Bureau of Environmental Services • City of Portland

System Plan

Combined and Sanitary Sewer Elements

Executive Report

March 2012

ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

Dan Saltzman, Commissioner • Dean Marriott, Director

CITY OF PORTLAND
ENVIRONMENTAL SERVICES
1120 SW Fifth Avenue, Room 1000, Portland, Oregon 97204 ▪ Dan Saltzman, Commissioner ▪ Dean Marriott, Director

March 8, 2012

SUBJECT: BES System Plan – Executive Report: Combined and Sanitary Sewer Elements

Dear System Plan Executive Report Readers:

The Bureau of Environmental Services (BES) is pleased to provide you with its latest edition of its infrastructure master plan, formerly known as its Public Facilities Plan; but now with a new name, the "BES System Plan." This System Plan reflects a shift to an asset management context; moreover, a more comprehensive view of what level of service is provided to our customers. Today, as the bureau faces the many environmental challenges presented by an ever changing world, BES is embracing asset management business practices to provide more transparent decision-making in meeting these challenges.

This 2012 edition of the BES System Plan supersedes the Public Facilities Plan 1999, and represents the next generation of BES planning. This System Plan represents the culmination of an eight year effort that in addition to this summary report, includes the completion of over one hundred supporting technical memorandums that describes in detail, every aspect of this work. This System Plan incorporates many industry leading innovations. Some of these key features include embedding the plan with state-of-the-art technological advances in GIS and hydraulic modeling, the incorporation of gray and green infrastructure solutions, utilizing asset management concepts that incorporate risk in prioritizing projects, and lastly, the layout of these digital documents enables the bureau to efficiently update the System Plan or create special purpose "ad hoc" reports, while allowing individuals to access its content through the internet.

This BES System Plan – Executive Report, summarizes the planning process, and contains a list of recommended projects needed to address the structural and capacity deficiencies within the City's combined and sanitary sewer infrastructure systems. System planning for other infrastructure elements (such as the stormwater and treatment plant elements) is currently under development, and upon their completion, will also join the BES System Plan family of companion infrastructure plans.

I hope you find this document interesting and the information useful in your own work. If you have questions or comments, please either call (503-823-7186), or email me (Lester.Lee@PortlandOregon.gov).

Very truly yours,

Lester E. Lee, PE, PLS
Program Administrator
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Acronyms and Abbreviations

AACE	Association for the Advancement of Cost Engineering
AR5	Fifth Assessment Report of the Intergovernmental Panel on Climate Change
ASM	Asset System Management
BES	Bureau of Environmental Services
CBWTP	Columbia Boulevard Wastewater Treatment Plant
CCTV	closed circuit television
CIP	capital improvement program
CSO	combined sewer overflow
CSP	concrete sewer pipe
DEQ	Department of Environmental Quality
ECV	environmental and community values
EMGAATS	Explicit Model Generation and Analysis Tool Set
EPA	Environmental Protection Agency
GIS	geographical information system
gpd/acre	gallons per day per acre
HYDRA	Hydrological Data Retrieval and Alarm
ICR	indicator to cost ratio
IDF	intensity-duration-frequency
MAO	Mutual Agreement and Order
mgd	million gallons per day
MS4	Municipal Separate Storm Sewer System
nBCR	net benefit to cost ratio
O&M	operations and maintenance

PBOT	Portland Bureau of Transportation
PBOT/MO	Portland Bureau of Transportation/Maintenance Operations
PFP	Public Facilities Plan
PVC	polyvinyl chloride
RCP	reinforced concrete pipe
RDII	rainfall dependent infiltration and inflow
ROI	return on investment
RUL	remaining useful life
SRDB	Sewage Release Database
SWMM	*City of Portland Stormwater Management Manual*
SWPI	Southwest Parallel Interceptor
TCWTP	Tryon Creek Wastewater Treatment Plant
T2R	Tabor to the River
USB	urban services boundary
VSP	vitrified clay sewer pipe

Overview

The City of Portland Bureau of Environmental Services (BES) prepared this Wastewater Sewer System Plan to address risks to its natural and built assets. This plan recommends projects that address structural and capacity deficiencies within its combined and sanitary sewer systems. These projects meet the BES core mission by protecting public health, water quality, and the environment in a manner that optimizes the return on investment for the rate paying customer. This Wastewater Sewer System Plan updates the combined sewer and sanitary sewer components of the 1999 *City of Portland Public Facilities Plan* (PFP).

Asset Management Approach

BES developed the Wastewater Sewer System Plan using an asset management approach focused on the assessment and mitigation of *risk* (in dollars), which is defined as the product of *consequences of failure (*in dollars*)* to meet BES levels of service and *likelihood of failure* (probability). In determining the consequences of failure, BES considered the impacts of structural and capacity deficiency failures, including sinkholes from collapsed sewers, basement sewer backups, surface flooding, and emergency repairs. These were quantified in dollars using triple-bottom-line (TBL) risk categories: economic, environmental, and social. Assessment of risk through a TBL analysis took into account not only the direct financial costs to BES and its customers, but also the cost attributed to not meeting levels of service related to physical habitat, compliance with regulations, public inconvenience and perception, and public health and safety. Using this approach, projects that mitigated the greatest risk to BES and were cost-beneficial were identified and recommended for implementation.

System Characterization

Pipe inspection data were used to characterize the structural condition of pipe segments throughout the combined and sanitary sewer systems. Most of the structural deficiency risk was found to be present in the eastside combined sewer basins.

Capacity deficiencies were identified for existing and future land use conditions through the use of detailed and calibrated computer models. These models predicted the locations where there is a risk of either combined sewage or sanitary sewage backing into basements or flooding onto streets or into streams. The most significant risk in the combined sewer area is predicted in the East Side Willamette CSO Service Area and in the Northwest Neighborhoods. The most significant risk in the sanitary sewer area is predicted in the West

Side Sanitary Sewer Service Area. The greatest number of unserved properties exists in the Southeast Sanitary Service Area.

Recommended Plan

After the development and evaluation of collection system improvement alternatives, the preferred alternatives were combined into recommended projects to address both structural and capacity risks within the system.

The recommended plan to address pipe structural deficiencies includes three types of pipe rehabilitation actions: monitor by inspection, perform spot repairs, and rehabilitate/replace the whole pipe. Monitor by inspection will be conducted as part of the ongoing BES operations and maintenance program. Spot repairs and whole pipe rehabilitations/ replacements formed the basis of four types of recommended plan projects that are based on pipe size, rehabilitation prioritizations, and relative location:

- Geographically-based, small-diameter (≤ 36 inches), large-scale projects
- Urgent, small-diameter, whole pipe rehabilitations/replacements and spot repairs
- Urgent, large-diameter (> 36 inches), whole pipe rehabilitations/replacements and spot repairs
- Remainder—small-diameter, structurally deficient pipes not included in the other previously described projects

The primary focus of the combined sewer system recommended plan projects is to provide adequate capacity to convey the design flow and resolve basement sewer backup risk. For the most part, this is accomplished by either increasing pipe capacity through the upsizing of pipe diameter or by routing stormwater runoff to street, roof, or parking stormwater control facilities to reduce flows into the collection system.

The recommended plan for the sanitary sewer system consists of projects to resolve capacity deficiencies and extend sewer service to unserved areas. Capacity deficiencies are resolved through a combination of gravity sewer improvement projects, pump station expansions, and a rainfall dependent infiltration and inflow (RDII) reduction program.

Short-Term Implementation Plan

The recommended short-term (10-year) implementation plan addresses structural deficiencies, capacity deficiencies, RDII, and odor control issues. The total capital cost of the short-term implementation plan projects is approximately $450 million, consisting of $175 million for pipe rehabilitation projects, $205 million for combined sewer capacity improvement projects, and $70 million for sanitary sewer capacity improvement projects.

Chapter 1: Introduction

1.1 Purpose

The Bureau of Environmental Services (BES) provides the City of Portland with programs to protect public health, water quality, and the environment primarily through the provision of wastewater collection and treatment, sewer construction and maintenance, stormwater management, and stream and watershed restoration and related services.

This *System Plan: Combined and Sanitary Sewer Elements: Executive Report* (Wastewater Sewer System Plan) identifies current and future sewer collection system infrastructure needs and recommends cost-beneficial repair and improvement projects for the next 20 years. This includes a short-term implementation plan for the next 10 years.

Recommended projects protect public health, water quality of local streams and rivers, and related environmental resources. This Wastewater Sewer System Plan has been developed within an asset management framework, and presents the mitigation of risks to the community related to structurally or hydraulically deficient pipelines, which may cause street flooding, basement sewer backups, unpermitted combined sewer overflows (CSOs), and excessive surcharging in major trunk lines. As such, this plan updates the combined sewer and sanitary sewer components of the 1999 *City of Portland Public Facilities Plan* (PFP). The stormwater component of the PFP is being updated separately.

1.2 Intended Readers

This Wastewater Sewer System Plan executive report was written for the following readers:

- Project design teams to provide a technical foundation for successful implementation of system improvements.
- Managers and staff of BES responsible for documenting and communicating plans to continue to provide reliable service, meet regulatory requirements, protect public health, protect the environment, and support the long-term goals of the community.
- City Council and City staff needing to know BES's long-term plans for sustaining the sanitary and combined sewer systems.
- Interested citizens to provide a better understanding of BES services and responsibilities, ongoing development and implementation of policies, methods, and projects to meet current and future needs and requirements.

1.3 Organization of this Report

This Wastewater Sewer System Plan is organized to provide an integrated synopsis of the main elements of the City's sewer system planning program, which includes development of pipeline rehabilitation, combined sewer, and sanitary sewer system plans within an asset management context.

The overview at the beginning of this report summarizes the purpose, asset management approach, system characterization, recommended plan, and short-term implementation plan.

