwater
- Enhanced water quality
- Improved aesthetics of urban areas
- Reduced existing and potential future costs of gray (conventional) infrastructure
- Increased property values
- Reduced energy consumption

GI practices can also provide traffic calming and transportation safety benefits. These practices may be integrated into capital improvement projects through the GI practices listed below, as summarized briefly in the fact sheets included in Attachment 1:

- Intersection improvements
- Neighborhood bioretention
- Road diets or narrowing
- Enhanced tree trenches
- Porous pavement

Transportation engineers would need to evaluate proposed improvements to ensure that new configurations are appropriate for traffic safety and mobility.

Euclid Avenue Water Main Replacement Case Study

The Euclid Avenue Water Main Replacement Project was a conventional infrastructure project completed in 2013. Later in 2013 after project completion, the project team searched the Euclid Ave Water Main Replacement project corridor for opportunities to integrate GI improvements in conjunction with the water main replacement, and evaluated the potential benefits and cost savings achieved through this integrated improvement approach. As Figure 1 shows, a variety of GI practices were explored and identified as integrated opportunities along the entire project. Summary fact sheets describing benefits, costs, and key siting and design considerations of each GI opportunity in the Euclid Avenue case study are provided in Attachment 1.

Intersection Improvements

Intersection improvements can provide more efficient use of space in non-standard intersections, provide "pocket parks" or public green space, improve safety, and provide stormwater management. Three distinct locations along the Euclid Avenue Water Main Replacement Project were considered appropriate for intersection improvements, as shown on Figure 1. In this strategy, stormwater management is provided by swales or bioretention installed where existing pavement could be reduced, which also provides traffic calming benefits. Intersection improvements, or similar repurposing of underutilized public right-of-way, are largely an opportunistic strategy that is not possible in all locations but can provide potential for partnership with nearby businesses or other public infrastructure. See Fact Sheet A in Attachment 1.

Neighborhood Bioretention/Vegetated Swales

Bioretention areas and vegetated swales (often called raingardens) are shallow surface depressions planted with native vegetation to capture and treat runoff and are sometimes underlain by a sand or gravel storage/infiltration bed. Opportunities for bioretention were identified within the ROW both in existing sidewalk planter strips and on neighborhood streets where space for curb bulbs (extensions of the curb) is present. Bioretention can be designed to provide water quality and minor volume control even in poorly draining soils by incorporating an underdrain.

Bioretention in Curb Bulbs. When existing planter strips are not wide enough to accommodate the linear bioretention swales, curb bulbs (extensions) can provide the space for stormwater infiltration as well as traffic calming/speed reduction benefits, while retaining street parking. Siting curb bulbs at intersections, pedestrian crosswalks, and existing "no parking zones" aids in achieving these benefits while also reducing the impervious roadway footprint. See Fact Sheet B in Attachment 1.

Bioretention within Planters. Linear bioretention swales are most practicable where existing planter strips are at least eight feet wide. See Fact Sheet F in Attachment 1. Bioretention planters and curb bulbs are often elements of neighborhood greenways, described below.

Neighborhood Greenways

Neighborhood greenways refer to a combination of GI and other elements that enhance pedestrian and bicycle safety and neighborhood aesthetics, while at the same time providing space for stormwater management. Along the Euclid Avenue Water Main Project corridor, implementing the neighborhood greenway concept would enhance the bike route network. Integrated construction activities would include installing signs and pavement markings for bicycles, and adding bioretention curb bulbs and/or bioretention planters. Other GI elements such as enhanced street tree trenches can also be incorporated (see Fact Sheet D in Attachment 1). Several locations along the Euclid Avenue project corridor have potential as a neighborhood greenway, as shown in Figure 1.

Road Diet/Narrowing

The road diet concept involves narrowing the roadway to create room for bioretention swales rather than relying on existing planter space. This is especially appropriate in areas where the roadway is wider than necessary for its current use, and narrowing could slow traffic, reduce accidents, reduce roadway maintenance needs, and provide room for stormwater management.

City street standards can be developed to encourage road diets where appropriate. See Fact Sheet C in Attachment 1.

Enhanced Tree Trenches/Tree Planting

Street trees can be considered a stand-alone stormwater management practice, as they provide runoff control through interception of stormwater. Enhanced tree trenches can provide greater value than other infiltration practices because of the additional benefits of a street tree (shade, habitat, and aesthetics). Enhanced tree trenches provide stormwater management by capturing runoff in a storage reservoir (typically made of stone) beneath the planting soil. The project team identified opportunities for enhanced tree trenches where existing street trees are limited or absent along the Euclid Avenue project corridor. Installation of tree trenches is also an opportunity to install porous pavement sidewalks or parking strips, as shown in Fact Sheet D in Attachment 1.

Porous Pavement

This GI practice consists of a porous paved surface (asphalt, concrete or pavers) with an underlying storage bed and uncompacted subgrade to facilitate stormwater infiltration. It is well-suited for sidewalks, parking areas, alleys, minor streets, and other low-traffic areas. Porous pavement was considered a potential element of the enhanced tree trenches and the green alley GI practices.

Parking lane porous pavement. Instead of repaving with conventional pavement, the Euclid Avenue Water Main Replacement project (or other infrastructure project) could repave the street parking strip (eight feet wide) with porous asphalt or concrete. This may require pavement removal in addition to that strictly necessary for the utility replacement work, but provides stormwater benefits while retaining all of the street parking. See Fact Sheet D in Attachment 1 for an example of combining porous parking with enhanced tree trenches (described above).

Porous Concrete Sidewalk. Porous concrete sidewalks could be combined with any of the above GI practices.

Green Alleys

A green alley consists of a porous pavement strip in the center of an alley, which captures and infiltrates stormwater runoff from the alley and adjacent impervious areas. In this case study, the project team evaluated the costs and benefits of rerouting the water main through the alley instead of the main road. See Figure 1 and Fact Sheet E in Attachment 1.

Costs and Benefits

Figure 2 illustrates a comparison of costs per square foot (sf) of mitigated tributary area for the Euclid Avenue Water Main Replacement Project GI opportunities, and the "differential" capital cost of providing GI along with the water main replacement is compared to the cost of implementing GI as a stand-alone project. Integrating construction of GI practices with the water main replacement provides additional stormwater and other benefits at a lower cost than construction of GI alone. The cost savings vary among the different GI practices, but in each case, integrating GI with the water main project provides multiple benefits with an efficient use of resources. The full pavement replacement under the road diet concept provides the greatest cost savings (with a cost of about $2/sf mitigated); see Figure 2. The enhanced tree trench practice is the least cost-effective integrated GI concept, and contains the most uncertainty (largest cost range).

It is important to note that these costs can vary depending on site- and project-specific conditions, so that a range of cost savings is a more accurate reflection of the integrated GI concept. These cost saving estimates also reflect many sizing and quantity assumptions, which would also vary for other projects.

If all of the GI practices were implemented in conjunction with the Euclid Avenue Water Main Replacement Project, the total area that would be managed is approximately 2.6 acres at an estimated total planning-level capital cost of $382,000. In contrast, the total plan-level cost of implementing these GI practices alone is an estimated $618,000.

Cannon Park CSO Basin (Basin 12) Opportunities

Partnering opportunities for implementing GI within the Cannon Park CSO Basin present potential cost-effective strategies for achieving multiple service area goals. This case study evaluated and mapped the constraints on the technical feasibility of implementing GI, then identified remaining locations where multiple public works service goals overlapped. The project team considered the same suite of GI practices developed from the Euclid Avenue case study (described above). This evaluation included field investigations, interviews with City of Spokane staff, identification of existing service area needs in the basin, and the concepts in the *Eastern Washington Low Impact Development Guidance Manual* (Washington Department of Ecology [Ecology], 2013a) to identify the potential GI implementation strategies. The areas where service goals overlapped with technically feasible areas for GI were then entered into a planning-level database and prioritized to evaluate potential cost savings and benefits.

The results of this case study could inform the development of a framework for prioritizing projects with partnering opportunities. This case study also estimates the level of implementation (i.e., the percentage of each block expected to actually be retrofitted with GI), and budget needed to achieve the basin's CSO reduction goals.

Constraints

A separate analysis for the City of Spokane Integrated Plan recently identified areas potentially feasible for underground injection control (UIC)/drywells and bio-infiltration within the City's CSO basins.

The areas considered to be potentially feasible for infiltration represent the areas that could be separated from the combined sewer system and diverted to UIC/drywells or swales (including rooftops and yards). The feasible area for UIC/drywells along includes additional land use and traffic use restrictions, and is therefore a smaller subset of the feasible area for swales. The feasibility criteria reflected requirements in Ecology's *Stormwater Management Manual for Eastern Washington* (Ecology, 2004), the *Spokane Regional Stormwater Manual* (Spokane County et al., 2008), and *Determination of Treatment and Source Control for UIC Wells in Washington State* (Ecology, 2006). In summary, these criteria included:

- 50-foot setback from the top of slopes greater than 15 percent
- 60-foot average setback from buildings on slopes of 5-15 percent
- 100-foot setback from contaminated sites (identified by Ecology)
- Excluded areas within U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) mapped soil units classified as Moderately Well Drained, Poorly Drained, and Very Poorly Drained under the Natural Drainage Class attribute (NRCS, 2012).
- Excluded areas within NRCS mapped soil units with less than 200 centimeters in the Depth to Any Restrictive Layer attribute (NRCS, 2012).
- Excluded areas within soil units with rock outcrops in the name, or rock described as within 60 inches of the surface in the soil map unit description (NRCS, 2012).

- Excluded areas within 100 feet of water wells and all areas within Wellhead Protection Zones
- UIC/drywells only: excluded areas within areas designated for non-residential land uses (City GIS data)
- UIC/drywells only: excluded areas within 50 feet of streets with an average daily traffic (ADT) value greater than 7,500, and within 150 feet of high traffic intersections (City GIS data)

Spokane County soil maps indicate an area of basalt bedrock in the southeastern portion of the Cannon Park CSO Basin. This mapped soil type was not incorporated into the feasibility criteria listed above, but may still limit the potential for infiltration and therefore GI implementation in this area. This area was excluded from the GI opportunities identified in this case study.

Beyond technical constraints, public perception and community willingness to participate will likely vary and in some cases may constrain GI implementation. However, it may also enhance opportunities to implement GI where community groups and individual residents are interested in the variety of benefits associated with the integrated projects described above. Therefore, a community participation factor (implementation level) was used to reflect assumed participation in this evaluation of the Cannon Park CSO Basin. This participation factor is based on professional judgment (including space constraints), however should be monitored and adjusted as the GI programs and projects mature.

Opportunities

Potential partnering opportunities were then identified in areas without the constraints listed above, and where City information (mainly in GIS form) indicated plans or potential for transportation and utility improvements. Figure 3 shows the blocks identified as integrated partnering opportunities, labeled by ID number as listed in the database. Figure 4 shows the background data used to identify these blocks. These data include:

- Planned bikeway opportunities (City GIS data)
- Bus route improvement plans (City GIS data; and Spokane Transit Authority plans [STA 2010])
- Possible lead pipe joint replacement in the City's water main (City GIS data)
- Re-paving needs, where the pavement condition index (PCI) is less than 60 (City GIS data)
- Absence of street trees (City arborist GIS data)
- Unimproved streets where sidewalks are absent (City GIS data)
- Residential streets where the community may be interested in participating in GI, although no other improvement opportunity (listed above) is present
- Accident-prone area (City map)

GI Database

The project team developed a database that contains key information about each block identified as a potential GI integrated opportunity in the Cannon Park CSO Basin. This database will help the City identify and track opportunities for integrating GI into other public works projects, which could result in significant cost efficiency. It also provides a mechanism for continuously refining planning-level cost estimates and estimations of CSO reduction benefits as more detailed information is gathered. The database is a Microsoft® Excel matrix that lists the following for each block identified as a potential opportunity:

- Unique identification number
- Opportunity type(s), e.g., bike plan, PCI <60
- Tributary area – assumed to be limited to the paved street area
- Implemented tributary area – a percentage of the total tributary area, based on an estimate of community acceptance and participation
- Most applicable GI practice
- Cost per sf of tributary area managed
- Total cost (planning level)
- Control volume reduction (individual blocks and cumulative)
- Priority ranking
- Cumulative cost

Database inputs and assumptions about implementation factors, tributary area, and unit costs may be refined in the future, in which case the cost-benefit results will also be updated.

To develop the cost estimates used in the database, the project team used the Euclid Avenue case study unit cost estimates, then added an additional five percent savings per partnering opportunity. This approach is based on the assumption that administrative, mobilization, traffic control, and non-physical costs would be shared among integrated projects.

GI Practices. In the GI database, each opportunity (block) was assigned a GI practice (i.e., strategy) that was considered most applicable to that location. The green street GI strategy used in the database is assigned only to arterials that have multiple objectives that would likely require a full street retrofit and would combine with a suite of GI practices (bioretention planters, curb bulbs, enhanced tree trenches). These green street opportunities likely have a lower implementation probability than others because they do not include a pavement improvement opportunity (PCI <60), and they therefore lack justification for a full street retrofit. Tree trenches were not considered a potential stand-alone GI practice in this case study. The GI practices considered in this Cannon Park Basin case study included the following:

- Bioretention planters
- Green alleys
- Porous pavement
- Curb bulbs
- Road diet (reduction in impervious area/road width)
- Green streets

If the block is a residential street, the most applicable GI practice was curb bulb unless the existing planter was at least 8 feet wide. In this case, the most applicable GI practice was considered to be a linear bioretention planter (i.e., roadside raingarden).

In one example, Maxwell Avenue represents an opportunity to implement the green street GI strategy by incorporating a combination of GI and other elements that enhance pedestrian and bicycle safety. This arterial is identified as a potential bikeway opportunity and is also a major bus route. An intersection improvement opportunity was identified at Maxwell Avenue and Cedar Street, where an existing island median could be replaced with a raingarden.

Costs

Figure 5 illustrates the relationship between the increasing cumulative cost of implementing GI throughout the basin and the increasing benefit (control volume reduction), based on the GI database inputs. Figure 5 includes data from the blocks where neighborhood participation is the only identified opportunity.

These data show that some GI practices can provide a lower cost per gallon of control volume (or sf impervious tributary area managed) than typical gray storage projects, which can range from $12.50 to $30 per gallon control volume reduction. The lower portion of the curves represent those GI opportunities that potentially provide benefits at a lower cost than gray projects. These opportunities should be considered first.

These planning level costs in the GI database are based on cost per sf of managed impervious area ($/sf) values developed for each GI practice under the Euclid Avenue case study. For example, curb bulbs are assumed to cost $2.50/sf of managed impervious when installed under a full project integration and full pavement restoration scenario. The estimated cost of curb bulbs in an area where the only opportunity is neighborhood participation, assuming no project integration, is $3.66/sf.

To provide a planning-level estimate of possible budget needs for implementing GI in the Cannon Park CSO Basin, total costs for several implementation scenarios were calculated based on the assumptions described above. Table 1 below lists a low, middle, and high cost range for implementing all of the integrated GI opportunities identified in the database; the total cost for moderate implementation of integrated GI opportunities; and the total cost for implementing all the GI projects without integration. The Moderate Implementation scenario reflects the point where GI is cost-competitive with gray infrastructure projects; above this implementation level, this competitiveness generally decreases. Each of these implementation scenarios is shown as a point on the curves in Figure 5.

TABLE 1
Planning-Level Cost Estimates for GI Implementation

Implementation Scenario	Total Planning-Level Cost Estimate	
	With Partnership	**Without Partnerships**
Full Implementation of Integrated GI Opportunities (~0.18 MG CV reduction)[1]	$2.8M ($2.0M - $4.2M)[2]	$3.7M ($2.6M - $5.5M)
Moderate Implementation of Integrated GI Opportunities (~0.12 MG CV reduction)[1]	$1.6M ($1.1M - $2.4M)	$2.5M ($1.7M - $3.8M)

[1] MG = million gallons; CV = control volume
[2] Approximate cost range per Level 5 Cost Estimate (-30% to +50%)

Operations and Maintenance

The following sections describe regulatory requirements and provide examples of GI operations and maintenance (O&M) programs in use by jurisdictions across the country.