In Section 2, the asset management approach is outlined as the framework for evaluating and implementing the various components of the plan. In Section 3, the future planning assumptions, levels of service, and performance measures that formed the basis for characterizing structural and capacity deficiencies and developing solutions are identified. The current and future states of the City's sewer system are assessed in Section 4.

The process for developing and analyzing collection system improvements is described in Section 5. The resulting recommended plan of improvements is presented in Section 6.

The plan for implementing these recommendations is outlined in Section 7. This consists of ranking the recommended projects by priority, developing short-term and long-term implementation plans, outlining a process for review and finalization of recommendations, and briefly discussing financial planning considerations.

Section 8 identifies the next steps of an adaptive management approach to ensure the plan is effective and cost beneficial and concludes with final thoughts about the results of this extensive planning effort.

Additional information about the material covered in the Wastewater Sewer System Plan can be found in a series of summary documents and technical memoranda listed in Appendix A—Select Bibliography. The recommended actions for CIP sewer system projects are summarized in Table B-1, provided in Appendix B.

Fact sheets are provided in Appendix C for each of the new projects recommended for the short-term implementation plan. The fact sheets are organized by pipe rehabilitation, combined sewer, and sanitary sewer in alphabetical order by project name or project number. Each fact sheet includes a project area map and the information needed to submit the project to the BES CIP development process for funding and implementation.

1.4 Overview of Sewer System Planning Program Tasks

This Wastewater Sewer System Plan integrates the results of the Pipe Rehabilitation Plan, Combined Sewer System Plan, and the Sanitary Sewer System Plan as one step in the BES asset management business process diagrammed in Figure 1-1.

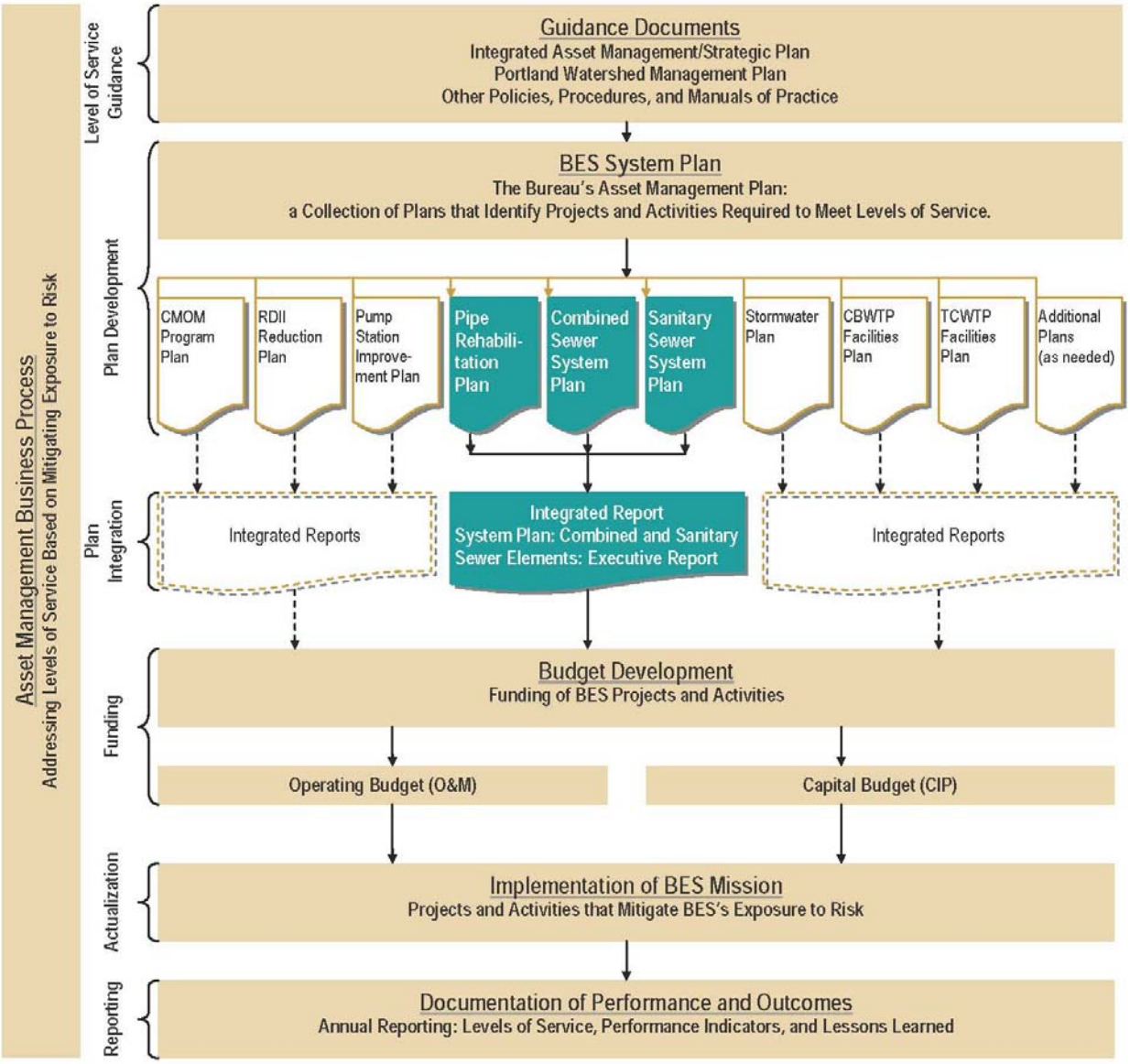


FIGURE 1-1
Relationship of the Executive Report with Other System Plan Elements and the Asset Management Business Process
(CBWTP = Columbia Boulevard Wastewater Treatment Plant; CMOM = Capacity Management Operations and Maintenance; RDII = infiltration and inflow; TCWTP = Tryon Creek Wastewater Treatment Plant)

The Pipe Rehabilitation Plan was prepared in two phases. Phase 1 focused on identifying and rehabilitating/replacing critical pipes in poor condition. The recommended projects

were submitted to the capital improvement program (CIP) and were either implemented or are in the process of being implemented. Phase 2 focused on comprehensive analysis of the City's pipe rehabilitation needs and the development of a recommended rehabilitation plan, which is summarized as a component of this Wastewater Sewer System Plan.

The Combined Sewer System Plan and the Sanitary Sewer Plan were developed in four stages: hydraulic model development and calibration, sewer hydraulic characterization, development and evaluation of alternatives, and formulation of recommended plans. Beginning in 2004, this was done basin by basin for the entire City of Portland sewer system.

As shown in Figure 1-1, several other plans are developed in parallel as part of the BES System Plan. This includes the Stormwater System Plan, which provides planning for the stormwater system, an element of the sewer system that is not addressed by this Wastewater Sewer System Plan. The stormwater system planning process was initiated in 2010. Currently, the Stephens Creek watershed basin is being evaluated under that planning process as a pilot project for the Stormwater System Plan. When the Stormwater System Plan is completed, the results will be integrated with the results of this Wastewater Sewer System Plan, which incorporates stormwater control and stormwater separation alternatives directly associated with combined and sanitary sewer capacity solutions.

The Columbia Boulevard Wastewater Treatment Plant (CBWTP) facilities plan was developed separately and completed in March 2010. The Tryon Creek Wastewater Treatment Plant (TCWTP) facilities plan will be initiated in 2012.

This Wastewater Sewer System Plan and the array of other plans shown in Figure 1-1 contribute to the development of the overall BES System Plan, which is the foundation for development of the budget for projects and activities to meet BES levels of service and mitigate exposure to risk.

1.5 Planning Process Advancements

The Wastewater Sewer System Plan was developed as a "living plan" for the ongoing cycle of BES planning, implementation, and evaluation. It was designed to be regularly updated to reflect continuing system changes, to improve the level of service, and to improve the effectiveness and cost benefits of infrastructure investment.

Improvements in asset data management and analytical capability, and the incorporation of spatial attributes, made it possible to develop the Explicit Model Generation and Analysis Tool Set (EMGAATS), which was used to evaluate capacity deficiencies in both major and minor facilities for this Wastewater Sewer System Plan. Significant advancements in the level of analysis of pipe structural condition have provided insight about the degree of risk

for structural failure of each pipe segment and have provided a systematic method to prioritize pipe replacement and repair.

These advancements in analytical methods have enabled BES to evaluate the sewer system at a higher level of detail than was possible when the 1999 PFP was prepared and consequently BES has developed more localized solutions that address the sources of problems and incorporate alternative cost-beneficial technologies such as stormwater inflow controls (green infrastructure).

1.6 Cost Estimate Accuracy

The cost estimates in this report are planning level estimates. These estimates were made without detailed engineering design data. Capital costs include direct construction cost plus indirect costs such as engineering, legal, administrative, and construction inspection. Estimates used the July 2010 *Engineering New Record* construction cost index of 8865.

Present worth costs were calculated for a 100-year analysis period at a discount rate of 2.5 percent incorporating total capital cost, operations and maintenance (O&M) costs, replacement costs, salvage value, and credits for removal of stormwater from the combined sewer system.

Based on the degree of project definition, the estimates presented in this Wastewater Sewer System Plan are equivalent to Class 3 estimates as defined by the Association for the Advancement of Cost Engineering International (AACE, 2011). Taking into account the end use, estimating method, and preparation effort, these estimates are expected to have an accuracy range of +40 percent to -20 percent.

Chapter 2: Asset Management Approach

2.1 Introduction

Management of the City's natural and built assets requires careful consideration of project costs and benefits to optimize the return on investment for rate paying customers. Asset management consists of a set of standard industry practices that incorporates risk mitigation when making decisions about how to best maintain, repair, and develop necessary facilities. BES and other agencies define asset management as: "Meeting agreed upon customer and environmental service levels while minimizing life cycle costs at an acceptable level of risk."

This chapter provides a brief description of City's sewer system assets, a short history of the development of the BES asset management approach, and an overview of key asset management principles and definitions. The chapter concludes with descriptions of how the asset management approach was incorporated in the development of the pipe rehabilitation, combined sewer system, and sanitary sewer system components of this Wastewater Sewer System Plan. A short glossary of asset management terms is provided in Appendix D for reference.