Regulatory Requirements and Guidance

Whether GI facilities within the ROW are maintained by the municipality or property owners, the state requires enforceable standards for GI maintenance, as well as the municipality's legal authority to inspect all facilities and enforce standards. The *Guidance Document: Western Washington Low Impact Development (LID) Operation and Maintenance (O&M)* (Ecology, 2013b) describes a variety of tools recommended for implementing a GI maintenance program. These tools are also applicable to eastern Washington.

The stormwater code and manual should establish the jurisdiction's legal authority to inspect privately-maintained GI facilities and enforce standards. It should also establish the enforcement mechanisms, including fee triggers, amounts and schedules. Formal maintenance agreements then form the basis for private maintenance of GI facilities in the ROW. Inspections should occur at least annually, and Ecology (2013b) also recommends spot checks of GI and other stormwater facilities after major storm events, to identify special maintenance needs.

A tracking system is necessary to support effective maintenance and maximize long-term performance of stormwater facilities. The tracking system typically includes location information, maintenance logs, legal agreements, enforcement documents, inspection forms, and the O&M manual used for the project. Guidance on maintenance tracking systems is available from http://stormwatercenter.net. The structure of the tracking system varies depending on the requirements set forth in the stormwater code.

Providing support for private property owners conducting maintenance can occur through various mechanisms, such as educational workshops and training programs, technical advice and materials, a dedicated staff contact or "hotline" for property owners to go to with questions or concerns, and awards and recognition for properly maintained facilities. Providing this support will help ensure compliance with required maintenance.

The following section describes different types of O&M programs and maintenance agreements and provides examples from other municipalities.

O&M Programs

Maintenance responsibilities for GI systems within the public ROW can be assumed completely by the City, shared between adjacent property owners and the City, transferred to third-parties (e.g., non-profit organizations), or transferred completely to adjacent property owners. For City investment in GI on private property (e.g., through partnerships, rebates or incentives), maintenance should generally be performed by the property owner but with mechanisms to ensure that maintenance occurs in perpetuity. Table 2 lists some of the key tools, examples, and considerations for each of these types of maintenance programs.

Note that for all of these programs, regardless of who is performing maintenance, the following are key considerations for the municipality:

- Maintenance manual – Development of a maintenance manual is critical to establishing standard operating procedures that meet the requirements necessary to promote long-term performance of GI projects.
- Tracking system

  - Several tracking software programs are available, such as GIS-based Cityworks.
  - Custom-built tracking systems using Microsoft™ Excel or Access are also an option.
- Inspections – Require training municipal staff and/or skilled professionals
- Reporting requirements – These are based on regulatory guidelines and standards, including City stormwater code.
- Staff time – City employee time will be needed either for actual maintenance or to provide technical assistance, which may include formal training of volunteers, property owners, and contractors.

TABLE 2
Summary of O&M Program Types for ROW Projects

Responsible O&M Entity	Program Type	Examples	Considerations
Municipality	Service Level designation	Seattle Public Utilities, WA Philadelphia, PA	Staffing Contracting of some routine/non-routine activities
Shared: Municipality & Property Owners	Level of service designation Training Covenants Homeowner agreements	Seattle Public Utilities, WA Olympia, WA – see Attachment 2 Seattle Public Utilities and King County, WA (RainWise)	Documentation of maintenance standards and corresponding levels of effort and resources required Documentation of legal obligations Enforcement mechanisms Technical assistance available to participants (e.g., manual) Reporting requirements
Property Owners	Stormwater fee discounts	Columbus, OH Charlotte, NC Tulsa, OK	Maintenance standards and/or facility effectiveness and corresponding discount values Technical assistance available to participants
Third Parties	Adopt-a-raingarden programs Agreements with NGOs, other third parties Public-private partnerships	City of Owatonna, MN Chittenden County, VT New Orleans, LA Onondaga Co., NY Victoria, BC St. Louis, MO Prince George's County, MD Kansas City, MO King County, WA	Types of incentives (monetary; recognition) Technical assistance available to participants (e.g., manual) Documentation of maintenance standards and corresponding levels of effort and resources required Contracting

Service Levels. Seattle Public Utilities (SPU) produced a manual for routine GI maintenance (SPU, 2009). This manual defines four different service levels (A through D, or “Excellent” through “Poor”), each of which correspond to specific conditions at different types of stormwater management facilities. For vegetated stormwater facilities, service levels and their matching characteristics are described in terms of aesthetics and functionality. Service Level B ("Good Effort") typically describes the conditions necessary to protect the facility's functions but not necessarily its aesthetics. Portland, Oregon, also uses a Service Level system.

Service levels should have unique and specific combinations of maintenance activities, frequencies, and standards, and be linked to cost estimates and budgets. For example, Service Level ***A*** for a roadside raingarden would include ***X*** site visits per year including ***X*** hours of weeding at a cost of $***X***.

Covenants. A maintenance covenant is a legal agreement between a property owner and the City/County that declares each entity's responsibilities and rights of access. As an example, the maintenance covenant with residential property owners developed for Olympia, Washington is included as Attachment 2. Several other examples are provided by Ecology (2013b). At a minimum, these covenants or maintenance agreements should include:

- Record of the maintenance covenant in the property deed
- Routine maintenance activities to be performed
- Maintenance schedules and reporting requirements
- Inspection responsibilities and frequency
- Right of access to private property (if necessary) for inspections
- Remedies for maintenance issues that arise, such as the City's commitment to provide technical assistance
- Remedies for failure to maintain, including the right to charge the property owner for the cost of repairs due to such failure

The Olympia, Washington, covenant provided in Attachment 2 includes language requiring the property owner to cover the cost of maintenance or repair in case the property owner is not able to perform the required maintenance.

Stormwater and/or Sewer Utility Fee Discounts. The framework for this type of maintenance program could include performance-based credits and associated discounts. The U.S. Environmental Protection Agency's (EPA) GI municipal handbook (EPA, 2009) describes stormwater fee discount programs in jurisdictions across the country. Examples of these programs include:

- Columbus, Ohio: a stormwater fee discount is available for commercial property owners who perform the maintenance on a publicly-owned stormwater system, on a dollar per linear foot per year basis, up to 100 percent of the fee (EPA, 2009).
- The Clean River Rewards Program in Portland, Oregon: awards a 65 percent stormwater fee discount to both residential and commercial property owners who maintain stormwater facilities in the public right-of-way according to standards in the project's on-file O&M plan (City of Portland Environmental Services, 2014a).
- Charlotte, North Carolina: the fee reduction (percent) is proportional to the effective reduction in impervious area from a properly maintained roadside raingarden in a program serving commercial and residential property owners (http://charmeck.org/stormwater/feesandbilling/pages/canireducemyswsfee.aspx; EPA, 2009).
- Tulsa, Oklahoma: the credit for private maintenance of onsite stormwater facilities is based on the estimated cost to the City of Tulsa for providing maintenance itself, up to the same

percentage (60 percent) of the City's budget that is reserved for maintenance (http://www.cityoftulsa.org/media/17773/Title11A_000.pdf; EPA, 2009).

Many other examples of stormwater fee discount programs across the country are described by EPA (2009). These programs are similar in concept to the adopt-a-raingarden programs described below, with the addition of a monetary incentive in the form of a utility fee discount.