2.2 Description of Assets

2.2.1 General

The City of Portland wastewater sewer service areas are shown in Figure 2-1. The combined sewer system serves approximately 31,700 acres; the sanitary sewer system serves approximately 60,800 acres. The total City of Portland wastewater sewer service area is approximately 92,500 acres.

The City owns approximately 9,663,382 linear feet (1,830 miles) of wastewater gravity sewer pipe.[1] Of this, the combined sewers consist of 4,672,313 linear feet (885 miles) and the separated sanitary sewers consist of 4,991,069 linear feet (945 miles). These pipes range in diameter from 6 inches to 252 inches.

The City's gravity sewer system pipes are inventoried by pipe diameter and pipe material in Table 2-1. The table is organized into four main categories: combined sewer system, CSO consolidation and storage tunnel, sanitary sewer system, and sanitary sewer system pipes owned by others but maintained by BES by agreement (for examples, pipes in the Dunthorpe-Riverdale area). Replacement costs are listed in Table 2-1 for City-owned pipes.

[1] The stormwater sewer component of the system is not within the purview of this report.

TABLE 2-1
Portland Sewer Service Area Pipe Inventory by Materials with Replacement Costs

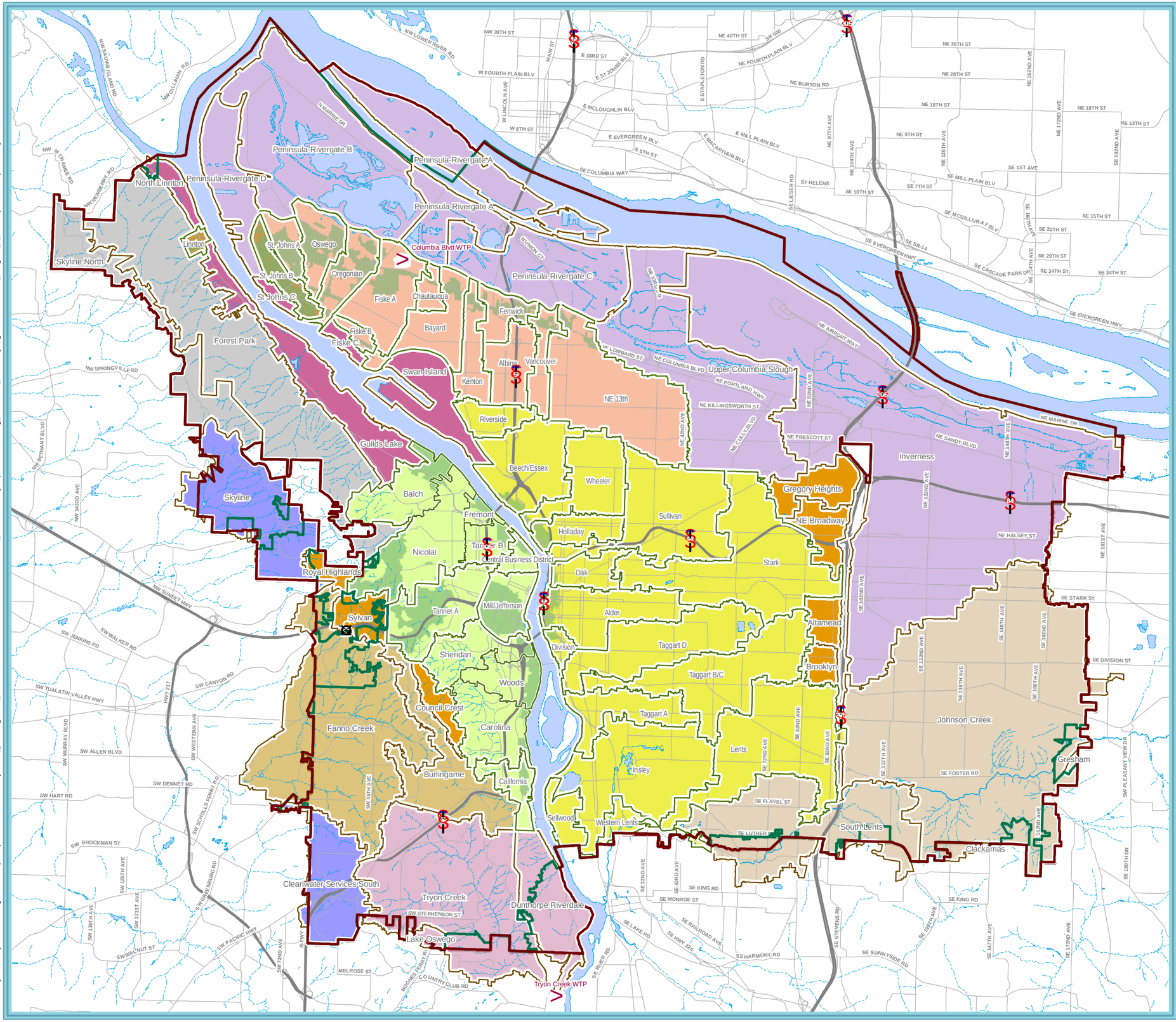
Diameter (inches)	CSP (feet)	RCP (feet)	VSP (feet)	PVC (feet)	Mono (feet)	Brick (feet)	Others (feet)	Total (feet)	Replacement Cost [a]
Combined Sewer System (CSS)									
≤ 12	1,199,121	5,238	1,421,049	99,084	357	0	296,724	3,021,574	$1,521,043,728
> 12 ≤ 18	294,062	18,302	255,414	22,689	30	0	54,972	645,469	$389,608,300
> 18 ≤ 24	127,760	33,388	115,505	3,370	1,323	450	30,536	312,332	$229,039,612
> 24 ≤ 36	151,603	42,528	6,855	440	53,714	8,407	37,563	301,110	$324,967,509
> 36 ≤ 54	75,406	20,751	0	0	28,232	8,904	16,150	149,443	$263,864,186
> 54	64,187	21,372	0	0	29,853	12,634	22,967	151,012	$389,348,119
CSS Total	1,912,138	141,579	1,798,822	125,583	113,509	30,395	458,912	4,580,939	$3,117,871,454
CSO Consolidation and Storage Tunnel									
≤ 12	345	189	0	593	0	0	235	1,362	-
> 12 ≤ 18	98	1,240	0	15	0	0	0	1,352	-
> 18 ≤ 24	211	36	0	0	0	0	61	308	-
> 24 ≤ 36	58	2,312	0	13	0	0	45	2,428	-
> 36 ≤ 54	195	1,094	0	0	185	0	91	1,565	-
> 54	18,173	66,126	0	0	0	0	59	84,358	-
CST Total	19,080	70,997	0	621	185	0	492	91,374	$870,562,000[b]
Sanitary Sewer System (SSS)									
≤ 12	1,789,162	16,670	45,470	2,276,200	160	0	274,434	4,402,097	$2,278,559,175
> 12 ≤ 18	128,435	15,942	3,846	12,219	0	0	29,169	189,611	$131,069,954
> 18 ≤ 24	88,879	13,810	777	1,029	0	0	6,158	110,653	$85,139,335
> 24 ≤ 36	99,154	7,547	0	1,569	896	0	22,339	131,505	$139,594,589
> 36 ≤ 54	46,100	6,532	0	0	13,820	0	1,596	68,048	$125,409,355
> 54	17,011	19,431	0	0	52,663	0	50	89,155	$609,340,481
SSS Total	2,168,741	79,932	50,093	2,291,017	67,539	0	333,746	4,991,069	$3,369,112,889
Sanitary Sewers Maintained by Agreement									
≤ 12	63,758	0	0	986	0	0	1,505	66,249	NA
System Total	**4,163,717**	**292,508**	**1,848,915**	**2,418,207**	**181,233**	**30,395**	**794,656**	**9,729,631**	**$7,357,546,343**

[a]Pipe inventory information obtained from the City of Portland Hansen Maintenance Management Database; replacement costs estimated using the BES cost estimating tool. Costs include planning, design, construction, and contingency.

[b]Replacement cost from BES Piper project accounting system. Includes planning, design, construction, and other full life costs of gravity sewers, but not contingency. Does not include pump stations or force mains. Cost breakdown as follows:

Project	*Job No.*	*Cost*
Columbia Slough	6181, 6182, 6183	$42,237,000
Westside	6680,7669,7317,7512,7070,7360,E05510	$394,043,000
Eastside	E05516	$434,282,000
	Total	$870,562,000

CSP = concrete sewer pipe; Mono = monolithic (i.e., poured in place); Other = asbestos cement, ductile iron, etc.; PVC = polyvinyl chloride; RCP = reinforced concrete pipe; VSP = vitrified clay sewer pipe.



Map Elements

- Urban Services Boundary
- City of Portland
- Combined Sewer Basin Boundary
- Sanitary Sewer Basin Boundary
- Columbia Slough CSO Service Area
- West Side Willamette CSO Service Area
- North Willamette CSO Service Area
- East Side Willamette CSO Service Area
- Durham Sanitary Service Area
- Tryon Creek Sanitary Sewer Service Area
- Willamette Sanitary Service Area
- Southeast Sanitary Service Area
- West Side Sanitary Sewer Service Area
- North Willamette Sanitary Service Area
- Columbia Slough Sanitary Sewer Service Area
- No Sewer Service Area
- Partially Separated Areas*

*The partially separated areas are areas where a portion of the stormwater runoff is directed to the CBWTP and a portion is diverted to a receiving water such as the Willamette River or the Columbia Slough

1 in = 1.5 miles

Figure 2-1

Sewer Basins and Service Areas

March 2012 - System Plan

ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

Produced by Asset Systems Management: Map Request 6119 \\Cassiolsystems_planning\8063_CombinedFacPlan\Documents\Recommended_Plan\SummaryReport\Overarching_Executive_Summary\Figures\MxdPhase_8\Figure_2_1.mxd (KDR, DCA) January 12th, 2012

Reinforced and non-reinforced concrete pipes were installed extensively beginning in the early 1900s. For small diameter pipe, vitrified clay pipe was the prominent pipe material until 1930. Polyvinyl chloride (PVC) pipe was installed on a limited basis (as sanitary sewers) in the 1980s, but was used more frequently after 1990. High-density polyethylene (HDPE) pipe has been used for both small and large diameter pipe in the last decade. Some large diameter pipes were constructed with brick (notably the Taggart basin outfall), but most were constructed of concrete with a brick or stone wear surface on the bottom of the pipe. These pipes were typically poured monolithically in place and contain some reinforcing steel.