Adopt-a-Raingarden Programs. Some municipalities or organizations host adopt-a-raingarden programs to provide routine maintenance on public raingardens that are completely voluntary, require no binding legal commitment, and provide no monetary incentive. These programs promote the community-building and educational benefits of volunteer work on the raingardens. A few of these programs include:

- City of Owatonna, Minnesota, where the participating organization is acknowledged on a sign at the raingarden (http://ci.owatonna.mn.us/stormwater/rain-gardens/adopt-a-rain-garden)
- Chittenden County, Vermont (http://ccstreamteam.org/index.php/volunteer/adopt-a-rain-garden)
- New Orleans, Louisiana (http://groundworknola.org/AdoptaRaingarden.html)

Several jurisdictions around the country provide a rebate for residential property owners who build their own raingardens. These types of programs are also often called adopt-a-raingarden programs. The City of Tacoma, Washington, provides a rebate of up to $2/sf of impervious surface mitigated by a residential raingarden constructed under a retrofit within two priority watersheds (http://www.cityoftacoma.org/cms/One.aspx?portalId=169&pageId=37486). The program includes a signed agreement for the owner's maintenance of the raingarden for five years.

Other Third-Party Agreements. Onondaga County in New York is developing a contract with a "Green Maintenance Task Force" based on unit costs for maintenance activities (weeding, watering, etc.). Under this contract, the Task Force will also be able to complete unfinished maintenance on projects assigned to private property owners. The contract with the Task Force will include tracking the maintenance activities using the County's system.

Recognition Awards for Exemplary Maintenance Performance. Recognition for green practices (maintaining GI) is used as an incentive for businesses in (among others) King County, Washington, (Businesses for Clean Water) and Portland, Oregon, (Eco-logical Business Program), where commercial award recipients receive certification, display materials, and recognition online and at public events. Recognition awards could also function as an incentive for residential participants.

Bonds. Bonds are a financial surety measure typically used to ensure proper facility maintenance on a new development. Performance or maintenance bonds for the contractor at a new development requiring stormwater treatment facilities typically expire after two years (at most).

O&M Guidance Materials. SPU has also developed a maintenance standards document for GI that describes proper maintenance and refers to corresponding SPU standard specifications where appropriate (SPU, 2009). The City of Portland, Oregon, also produced a 22-page guidance manual specifically for homeowners responsible for maintenance of stormwater facilities (City of Portland Environmental Services, 2014b). Onondaga County developed a detailed maintenance guidance manual describing the level of effort and recommended schedule for specific maintenance activities for a range of GI practices (CH2M HILL, 2012).

O&M Costs

O&M costs vary based on the type of GI, its location and its complexity. For example, vegetated GI systems located in more visible urban areas will require more intensive maintenance than more naturalized approaches that are less visible to the public. Also, costs may be higher in the first few years following installation, and become lower as vegetation becomes fully established. The City of Seattle estimated labor hours and costs for maintenance of simple (e.g., raingarden) and complex (e.g., cascading swales) GI sites. Estimated costs per linear foot were between $1 and $4, depending on the complexity of the GI facility. For Service Level B (necessary to preserve function) under this labor cost estimate, the following maintenance steps are assumed:

- Twice-monthly landscape inspection and maintenance
  - Invasive insect, weed, and disease control
  - Watering
  - Mulching
  - Erosion control
  - Removal/trimming of organic material on pedestrian paths
  - Pruning
  - Litter and debris pickup and disposal
- Yearly hardscape inspection and maintenance: weirs, catch basins, curb cuts, culverts, pedestrian paths, etc.

Pierce County, Washington, estimates that annual maintenance costs for stormwater facilities are five to ten percent of the facility's capital cost (Appendix B, Ecology 2013b). This is consistent with other estimates from elsewhere in the country.

The City of Lancaster, Pennsylvania, estimates an annual maintenance cost of $10-17 per square foot of raingarden (http://www.saveitlancaster.com/wp-content/uploads/2011/10/Bioretention.pdf).

Conclusions

Both case studies described above demonstrate the potential for GI to provide value beyond that typically provided by conventional gray infrastructure and isolated (non-integrated) public works projects. The Euclid Avenue Water Main Replacement case study demonstrates a method for estimating cost savings (i.e., additional value provided at a lower cost) from integrating GI into other public works projects. The Cannon Park CSO Basin Opportunities case study provides the foundation for identifying opportunities to address multiple needs and for developing planning-level cost estimates.

A variety of incentive mechanisms can be used to encourage O&M cost-sharing between private property owners and municipalities. Clear legal agreements must complement these incentives in order to ensure the long-term success of GI facilities. A wide range of existing maintenance program structures, tracking tools, manuals, and other technical guidance is available from municipalities across the Pacific Northwest and the country, all of which can help the City develop an effective and sustainable GI program.

Recommendations

The project team recommends continuing to refine the GI database developed for the Cannon Park CSO Basin (Basin 12). This analysis should also better define the implementation levels of specific GI in the basin, track GI partnership costs and implementation levels, and refine the methodology for applying GI to other basins in the future.

The project team also recommends initiating City code modifications to support GI facilities, specifically those with private-public partnerships for maintenance, and developing supporting GI maintenance standards (e.g., service levels) and materials (manuals).

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Acronyms and Abbreviations

CSO	combined sewer overflow
EPA	Environmental Protection Agency (U.S.)
Ecology	Washington Department of Ecology
GI	green infrastructure
GIS	geographic information system
LID	low-impact development
O&M	operations & maintenance
NRCS	Natural Resources Conservation Service
PCI	pavement condition index
ROW	right-of-way
sf	square foot (feet)
SPU	Seattle Public Utilities
UIC	underground injection well
USDA	U.S. Department of Agriculture