In addition to gravity sewer pipes, the City's wastewater sewer system includes nearly 90 pump stations, more than 237,600 linear feet (45 miles) of force main, and two wastewater treatment plants.

2.2.2 Combined Sewer System

The combined sewer system collects and transports sewage and stormwater in a pipe network to the CBWTP for treatment. The combined sewer system comprises 41 basins which are grouped into four major CSO service areas: West Side Willamette, East Side Willamette, North Willamette, and the Columbia Slough. Raw sewage is collected from local properties, and stormwater runoff is collected from public right-of-ways, rooftops, and parking areas. The system includes approximately 650 publicly-owned stormwater control facilities in the streets and 14 small pump stations. The combined sewage is conveyed through a series of collector sewers and trunk sewers to diversion structures located at the downstream ends of the basins. The diversion structures route the combined sewage from the basins into the interceptor system that conveys the flow to the CBWTP. When capacity is not available in the interceptors, the diversion structures overflow to the CSO control facilities (storage tunnels and pumping systems) to deliver captured CSOs to the CBWTP for treatment. During large, infrequent storms when the tunnels fill, the excess combined sewage spills over the control dams in the tunnel shafts and discharges to the river or slough.

2.2.3 Sanitary Sewer System

The separated sanitary sewer system receives domestic sanitary and industrial wastewater flows via building service connections. Areas served by separated sanitary sewers have been divided into 29 basins. The basins are defined by the network of sanitary sewers that collect wastewater and convey it to either a major sanitary trunk sewer or a combined interceptor sewer. Seventy-four of the City's pump stations pump separated sanitary flow, 55 of which are located in the Columbia Slough Service Area shown in Figure 2-1. The sanitary flow from the Tryon Creek Service Area (Tryon Creek and Dunthorpe-Riverdale

basins) is treated at the TCWTP. Flow from the Durham Service Area (i.e., Skyline and Clean Water Service South basins) flows to the Durham Advanced Wastewater Treatment Facility, which is owned and operated by Clean Water Services of Washington County. Aside from the few customers served by Gresham, the remaining flow is treated at the CBWTP.

2.3 Development of Asset Management Approach

BES began incorporating asset management into its business practices more than 20 years ago. A few historical asset management milestones include:

- 1990—Implementation of Hansen Maintenance Management Database and condition assessment scoring system.
- 1995—Development of a pipe risk of failure assessment and prioritization process (as part of the sewer collection system Maintenance Management Manual).
- 2004—Implementation of Synergen asset management software at the CBWTP.
- 2005—Incorporation of asset management elements in the update of the BES System Plan.
- 2008—BES participation in an international asset management benchmarking project.

In 2010, BES launched an Asset Management Improvement Program to better define asset management principles and practices as they should be applied to BES assets, identify opportunities for improvement, and establish a framework for implementing improvements. As the Asset Management Improvement Program matures, the Sewer System Planning Program will continue to integrate additional asset management principles into the evaluation and prioritization of sewer system improvements.

2.4 Overview of Asset Management Approach

The focus of the asset management approach is assessment and mitigation of *business risk*. Business risk is calculated as the product of *consequences of failure* to meet levels of service and *likelihood of failure.* The primary reason to implement a project or a program is to achieve a reduction in the business risk, which is considered to be the chief benefit. Expressed in dollar values, the business risk can be compared with the cost of the project to mitigate that risk. In other words, the cost of the project can be compared with the benefits of the project expressed as risk reduction. The calculation used to represent the comparison of benefits to costs is termed the net benefit cost ratio (nBCR).

Discussed separately below are *Consequences of failure* to meet levels of service, *likelihood of failure* to meet levels of service, and *nBCR*.

2.4.1 Consequences of Failure to Meet Levels of Service

Consequence of failure represents the outcome of an event expressed qualitatively or quantitatively, such as a loss, injury, disadvantage, or gain. *Level of service* is a defined standard against which the quality and quantity of service can be measured. A level of service can include reliability, responsiveness, environmental acceptability, customer values, and cost. The levels of service established by BES are outlined in Section 3.4.

In determining the consequences of failure to meet levels of service, BES considered the economic, environmental, and social (triple-bottom-line) risk factors presented in Table 2-2. These factors take into account not only the direct financial costs to the administering governmental agency (in this case BES) and its customers, but also the effects on physical habitat, compliance with regulations, public inconvenience and perception, and public health and safety. These factors may be revised in the future as the Asset Management Improvement Program described above proceeds.

TABLE 2-2
Standard Triple-Bottom-Line Asset Management Factors Selected for Development of the Wastewater Sewer System Plan

Factor	Description of Risk	Factors Used in the Wastewater Sewer System Plan	
		Base Risk Development	Project Risk for Prioritization
Economic			
Operations	Requires increased operational attention; increases operational costs.		✓
Maintenance	Requires increased maintenance activity, scheduled or unscheduled; increases maintenance costs.	✓	✓
Replacement & Emergency Costs	Requires capital investment to replace facility.	✓	✓
Environmental			
Physical Habitat	Reduces quantity or quality of wildlife habitat.	✓	✓
Biological Communities	Reduces quantity, diversity, or health of plants and animals.		
Compliance with Regulations	Does not meet regulations or causes regulatory notifications or permit violations.	✓	✓
Social			
Public Inconvenience and Perception	Expends time or costs money; inconvenience or nuisance to citizens; creates an unfavorable impression that decreases public cooperation, participation, and approval.	✓	✓
Public Health and Safety	Causes disease, injury, or death; increases health risks or unsafe conditions.	✓	✓

How these factors were used in the development of the Wastewater Sewer System Plan is indicated in the last two columns of Table 2-2. If the factor was considered in the calculation of the potential risk associated with failure of an asset, then it is checked in the *Base Risk Development* column. If the factor was considered in the calculation of risk associated with implementation of a proposed infrastructure improvement to rank projects by priority, then it is checked in the *Project Risk for Prioritization* column. As indicated, six of the eight factors were used for the calculation of base risk and seven were used for project risk.

The biological communities factor was not used in the development of the Wastewater Sewer System Plan because consequence values and likelihood estimates were not yet developed by the Asset Management Improvement Program.

Starting with the selected triple-bottom-line asset management factors shown in Table 2-2, BES identified specific types of risk and associated dollar values as they pertain to the individual consequences of capacity and structural failures. The potential consequences of structural pipe failure are as follows:

- Partial blockage may occur, causing basement sewer backups, which would inconvenience the public and pose a threat to public health. Assumes sewer backups into two basements.
- Surface flooding (i.e., sewage overflows to the surface) may occur with potential threats to the environment and public health.
- Sinkhole may open to the surface, posing a threat to the environment and public safety. Maintenance crews must clean up the spill and make an emergency spot repair.

The potential consequences of capacity failure are basement sewer backups and surface flooding. Although surface flooding was considered for the capacity failures in the sanitary sewer system, the capacity evaluation for the combined sewer system only assigned costs for the risk of basement sewer backups. The costs associated with the risk of surface flooding will be integrated into the combined sewer system evaluation in the future as a part of the Asset Management Improvement Program.

The triple-bottom-line consequence assumptions used in the development of base risk and the ranking of recommended projects by priority are summarized in Table 2-3. Calculation details are provided in the footnotes.

The values presented in Table 2-3 are initial assumptions about the costs associated with each of the consequences. These costs will be updated in the future as BES completes more research and review of actual costs and implements the Asset Management Improvement Program.

TABLE 2-3
Assumptions about Structural and Capacity Failure Consequences (Impacts)

Event	Individual Conse-quence	Types of Consequences and Associated Dollar Values				
			Environmental		Social	
		Economic	Physical Habitat	Regulatory	Public Inconvenience and Perception	Public Health and Safety
Structural Failure	Sewage backs up into two basements	Not used for this plan	Not used for this plan	Not used for this plan	Disruption, cleanup, and property damage: $6,000[a]	Illness from contact with sewage or injury from hazards: $4,000
	Surface flooding (sewage overflows to the surface)	Not used for this plan	Not used for this plan[b]	If sanitary sewer system area, regulatory fines and reporting costs of $10,000	Not used for this plan	Injury from hazard or illness from contact with sewage: $5,000, but if near school: $10,000
	Damaged pipeline causes sinkhole to the surface	Emergency spot repair: Cost varies according to depth, size, and location[c]	Spot repair causes environ-mental damage in Environ-mental Zones "C" and "P": $1,000 to $50,000[d]	Not used for this plan	Not used for this plan	Injury from hazard or interference with emergency services: $10,000 to $30,000[e]
Capacity Failure	Sewage backs up into basements (number varies according to location)	Not used for this plan	Not used for this plan	Not used for this plan	Disruption, cleanup, and property damage: $3,000[a]	Illness from contact with sewage or injury from hazards: $2,000
	Surface flooding (sewage overflows to the surface in separated sanitary sewer area[f])	Clean-up costs: $4,000	Environ-mental damage: $10,000	Regulatory fines, reporting costs, and monitoring: $19,000	Disruption and negative publicity: $10,000	Injury from hazard or illness from contact with sewage: $5,000, but if near school: $10,000
Failure to Provide Sewer Service to Unserved Areas	Loss of revenue	$28,800 per dwelling unit[g]	Not used for this plan	Not used for this plan	Not used for this plan	Not used for this plan