Figures

Attachments

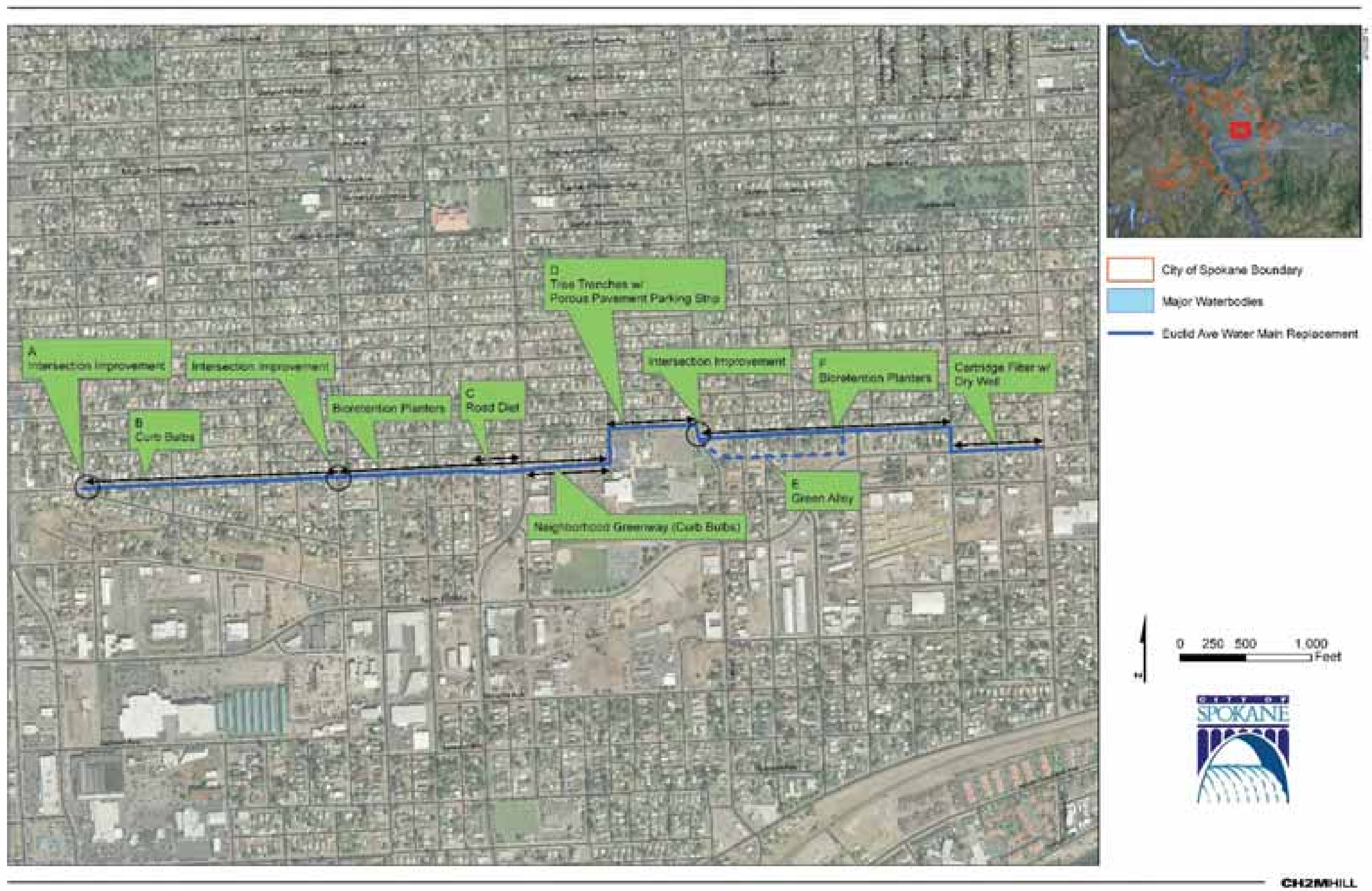


Figure 1
Overview: Euclid Avenue Case Study GI Opportunities

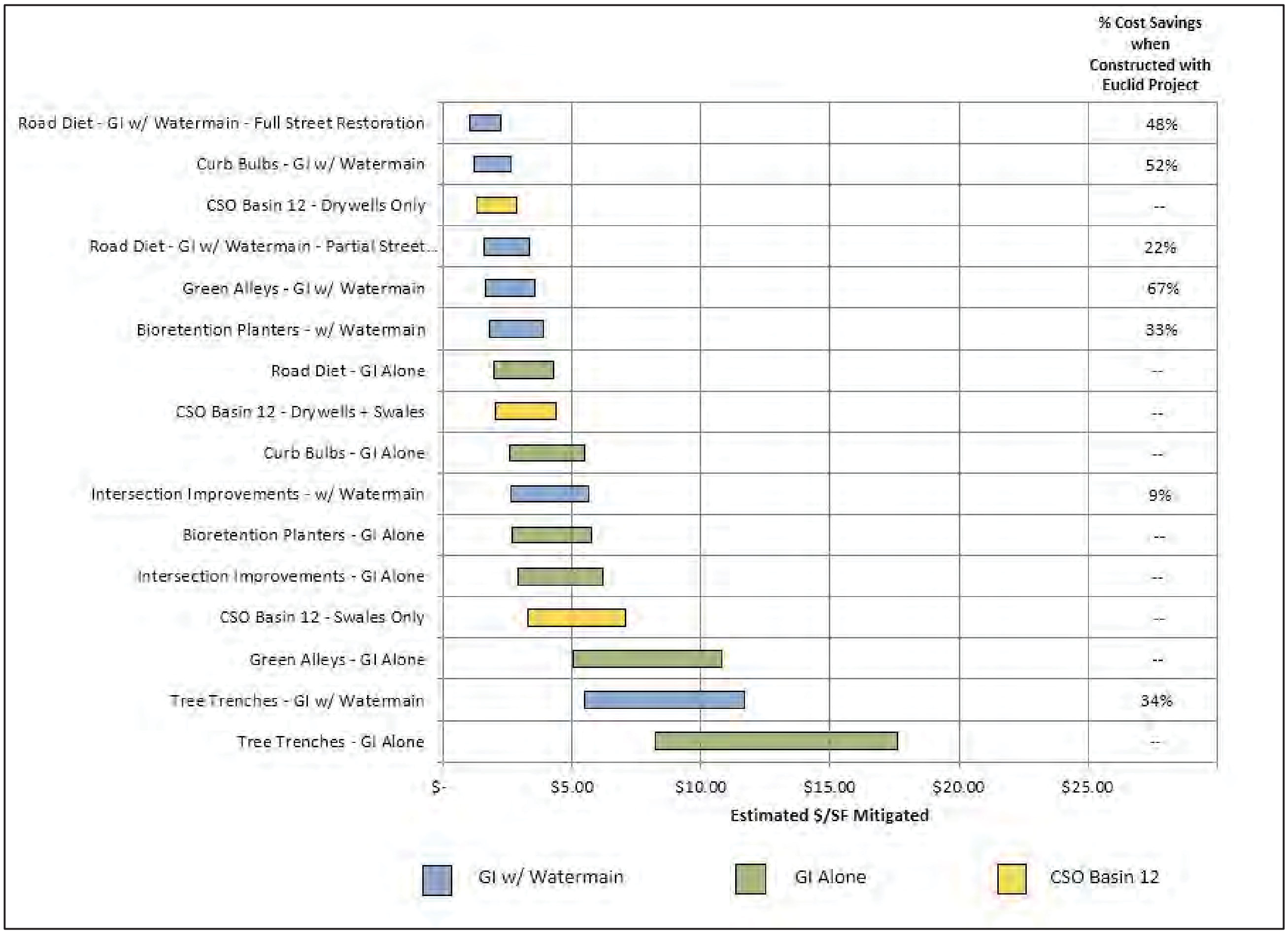


Figure 2
Comparison of Costs in Dollars per Square Foot Mitigated for GI Opportunities in the Euclid Avenue Water Main Replacement Project