TABLE 2-3
Assumptions about Structural and Capacity Failure Consequences (Impacts)

Event	Individual Conse-quence	Types of Consequences and Associated Dollar Values				
			Environmental		Social	
		Economic	Physical Habitat	Regulatory	Public Inconvenience and Perception	Public Health and Safety

[a]BES's average cost to settle basement sewer backup claims over the last decade has been approximately $3,000. In addition, there is the cost to BES to evaluate the causes of the occurrence. These costs are a starting point in developing information about the costs associated with basement sewer backups. It is expected that as BES collects more data, these cost estimates will be refined.
[b]Regulatory fines were assumed to serve as proxy for damage to habitat and biological communities.
[c]Cost of emergency spot repair = 1.4 x (replacement cost x 10)/pipe length.
[d]Environmental damage cost = (Length of Pipe in "C" or "P" x 50 feet)/43,560 x $100,000 x (10/pipe length).
[e]Public health and safety cost for residential street = $10,000; major arterial = $15,000; highway = $30,000; plus $30,000 near school, police, hospital. Costs increase as traffic increases because more people are affected and increases near police stations and hospitals because of greater possibility of interfering with emergency services.
[f]The consequence of a sewage release to surface in the sanitary sewer area is calculated per incident per *subbasin*, not per manhole.
[g]100-year present value of revenues lost from not serving properties in unserved area based on average revenues from average water user per month. The present value was calculated assuming a new service area would be built out 20 years after completion of the sewer extension project.

2.4.2 Likelihood of Failure to Meet Levels of Service

Likelihood of failure is the probability or possibility of an event that will cause the asset to fail. This was calculated differently for pipe structural deficiency risk and capacity deficiency risk.

For structural deficiency risk, likelihood of failure was determined from condition assessment data and literature curves that relate pipe condition grades to remaining useful life for different pipe materials. The process is described in Section 4.2.

For capacity deficiency risk, likelihood of failure was estimated by computer model simulation of flows for design storms with different return frequencies and under existing and future community development conditions. The process is described in Section 4.3 for the combined sewer system and in Section 4.4 for the sanitary sewer system.

2.4.3 Net Benefit Cost Ratio

The nBCR was used to rank projects by priority for the sewer system implementation plan as described in Section 7. The equation used to calculate nBCR is as follows:

$$\text{nBCR} = \frac{(\text{100-Year Present Worth Base Risk} - \text{100-Year Present Worth Alternate Risk})}{\text{Project Cost}}$$

Base Risk is the current risk before making a repair. Alternate Risk is the deferred risk remaining after the repair is performed. The Alternate Risk includes the Project Cost; therefore, the break-even point for cost-beneficial projects is zero. Using this formulation, the nBCR essentially represents the return on investment for the expenditure in terms of reduced risk costs.

The different methods used to evaluate benefits and costs during development and analysis of the pipe rehabilitation, combined sewer, and sanitary sewer project alternatives are described in Section 5.

2.5 Implementation of Asset Management Approach

2.5.1 Pipe Rehabilitation

BES evaluated its sanitary and combined sewer pipe segments using a geographical information system (GIS)/database tool to prioritize and map potential spot repairs and whole pipe rehabilitation/replacement in an asset management context. The database is a GIS coverage that includes information from pipe inspection regarding condition, grade, and defects of the pipe, as well as asset management data concerning consequence of failure, likelihood of failure, estimated cost, and prioritization data. This pipe rehabilitation asset management tool was utilized to effectively address rehabilitation/replacement needs of the sanitary and combined sewer collection systems.

2.5.2 Combined Sewer System

Pipe assets in the combined sewer system were evaluated to determine the existing and potential future capacity risk. The capacity risk components were assigned dollar values so that these risks could be quantified in terms of business risk or the cost and likelihood of the asset failing because of capacity problems. The structural risk that was derived using the pipe rehabilitation asset management tool was then integrated into the analysis of risk in the combined sewer system.

During development of alternatives to address capacity and structural risks, alternative improvement projects were evaluated for cost-effectiveness in reducing sewage backups into basements and were evaluated against level of service *goals* developed by BES staff as

part of the combined sewer system planning effort to represent environmental and community values. These *goals* were developed (and the evaluations using them were completed) before the BES sewer system levels of service outlined in Table 3-1 were established. The alternatives evaluation process is described in Section 5.3.

After cost estimates were generated, the business risk costs were compared to the costs to design and build the projects to mitigate the risk, and then nBCRs were developed for the projects. Those projects with the highest nBCRs were determined to be the highest priority projects to complete.

2.5.3 Sanitary Sewer System

The sanitary sewer system pipe assets were evaluated to determine the existing and potential future capacity risks, and these risks were assigned dollar values so that they could be compared against costs to mitigate the risks.

Projects were developed and evaluated for cost effectiveness. This included evaluation of rainfall dependent infiltration and inflow (RDII), which is the biggest cause of capacity deficiencies in the sanitary system. The effects of RDII were evaluated for the pipelines and pump stations using flow monitoring data; for areas without flow monitoring data modeling assumptions were based on pipes of similar age and location.

During development of the implementation plan, structural condition assessment data were used to determine structural deficiency risks for calculation of project nBCRs.

Chapter 3: Basis of Planning

The Wastewater Sewer System Plan was developed to provide for future community growth and to continue to meet City of Portland levels of service. The planning horizon for the Wastewater Sewer System Plan is 20 years.

3.1 Planning Area Boundaries

In accordance with Section 11.1 of the *Comprehensive Plan Goals and Policies* (City of Portland Bureau of Planning, 1980), BES provides sewer service within the City's incorporation boundary (City limits) and to areas outside the City limits within the City's established urban services boundary (USB). The City of Portland City limits and USB are shown on Figure 2-1.

In addition, BES provides sewer service to specific areas outside the USB via existing contract agreements with neighboring jurisdictions where sanitary sewers from outside the USB flow to a BES sewer or treatment facility (for example, with Clean Water Services and Lake Oswego in the southwest, Water Environment Services of Clackamas County in the southeast, and City of Gresham in the east). Similarly, some neighboring jurisdictions treat sewage from the BES system.

The planning area for this Wastewater Sewer System Plan coincides with the City's sewer service areas shown on Figure 2-1.

3.2 Future Development Assumptions

Portland's Comprehensive Plan (City of Portland Bureau of Planning, 1980) demonstrates how the City complies with state and regional land use planning requirements. In general, the plan requires that the City provide for a greater density of development. The requirements specified in the *City of Portland Stormwater Management Manual* (SWMM) (BES, 2008) and *Sewer and Drainage Facilities Design Manual* (BES, 2007) attempt to reconcile the need for greater density of development with the need to reduce the volume of stormwater runoff.

Future development assumptions for the Combined Sewer System Plan and the Sanitary Sewer System Plan were based on information about the following Comprehensive Plan build-out areas (shown in Figure 3-1) provided by the City of Portland Bureau of Planning in 2004:

- Metro 2025 Refill areas. These areas reflect high potential re-development and infill areas that are expected to be 60 percent developed by 2025 and approximately 100 percent by 2040.
- Main Street corridor town-centers.
- Vacant Lands coverage.

These areas were assumed to be developed to build-out as appropriate for the zoning designations. For example, the Vacant Lands coverage in Figure 3-1 is overlain with open space, cemetery, and parks zoning to clarify development assumptions.

3.2.1 Combined Sewer System

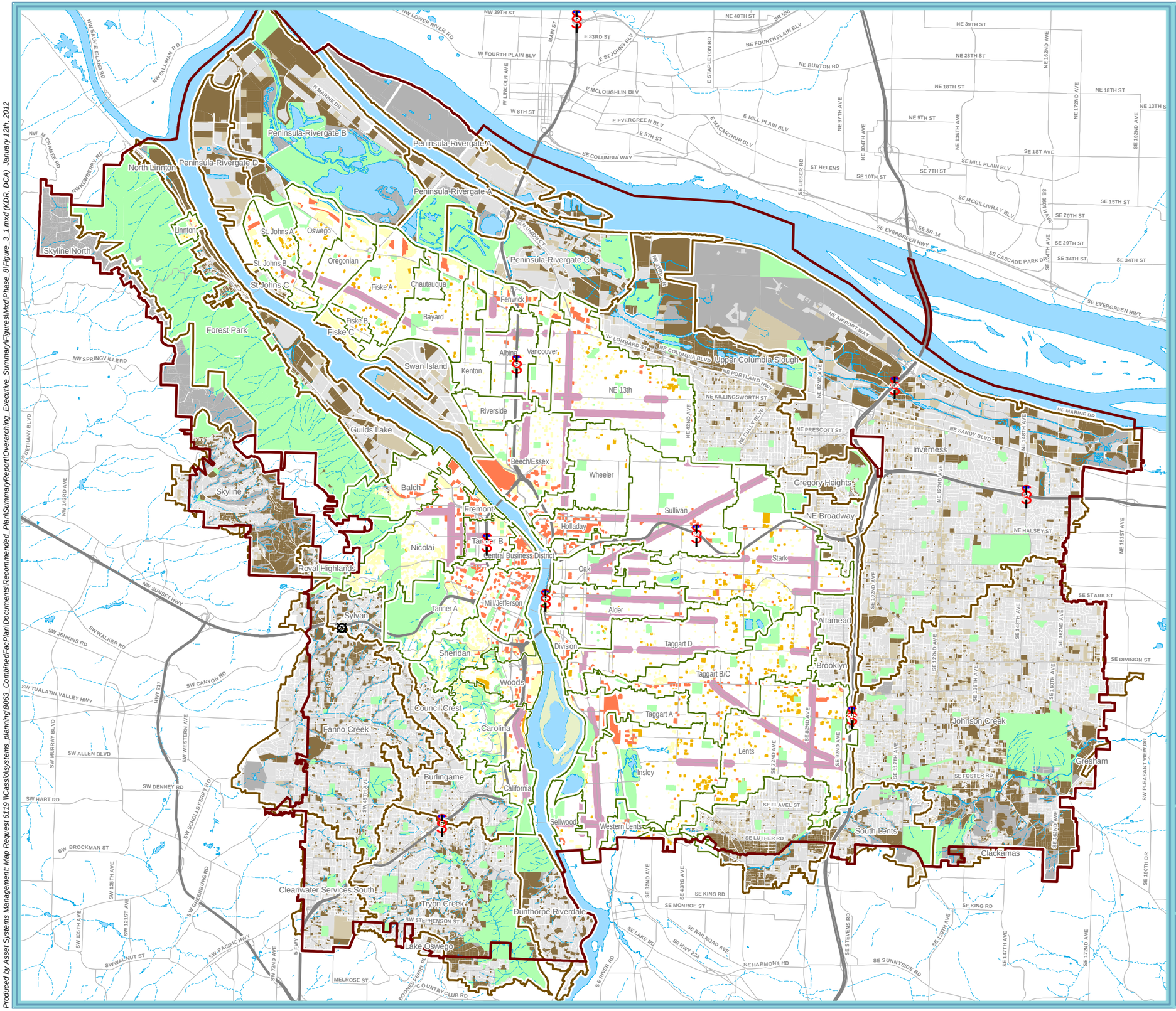
The Combined Sewer System Plan assumptions about future conditions are similar to those used for the 2005 CSO Sizing and Flow Management Predesign Project. The specific future condition assumptions were reviewed and approved in January 2004 by the BES Standards & Practices Committee.[2] The future condition assumptions were developed in two steps.