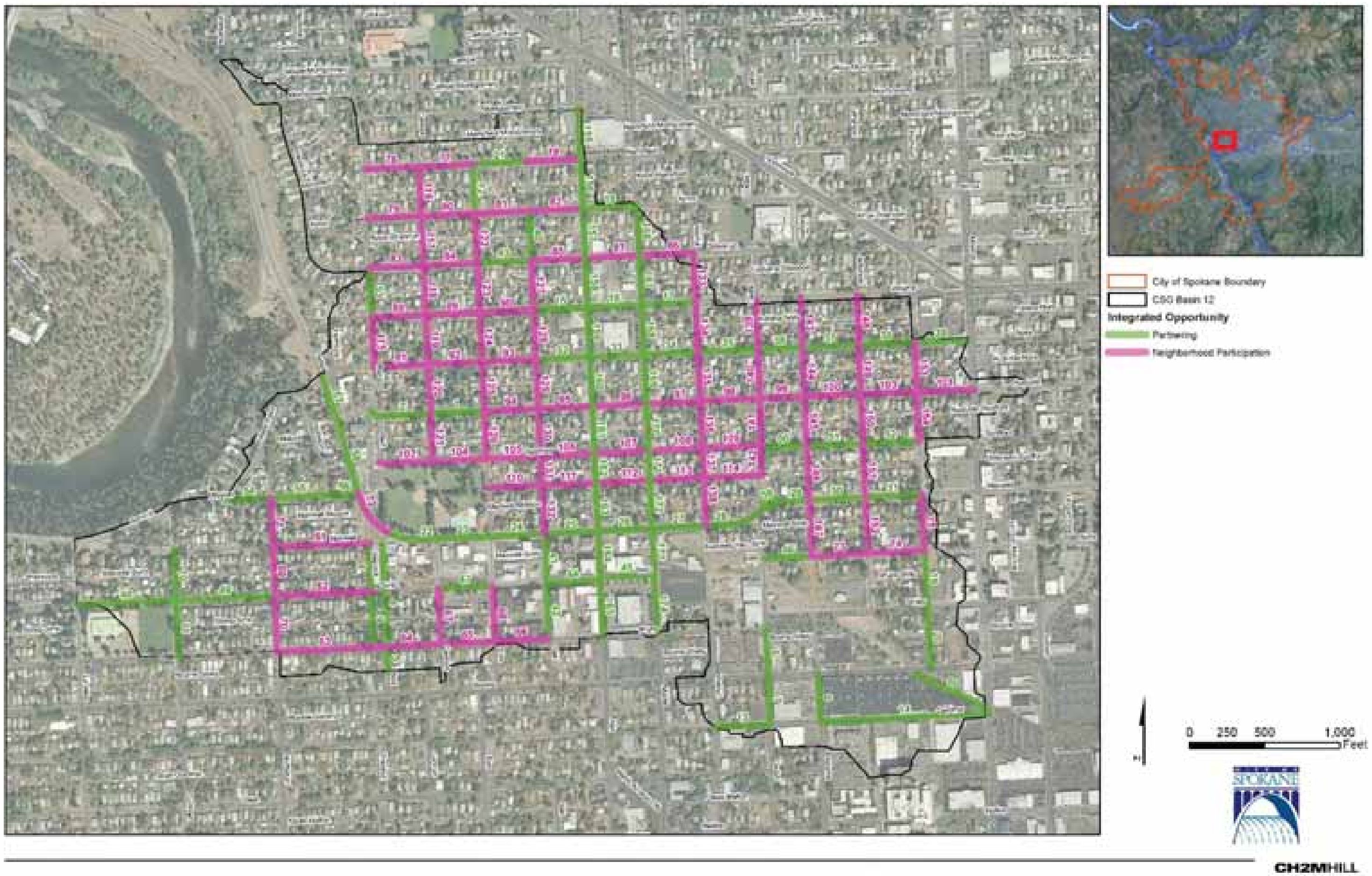


Figure 3
Cannon Park CSO Basin (Basin 12) Potential Integrated Partnership Opportunity Locations

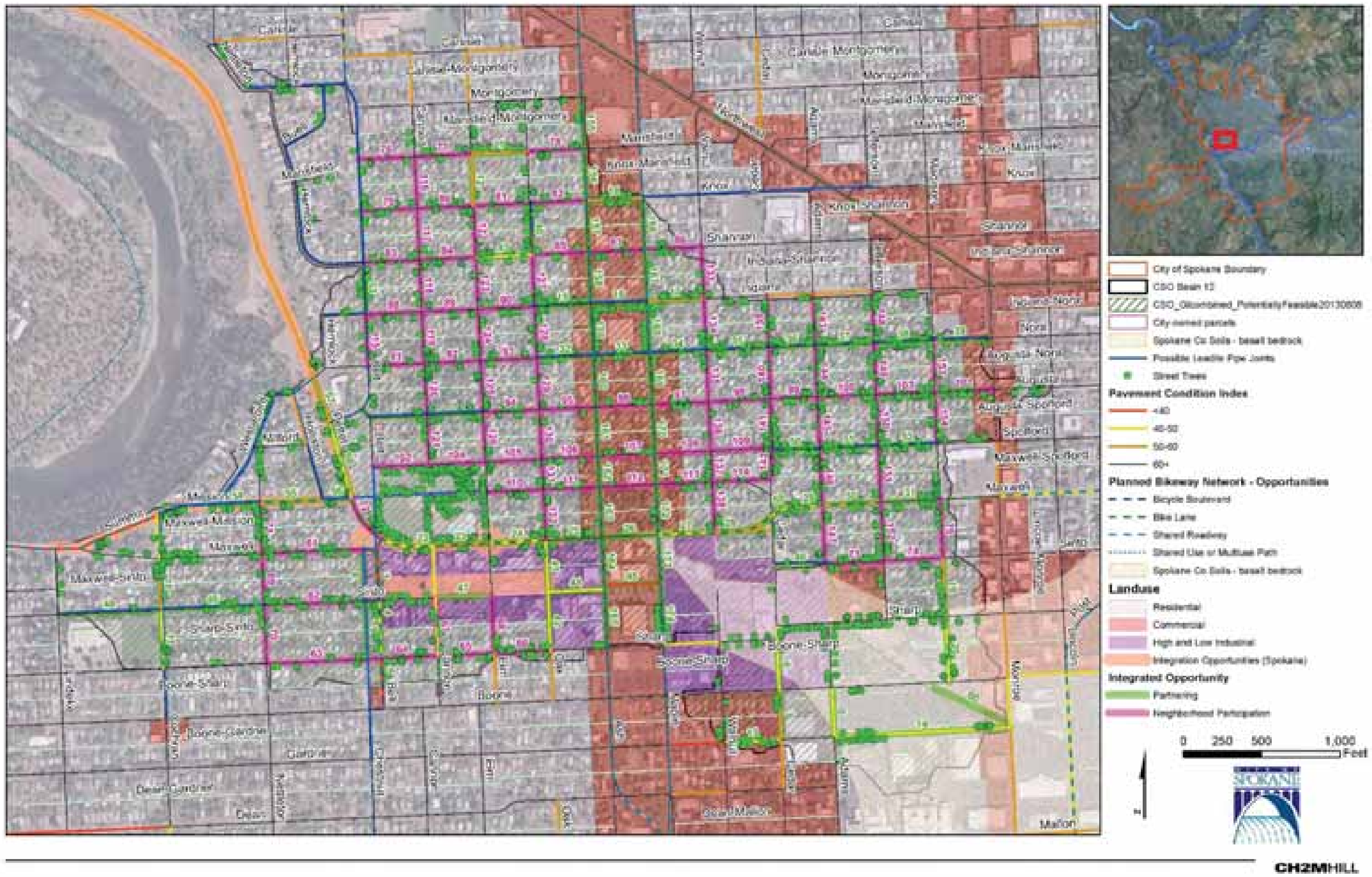
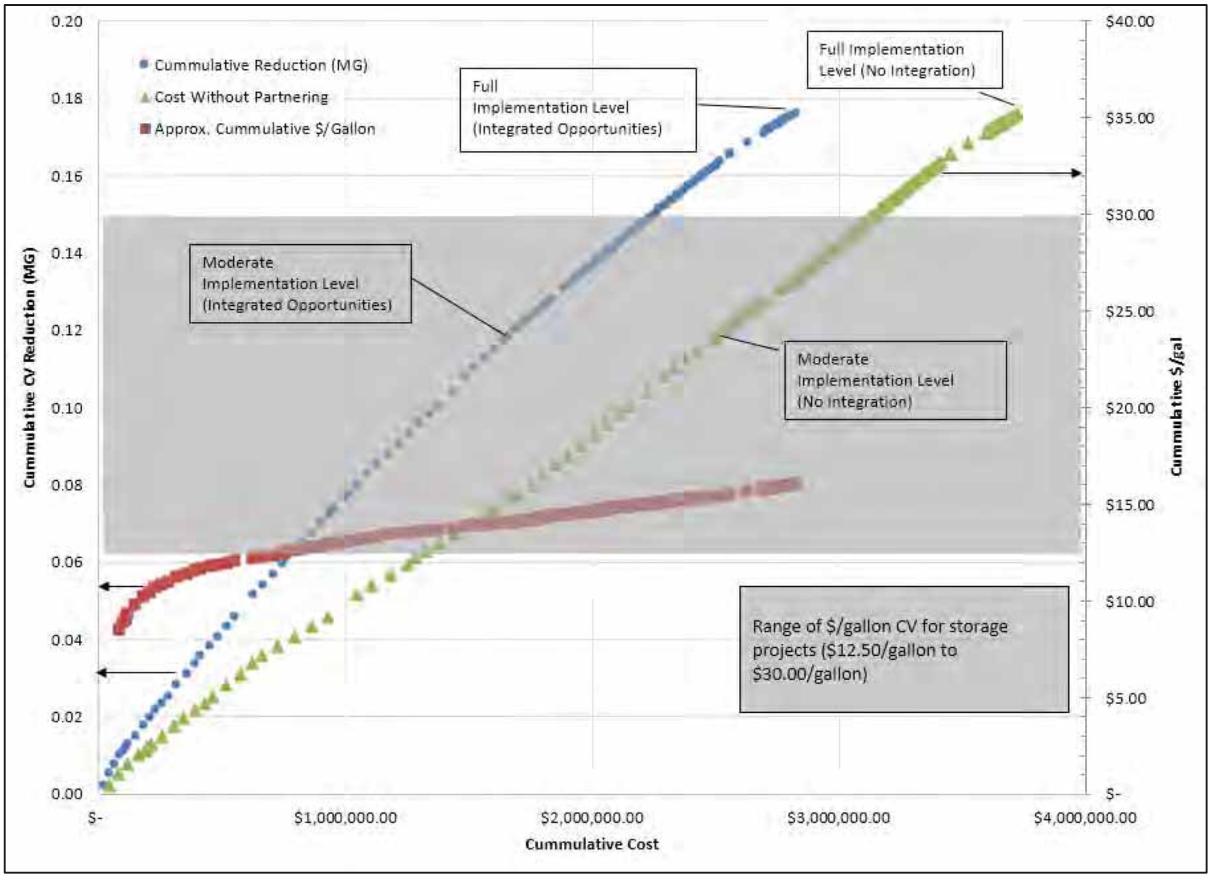