The first step was to estimate impervious area increases in the Comprehensive Plan build-out areas described above and shown in Figure 3-1. The second step was to adjust the impervious area estimates to account for the level of stormwater inflow relief that was expected to be achieved through implementation of the Downspout Disconnection Program and application of *Stormwater Management Manual* requirements at new development and redevelopment sites.

3.2.2 Sanitary Sewer System

The Portland Comprehensive Plan identifies areas of the City where separated sanitary sewers do not exist. Therefore, it was necessary to develop a new approach to determine if these potential future development areas will eventually connect to Portland's sanitary system. The new approach utilized the Bureau of Planning guidelines discussed above and additional spatial analysis to produce four development categories. This approach was presented to and approved by a sub-committee of the Standards & Practices Committee in March 2007.

[2] One exception is the North Interstate Plan District, which was not included in the future condition assumptions because that polygon was not provided by the Bureau of Planning in 2004. Since the extent of the plan district was not known in 2006 when the sewer basins in that area were characterized, no future growth assumptions for that area were included in this Sewer System Plan. The extent of that district was finalized in August 2008 when Chapter 33.561 was added to the City of Portland Code and is now available for inclusion into the modeling master data structure. The zoning designations for properties in the North Interstate Plan District were updated in the sewer modeling database in autumn 2011, but this Sewer System Plan does not reflect these updates because the analysis documented in this report was performed before the update.



Map Elements

- Urban Services Boundary
- Combined Sewer Basin Boundary
- Sanitary Sewer Basin Boundary
- Parks and Open Space

Bureau of Planning Development Assumptions*

Combined Sewer System

- Vacant Land Development
- Main Street Development
- Residential Refill Area Development
- Commercial Refill Area Development

Sanitary Sewer System

- Will Not Connect
- Connected, No Changes
- Connected, Future Redevelopment
- Future New Connection

*These assumptions represent 2004 Bureau of Planning predictions about future development. Since that time, there has been significant research into property connection records and land use assumptions in the Portland Harbor Superfund project area. This research revealed new information that makes some of the assumptions in that area obsolete.

1 in = 1.5 miles

Figure 3-1

Future Development Assumptions

March 2012 - System Plan

Environmental Services
City of Portland
working for clean rivers

Produced by Asset Systems Management: Map Request 6119 \\Cassio\systems_planning\8063_CombinedFacPlan\Documents\Recommended_Plan\SummaryReport\Overarching_Executive_Summary\Figures\Mxd\Phase_8\Figure_3_1.mxd (KDR, DCA) January 12th, 2012

The development categories used for the sanitary sewer system service areas are as follows:

- **Will not Connect**. These areas are currently unconnected and there are no plans to connect in the future.
- **Connected, No Changes**. These tax lots are currently connected and will remain unchanged.
- **Connected, Future Development**. These tax lots are currently connected and will redevelop in the future.
- **Future New Connection**. These tax lots are currently unconnected and will connect in the future.

These development assumptions are mapped on Figure 3-1.

3.3 Climate Change Assumptions

For the development of this plan, it was assumed that climate change will not affect precipitation and hydrology in the service area within the 20-year planning horizon to a degree that requires substantial alteration of the modeling approach. Moreover, because of the selected design storms used in the capacity deficiency modeling for future conditions (2050), it is expected that the hydraulic modeling results will be conservative enough to encompass potential climate change effects.

An overview of climate data for the Pacific Northwest shows the following:

- Projected sea level rise on the west coast in the range of 7 to over 9 inches from 1990 to 2050[3]
- An average temperature increase of 1.5°F has been observed for the Pacific Northwest between 1920 and 2000[4]
- Data show increases in "very heavy" (defined as the top 1 percent of the daily precipitation at selected stations) daily precipitation of 16 percent from 1958 to 2007[5]
- Mean annual precipitation changes projected from the 1950-1979 period to 2030-2059 are between 2 and 4 percent in the Portland/SW Washington area[6]

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[3] CH2M HILL, October 2009, Report for the National Association of Clean Water Agencies NACWA.

[4] University of Washington, Climate Impacts Group, Past and Future Trends in Pacific Northwest Climate, http://cses.washington.edu/cig/pnwc/pnwc.shtml

[5] Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press, 2009.

[6] U.S. Department of Interior, Bureau of Reclamation, 2009, *Literature Synthesis on Climate Change Implications for Reclamation's Water Resources*, Technical Memorandum 86-68210-091, Technical Service Center Water Resources Planning and Operations Support Group, Water and Environmental Resources Division (Mark Spears, Levi Brekke, Alan Harrison, and Joe Lyons [peer reviewer])

These are some of the currently available data for precipitation that are limited to annual average data, which should be revisited in the future after event-based local data have been developed and analyzed. It is not expected, however, that the standard design storm intensities or volumes will be modified to account for any predicted future changes due to climate change. It is the standard within BES to base design storm intensities and volumes on historical data. However, ASM may extrapolate and perform sensitivity analyses based on predicted changes. This will be determined as data become available on the localized effects, as recommended in Section 8.1.6.

It is anticipated that BES's focus on development of green infrastructure for stormwater volume management, continued implementation of SWMM, and revegetation and restoration of natural systems via the City's Green Streets Program, Portland Watershed Management Plan, and Grey to Green Initiative will help improve the adaptive capacity of the City's watersheds to handle climate change.

3.4 Wastewater Sewer System Levels of Service

Levels of service for the wastewater sewer system were defined to establish a framework for characterization of system deficiencies, development and evaluation of alternative solutions, and selection of recommended improvements.

The asset management levels of service that directly pertain to the Wastewater Sewer System Plan are summarized in Table 3-1. The levels of service provide a mechanism to translate BES's mission into a format that links customer core values to BES work activities.

TABLE 3-1
BES Wastewater Sewer System Levels of Service

Customer Core Value	Strategic Outcome	Customer Level of Service	Technical Level of Service
Accessibility			
Fulfill BES mission for entire service area.	Services are available to the whole community.	Customers are provided with sewer services.	Provide sewage service to support development consistent with Portland's Comprehensive Plan.
Affordability and Cost Effectiveness			
Provide cost effective services to customers.	Services are affordable and managed at the lowest long-term cost for the level of service.	Customers feel sewer connection fees are reasonable. Ratepayers are satisfied with the fairness, equity, and affordability of BES fees and charges. Ratepayers are satisfied with the value received from BES services, programs, and investments.	Capital Improvement Program is managed on time, within scope and budget, and to the appropriate standard. Operation, maintenance, and renewal expenditures are managed within budget and to the appropriate standard.

TABLE 3-1
BES Wastewater Sewer System Levels of Service

Customer Core Value	Strategic Outcome	Customer Level of Service	Technical Level of Service
Accountability and Transparency			
Work in partnership with the community.	Regulatory compliance is achieved.	Customers have easy access to long-term plans for wastewater systems.	Decisions are documented and accessible to the public. BES is in substantial compliance with relevant laws and regulations. Customers properly connect and maintain sewer connections per City standards. Customers are supported and enabled to manage stormwater onsite, prevent pollution from entering surface water and groundwater, and protect upland vegetation.
Public Health and Safety			
Protect public health.	Wastewater is managed to protect public health.	Wastewater does not escape due to faults in the public wastewater system. Health nuisances from BES facilities or assets do not occur. Water contact is safe for recreational use.	Convey combined sewage to prevent releases to buildings or streets up to a 25-year storm frequency. Prevent combined sewer overflows to frequencies established by the NPDES permit. Public sanitary/combined conveyance facilities are maintained in accordance with standards.
Environmental Health			
Value our natural environment and watershed health to support biological communities.	Water quality is protected and enhanced. Habitat is protected and enhanced. Biological communities are restored and protected.	Citizens are satisfied with the quality of shorelines, rivers, and streams. Citizens/ratepayers are satisfied with the quality of upland habitats and natural areas.	Sewage releases to surface waters are prevented for storm events up to a 5-year frequency. Quality of receiving water is enhanced and maintained at levels required for sustainable watershed health. Natural stream corridor connectivity and conditions are improved and maintained from headwaters to mouth. Maintain or increase native vegetation in riparian areas and uplands.
Sustainable Practices			
Provide long-term reliability.	Facilities are managed with respect for future generations.	A system plan is in place for wastewater, approved by the appropriate authorities, and kept current. Risk is managed across social demographics and geographical areas.	System plans are current to direct investment into the system. Assets are cost effectively maintained to meet performance expectations. CIP requests are evaluated against the current risk profile. Projects are equitably distributed to eliminate public health risks and provide environmental benefit across social and economic demographics.