Figure 4
Cannon Park CSO Basin (Basin 12) Potential Integrated Partnership Opportunities – Data Used to Identify Opportunities



MG = million gallons
CV = control volume

Figure 5
Cannon Park Basin (CSO Basin 12) Integrated Projects
Cumulative Cost and Control Volume Benefit

Attachment 1

GI Practice Fact Sheets

Fact Sheet A – Intersection Improvements

Estimated GI Cost: $59,170
Estimated Savings from Combining with Water Main Project: (9%)
Estimated $/Square Foot Mitigated: $5.91

Benefits:

- Traffic calming
- Shared mobilization/traffic control/TESC/CM costs
- Increased public green space
- Reduces impervious footprint by narrowing road/intersection

Siting & Design Considerations:

- Revised layouts and siting should consider traffic movements, sight distance, maintenance access, etc.
- Ideally sited in areas suitable for infiltration, however, may be constructed with liners and underdrains (with flow restriction) to provide water quality and peak flow reduction
- Consider potential to route adjacent storm sewers to expand the area infiltrated beyond the directly adjacent pavement areas.

City of Lancaster "Green Infrastructure Project" for Stormwater Collection – the Walnut Street Project

- Captures runoff from 1.7 acres of streets and sidewalks
- Curb extensions with bioretention areas, subsurface infiltration beds, rain water harvesting cistern, porous paver patio on private property, porous paver parking in ROW
- Provides a green buffer between the busy roadways and pedestrians & restaurant outdoor dining
- Integrated with cart way repaving and pedestrian crosswalk improvements
- Removes 1.7 million gallons of runoff from Combined Sewer ($0.37/gal including roadway improvements)

Fact Sheet A – Intersection Improvements

This project utilized traffic safety and transportation funding (including grant funding), and showcases the efficient use of funding that can be achieved by integrating GI with other infrastructure improvements.

Fact Sheet B – Vegetated Curb Bulbs & Neighborhood Greenways

Estimated GI Cost: $19,230
Estimated Savings from Combining with Water Main Project: (46%)
Estimated $/Square Foot Mitigated: $3.15

Benefits:

- Traffic calming
- Pedestrian improvements
- Shared mobilization/traffic control/TESC/CM costs
- Reduces impervious footprint by narrowing road/intersection

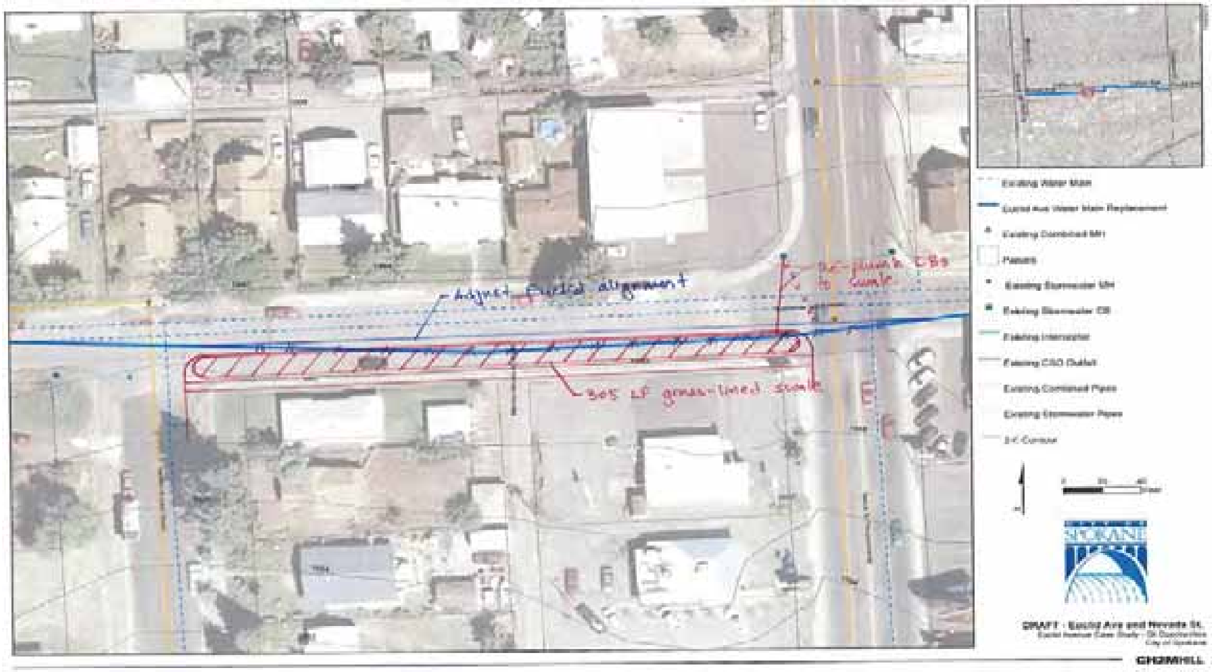
Siting & Design Considerations:

- New curb bulbs can overflow to existing inlets
- Feasible on steeper slopes with check dams
- Ideally sited in restricted parking areas, i.e. within 30-feet of stop signs and at fire hydrants.
- Bulbs should be sited so as to be detectable and compatible with snow removal and sweeping operations.

Curb bulbs in Berwyn, PA

Curb bulbs in Portland, OR

Fact Sheet C – Road Diet



Estimated GI Cost: $54,174 – 80,963
Estimated Savings from Combining with Water Main Project: (22-48% savings)*
Estimated $/Square Foot Mitigated: $1.49 – 2.23
**Cost range due to pavement patch vs. full restoration*

Benefits:

- Traffic calming
- Shared mobilization/traffic control/TESC/CM/pavement replacement/excavation/curb and gutter placement costs
- Reduces impervious footprint by narrowing road/intersection

Siting & Design Considerations:

- Revised layouts and siting should consider traffic movements, sight distance, maintenance access, etc.
- Ideally sited in areas suitable for infiltration, however, may be constructed with liners and underdrains (with flow restriction) to provide water quality and peak flow reduction
- Consider potential to route adjacent storm sewers to expand the area infiltrated beyond the directly adjacent pavement areas.

Both photos show infiltration cells used in a road diet.

Fact Sheet D – Tree Trenches

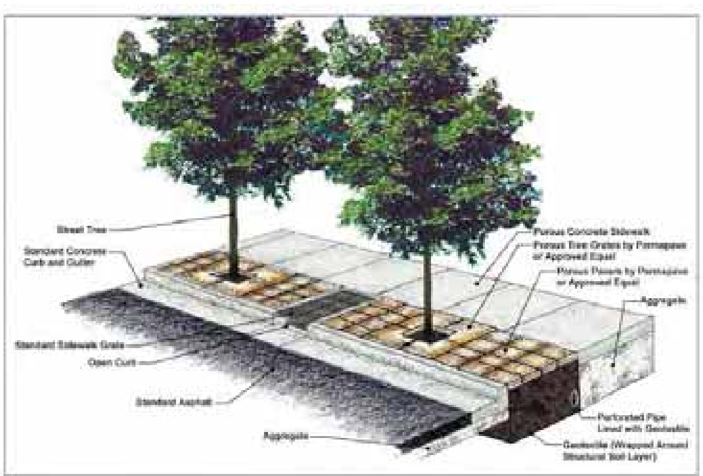
Estimated GI Cost: $187,145
Estimated Savings from Combining with Water Main Project: $94,456 (34%)
Estimated $/acre: $7.80

Benefits:

- Shared mobilization/traffic control/TESC/CM costs
- Tree canopy
- Preserved parking, consistent street section

Siting & Design Considerations:

- Prefabricated units available
- Requires careful species selection and sufficient root zone area
- Must avoid conflicts with overhead utilities and street signs



Typical street tree trench cross-section with structural soil and adjacent infiltration trench

Fact Sheet E – Green Alleys

Estimated GI Cost: $23,660
Estimated Savings from Combining with Water Main Project: $48,409 (67%)
Estimated $/Square Foot Mitigated: $2.37

Benefits:

- Improved water quality (unpaved roads)
- Shared mobilization/traffic control/TESC/CM costs
- Improved residential access and garbage pickup

Siting & Design Considerations:

- Need to avoid utility and building foundation conflicts

Typical green alley cross-section

Fact Sheet F – Bioretention Planters

Estimated GI Cost: $31,059
Estimated Savings from Combining with Water Main Project: $15,078 (33%)
Estimated $/Square Foot Mitigated: $2.59

Benefits:

- Minor traffic calming
- Low cost (no repaving)
- Shared mobilization/traffic control/TESC/CM costs
- Maintains parking

Siting & Design Considerations:

- Requires careful plant selection & possibly soil amendment
- Maintenance cost is similar to traditional landscaping
- Requires consideration of parking step-off and crossing areas

A recently-installed bioretention planter in a residential area.

Bioretention planter in an urban area in Syracuse, NY

Attachment 2
Example GI Maintenance Covenant

(CORPORATE VERSION)

AGREEMENT TO MAINTAIN
STORMWATER FACILITIES AND TO IMPLEMENT A
POLLUTION SOURCE CONTROL PLAN
BY AND BETWEEN ___________________________
(HEREINAFTER "THE LOCAL GOVERNMENT") AND
_________________________________, AND
ITS HEIRS, SUCCESSORS, OR ASSIGNS
(HEREINAFTER "OWNER")

The upkeep and maintenance of stormwater facilities and the implementation of pollution source control best management practices (BMPs) is essential to the protection of water resources in _____________. All property owners are expected to conduct business in a manner that promotes environmental protection. This Agreement contains specific provisions with respect to maintenance of stormwater facilities and use of pollution source control BMPs. The authority to require maintenance and pollution source control is provided by ordinance.

LEGAL DESCRIPTION:

Whereas, Owner has constructed improvements, including but not limited to, buildings, pavement, and stormwater facilities on the property described above. In order to further the goals of the Local Government to ensure the protection and enhancement of Local Government's water resources, the Local Government and Owner hereby enter into this Agreement. The responsibilities of each party to this Agreement are identified below.

OWNER SHALL:

(1) Implement the stormwater facility maintenance program included herein as Attachment "A".

(2) Implement the pollution source control program included herein as Attachment "B".

(3) Maintain a record (in the form of a log book) of steps taken to implement the programs referenced in (1) and (2) above. The log book shall be available for inspection by Local Government staff at Owner's business during normal business hours. The log book shall catalog the action taken, who took it, when it was done, how it was done, and any problems encountered or follow-on actions recommended. Maintenance items ("problems") listed in Attachment "A" shall be inspected on a monthly or more frequent basis as necessary. Owner is encouraged to photocopy the individual checklists in Attachment A and use them to complete its monthly inspections. These completed checklists would then, in combination, comprise the monthly log book.

(4) Submit an annual report to the Local Government regarding implementation of the programs referenced in (1) and (2) above. The report must be submitted on or before May 15 of each calendar year and shall contain, at a minimum, the following:

(a) Name, address, and telephone number of the business, the person, or the firm responsible

For recording purposes, please ***do not*** write in margins.

for plan implementation, and the person completing the report.

(b) Time period covered by the report.

(c) A chronological summary of activities conducted to implement the programs referenced in (1) and (2) above. A photocopy of the applicable sections of the log book, with any additional explanation needed, shall normally suffice. For any activities conducted by paid parties not affiliated with Owner, include a copy of the invoice for services.

(d) An outline of planned activities for the next year.

THE LOCAL GOVERNMENT WILL, AS RESOURCES ALLOW:

(1) Provide technical assistance to Owner in support of its operation and maintenance activities conducted pursuant to its maintenance and source control programs. Said assistance shall be provided upon request and at no charge to Owner.

(2) Review the annual report and conduct occasional site visits to discuss performance and problems with Owner.

(3) Review this agreement with Owner and modify it as necessary.

REMEDIES:

(1) If the Local Government determines that maintenance or repair work is required to be done to the stormwater facility existing on the Owner property, the Stormwater Manual Administrator shall give Owner within which the drainage facility is located, and the person or agent in control of said property if different, notice of the specific maintenance and/or repair required. The Administrator shall set a reasonable time in which such work is to be completed by the persons who were given notice. If the above required maintenance and/or repair is not completed within the time set, written notice will be sent to the persons who were given notice stating the Local Government's intention to perform such maintenance and bill Owner for all incurred expenses. The Local Government may also adjust stormwater utility charges on the Owner's bill if required maintenance is not performed.

(2) If at any time the Local Government determines that the existing system creates any imminent threat to public health or welfare, the Administrator may take immediate measures to remedy said threat. No notice to the persons listed in (1), above, shall be required under such circumstances.

(3) The Owner grants authority to the Local Government for access to any and all stormwater system features for the purpose of inspection, and performing maintenance or repair as may become necessary under Remedies (1) and/or (2).

(4) The persons listed in (1), above, shall assume all responsibility for the cost of any maintenance and for repairs to the stormwater facility. Such responsibility shall include reimbursement to the Local Government within 30 days of the receipt of the invoice for any such work performed. Overdue payments will require payment of interest at the current legal rate for liquidated judgments. If legal action ensues, any costs or fees incurred by the Local Government will be borne by the parties responsible for said reimbursements.

(5) The owner hereby grants to the Local Government a lien against the above-described property

in an amount equal to the cost incurred by the Local Government to perform the maintenance or repair work described herein.

This Agreement is intended to protect the value and desirability of the real property described above and to benefit all the citizens of the Local Government. It shall run with the land and be binding on all parties having or acquiring from Owner or their successors any right, title, or interest in the property or any part thereof, as well as their title, or interest in the property or any part thereof, as well as their heirs, successors, and assigns. They shall inure to the benefit of each present or future successor in interest of said property or any part thereof, or interest therein, and to the benefit of all citizens of the Local Government.

Dated at ____________, Washington, this ______ day of _________________, _____.

OWNER

By:________________________________
Authorized Agent for Owner

____

STATE OF WASHINGTON)
) **ss**
COUNTY OF THURSTON)

On this day and year above personally appeared before me, a Notary Public in and for the State of Washington duly commissioned and sworn, personally appeared __________________, to me known to be the ______________________ of _______________________ and acknowledge the said instrument to be the free and voluntary act and deed of said corporation, for the uses and purposes therein mentioned, and on oath stated that _____ is authorized to execute the said instrument and that the seal affixed is the corporate seal of said corporation.

WITNESS my hand and official seal the day and year first above written.

____

Notary Public in and for the State of
Washington, residing in ___________________

My Commission Expires: __________________

Dated at ____________, Washington, this ______ day of _________________, _____.

LOCAL GOVERNMENT

By:______________________________
Authorized Agent for Local Government

STATE OF WASHINGTON)
) ss
COUNTY OF THURSTON)

On this day and year above personally appeared before me, ______________________, to me known to be acting as Authorized Agent for_______________, a Municipal Corporation, who executed the foregoing instrument and acknowledged the said instrument to be the free and voluntary act and deed of said Municipal Corporation for the uses and purposes therein mentioned and on oath states he is authorized to execute the said instrument.

Given under my hand and official seal this ______ day of _____________, _____.

____
Notary Public in and for the State of
Washington, residing in _________________

My Commission Expires: ________________

APPROVED AS TO FORM:

____
Local Government Attorney

\\Calvin\cpd\FORMS\Agree to Maint Strmwtr Facilties-Corporation.wpd 12/9/09