TABLE 3-1
BES Wastewater Sewer System Levels of Service

Customer Core Value	Strategic Outcome	Customer Level of Service	Technical Level of Service
Reliability and Responsiveness			
Provide responsive, reliable services to customers.	BES maintains services at levels that are acceptable to property owners and ratepayers.	Customers are satisfied with the reliability of their wastewater services.	Unplanned service disruptions occur no more than once in 25 years for no longer than 24 hours.

Source: Selected from the *BES Asset Management Improvement Program 2011 Annual Report* (BES, 2011) Figure 6: BES Level of Service Table as pertinent to wastewater sewer system planning.
NPDES = National Pollutant Discharge Elimination System.

Levels of service are discussed separately below for pipe rehabilitation, the combined sewer system, and the sanitary sewer system and discussed in terms of specific performance measures used in the system analysis.

3.4.1 Pipe Rehabilitation Performance Measures

Performance measures were developed by defining structurally deficient pipes to include pipes with condition Grades 4 or 5. (Refer to Section 4.2.2.2 for more information about structural condition grading.)

Pipes with structural condition Grades 4 or 5 were discretized into 10 foot segments to analyze the distribution of structural defects along the pipe. Each of the discretized segments was graded with the same formula used in the Hansen Maintenance Management Database. Segments receiving condition Grades 4 or 5 were considered either failed or near failure. Also, segments that were previously repaired, as indicated by a change in pipe material, were identified as previously failed.

3.4.2 Combined Sewer System Capacity Performance Measures

The BES combined sewer system performance measures focus on providing sufficient capacity to eliminate or significantly reduce street flooding risk and basement sewer backup risk for the 25-year design storm under future (2050) conditions. The 25-year design storm is defined as a 6-hour, 25-year event with a peak rainfall intensity of 3.32 inches per hour and a total rainfall depth of 1.89 inches.[7]

An additional performance measure is to eliminate untreated CSO discharges to the Willamette River from May 1 to October 31 except during storms greater than or equal to a

[7] Based on Portland Airport precipitation data.

summer storm with a 3-year return frequency under future conditions.[8] The 3-year return frequency storm has a continuous definition from 15 minutes (0.6 inch/hour) to 24 hours (1.41 inches) and even out to 7 days (3.0 inches). Typically, this performance measure impacts only the stormwater control facilities and CSO tunnels and not the collection system capacity.

The performance measure used to identify locations of potential capacity deficiency was basement sewer backup. Individual tax lots were determined to be at risk for basement sewer backups when the maximum water surface elevation in the sewer pipe was within 8 feet of the estimated main floor elevation of the property. The estimated main floor elevation was 3 feet above the estimated ground elevation. The accuracy of the basement sewer backup risk was limited by the estimated main floor and ground elevations, which were determined with a digital terrain model. The estimated ground elevation was the maximum elevation of the building footprint. In the absence of reliable and systematic data, it was assumed for the purpose of estimating risk that each tax lot contained a basement.

The development and analysis of combined sewer alternative projects focused on reducing the frequency of predicted basement sewer backups as well as predicted street flooding locations, surcharging in brick sewers, and long duration pipe surcharge.

3.4.3 Sanitary Sewer System Capacity Performance Measures

The capacity-related sanitary sewer system technical levels of service are to convey sewage to prevent releases to buildings or streets up to a 5-year[9] storm frequency and to prevent releases to surface waters for storm events up to a 5-year frequency.

The performance measures for these are the same as the combined sewer system regarding basement sewer backups, street flooding, surcharging in a pipe constructed of brick, and pipe surcharge for a duration greater than 30 minutes. There is an additional system performance measure, however, regarding pump stations. Separated sanitary pump stations should have adequate firm capacity to pump the peak hourly and peak instantaneous flows associated with the 5-year, 24-hour storm intensity of its tributary area, without overflows. Firm capacity is defined as the capacity of the pump station with the largest pump out of service. In the analysis of these performance measures, the future condition results were used to identify future capacity problems and to size recommended projects. The existing

[8] As documented in the 1994 CSO Facilities Plan (CH2M HILL, Brown and Caldwell Consultants, and Associated Firms) and the Amended Stipulation and Final Order (ASFO) between the Oregon Environmental Quality Commission (EQC) and BES (1994).

[9] The sanitary sewer system analysis was done before the 25-year storm frequency was specified as the technical level of service for protection of public health and safety.

conditions were used to determine the severity of the problems in order to rank capacity problems by priority and develop an implementation schedule.

An additional technical level of service applicable to the Wastewater Sewer System Plan is to provide sewage service to support development consistent with Portland's Comprehensive Plan. The sanitary sewer system planning effort addressed potential extensions of the City of Portland sewer service area to areas currently unserved. These planning considerations are consistent with the Comprehensive Plan as of 2004. Ultimately, implementation will depend on policy decisions by the City of Portland and the development of service agreements with representatives of the unserved areas. For planning purposes, it is presumed that the capacity-related technical levels of service should be applied for future connections in the unserved areas.

Chapter 4: System Characterization

4.1 Overview

BES evaluated the sanitary and combined sewer pipe systems for structural integrity and the capacity to convey design flows. Also, BES evaluated pump station capacities to determine whether they could adequately pump the collection system design flows. These were the primary elements of system characterization.

The characterization was conducted by comparing system analysis results against performance measures that correspond to the technical levels of service. The performance measures are specific to the sanitary sewer, combined sewer, and pump station systems.

Characterization of these systems is presented in terms of the risk of not meeting the technical levels of service. As discussed in Section 2, the risk is expressed as the estimated social, economic, and environmental impacts in dollars of the asset failing to meet its expected levels of service.

The estimated total sewer system capacity and structural deficiency risk for the City of Portland is shown in Figure 4-1. In this figure, risk is expressed in dollars per acre and summarized in 25-acre grid cells, which are color coded to signify different ranges of risk. Total risk for each cell consists of structural deficiency risk plus capacity deficiency risk for that area. The purpose of this figure is to show the areas of the system where total sewer risk is currently highest.

The processes undertaken to develop the sewer system characterization are described separately below for pipe structural deficiencies, combined sewer system hydraulic capacity deficiencies, and sanitary sewer system hydraulic capacity deficiencies.

4.2 Pipe Structural Deficiencies

4.2.1 Analysis Tools

The primary method of determining structural pipe deficiency is through visual inspection using closed circuit television (CCTV). Inspection data are stored in the Hansen Maintenance Management Database.

Since 2009, video inspections have been recorded on DVD. Each inspection is manually reviewed by staff in the Maintenance Engineering section as part of an ongoing quality control process to ensure consistency and accuracy of data entry. Review of the videos is prioritized based on the structural condition scores of inspections. Updated inspection results are used in condition assessment analyses. If deficiencies in operator data entry are

detected, these are addressed during CCTV inspection operator training. Inspection operator training refresher meetings are held approximately every 2 months and full training every 2 years.

4.2.2 Structural Problem Identification

4.2.2.1 Condition Inspection

BES inspects sanitary and combined sewers to determine both structural and operational condition. Over the past 40 years, the City has inspected most of the collection system.

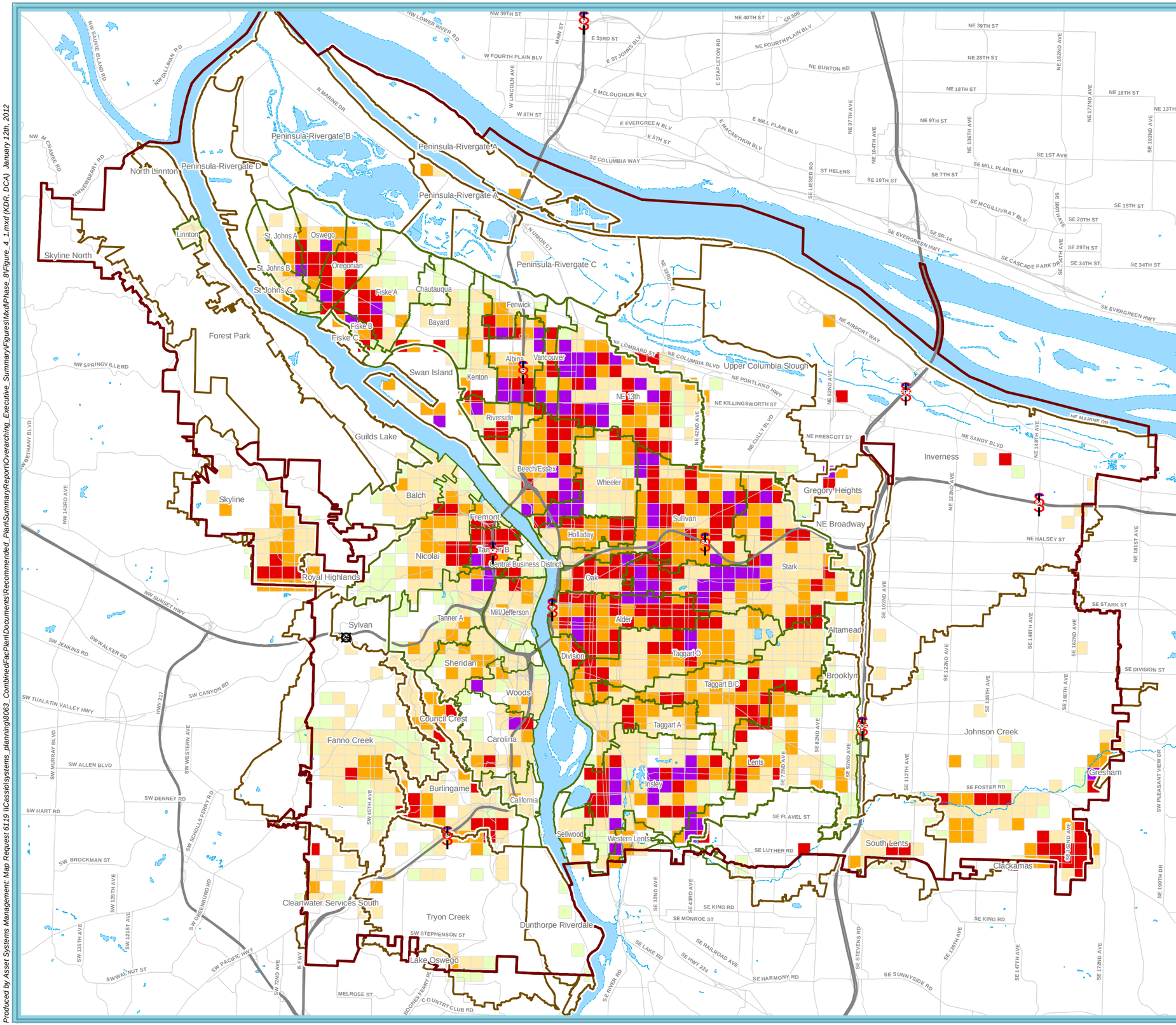
Small diameter sewer pipes less than or equal to 36 inches in diameter are inspected by the City on an ongoing basis as an integral part of the City's sewer maintenance program.

Large diameter sewer pipes pose a more challenging issue. When possible, large diameter sewers are inspected as part of the ongoing maintenance program. However, due to size, accessibility, and/or flow rates, some of the large diameter sewers require special inspection methods and are generally inspected by outside contractors. A comprehensive project for inspecting most of the City's large sewers (greater than 36 inches in diameter) was undertaken from 1995 through 1998.

The City has inspected more than 32,000 sanitary and combined sewer segments throughout the City in the past 10 years. Approximately 10,000 sewer segments have not been inspected recently, but 65 percent of these were constructed within the past 20 years and are therefore assumed to be in good to excellent condition.

4.2.2.2 Condition Grading

As CCTV inspections are conducted, structural defects are noted and scored. The inspection data and defects are entered into the Hansen Maintenance Management Database and a structural score is automatically calculated for each pipe. In addition to the main line structural defects, defective laterals (laterals with defects beyond the wye-head connection) are counted for each main line. These defective laterals may be repaired without impacting the main line and thus do not alter the main line structural score. These laterals may, however, deteriorate to the point of impacting the main line bedding and thus the structural integrity of the main line pipe itself. The condition scoring method for sewer mains uses five grade ranges as shown in Table 4-1.



Map Elements

- Urban Services Boundary
- Combined Sewer Basin Boundary
- Sanitary Sewer Basin Boundary

Risk in Dollars Risk per Acre

- $1,000 to $5,000
- $5,000 to $25,000
- $25,000 to $50,000
- $50,000 to $100,000
- $100,000 and Greater

1 in = 1.5 miles

Figure 4-1

Present Worth of Total Sewer System Risk

March 2012 - System Plan

Environmental Services City of Portland
working for clean rivers

Produced by Asset Systems Management: Map Request 6119 \\Cassiolsystems_planning\8063_CombinedFacPlan\Documents\Recommended_Plan\SummaryReport\Overarching_Executive_Summary\Figures\MxdPhase_8\Figure_4_1.mxd (KDR, DCA) January 12th, 2012

TABLE 4-1
Pipe Condition Grade Descriptions

Grade	Condition	Description	Structural Score Range*
1	Excellent	No defects or few minor defects	0 – 9
2	Good	Minor defects or few moderate defects	10 – 99
3	Fair	Moderate defects that will continue to deteriorate	100 – 999
4	Poor	Moderately severe defects that will become Grade 5 defects in the foreseeable future	1,000 – 9,999
5	Very Poor or Immediate Attention Required	Defects requiring immediate attention. (Failure or failure imminent.)	10,000 +

*Structural scores are automatically calculated by the Hansen Maintenance Management Database based on inspection data.

4.2.2.3 Structural Deficiency Risk

All pipes are at risk of structural failure at some point in time. Pipes in poor condition are at risk to fail in the near future, while pipes in good condition are at risk to fail in the future. In accordance with the asset management approach discussed in Section 2.4, the business risk of a structural failure, for any given pipe, was estimated by calculating the potential cost of consequence of failure, estimating the likelihood of failure, and taking the product of both to develop a risk distribution as a function of time. The process for doing this is outlined below using an example structural failure. The example pipe is 8 inches in diameter, 290 feet long, and located along NE Fremont Street between NE 28th Avenue and NE 29th Avenue.

4.2.2.3.1 Consequence of Failure Valuation

The consequences of a structural failure vary depending on the size, depth, and location of the pipe. For the example pipe, the consequence of failure valuation is shown in Figure 4-2. In this example, it is assumed the structural failure causes the following:

- Sewage to back up into two basements
- Sewage to overflow into the street
- Development of a sinkhole in the street

These consequences and the associated costs listed in Figure 4-2 correspond to those summarized in Table 2-3 of Chapter 2—Asset Management Approach. The average depth of the example pipe is 11 feet; moreover, it is located near a school and on a residential street that serves as an emergency route. These factors affect the valuation of consequence of failure.

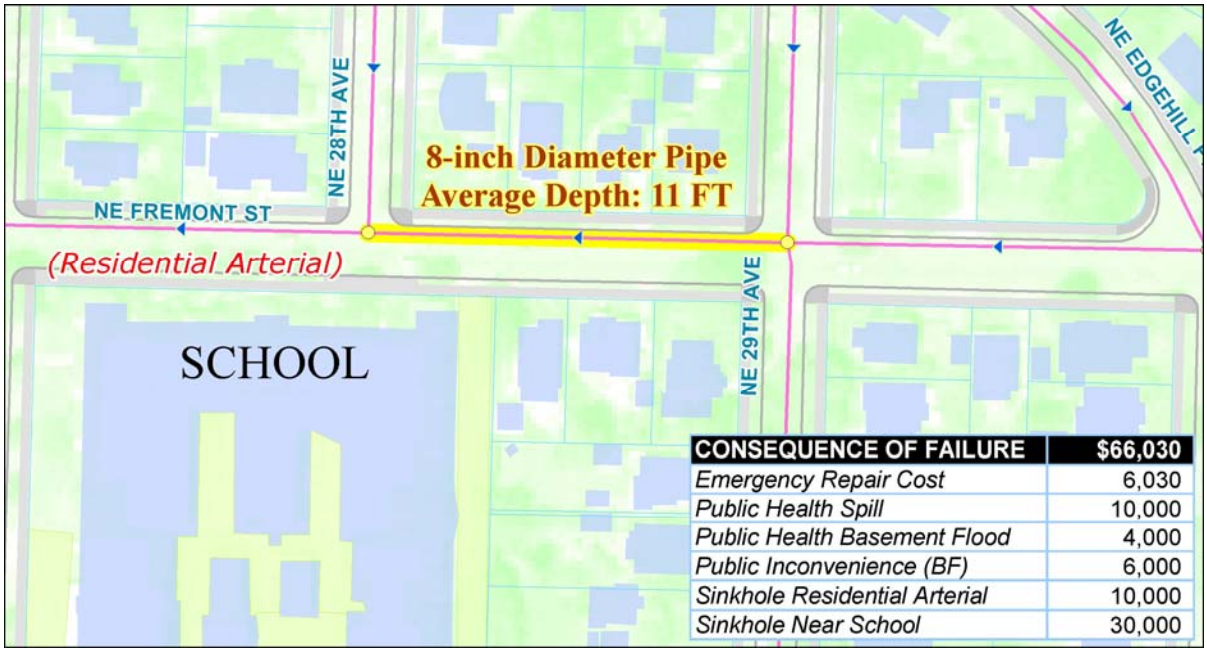


FIGURE 4-2
Example of Consequence of Structural Failure Valuation

In the example shown in Figure 4-2, *Emergency Repair Cost* represents the estimated cost of a spot repair to fix the sinkhole. *Public Health Spill* refers to injury from hazard or illness from contact with sewage from surface flooding with regard to its location, which in this case is near a school. *Public Health Basement Flood* refers to illness from contact with sewage or injury from hazards associated with basement sewer backup. *Public Inconvenience (BF)* refers to disruption, cleanup, and property damage associated with basement sewer backup. *Sinkhole Residential Arterial* refers to injury from hazard or interference with emergency services as it applies to a residential street. *Sinkhole Near School* refers to injury from hazard or interference with emergency services as it applies to a street near a school.

4.2.2.3.2 Likelihood of Failure

Sewer pipes are likely to fail at spots or segments that are in poor structural condition. The likelihood of a structural failure increases as the number of segments that are in poor condition increases.

For pipes with CCTV inspections documented in the Hansen Maintenance Management Database, information is available about structural defects, their severities, and positions along the pipe. To capture the distribution of defects, pipes were analyzed in 10 foot segments. Pipes were discretized into 10 foot segments in the GIS, and a database routine was used to determine the condition grade of each 10 foot segment in the same manner as whole pipes are graded in the Hansen Maintenance Management Database.

Pipes without a CCTV inspection were assigned a condition grade based on best available data such as the average grade from graded pipes of similar size and material, or the age of the pipe. If the condition grade of the pipe was estimated, all 10-foot pipe segments were assumed to be in the same condition.

The discretized scoring of the example pipe is shown in Figure 4-3. The example pipe is 290 feet long, so there are twenty-nine 10-foot segment scores, which are highlighted in yellow. The segments are color coded according to the segment scoring ranges that correspond to the pipe condition grades explained in Table 4-1. For instance, the seventh segment from the left with a score of 100 is given a condition Grade 3. As can be seen, the example in Figure 4-3 includes pipe segments with condition Grades of 1, 3, 4, and 5. This pipe is rated Grade 5 overall.

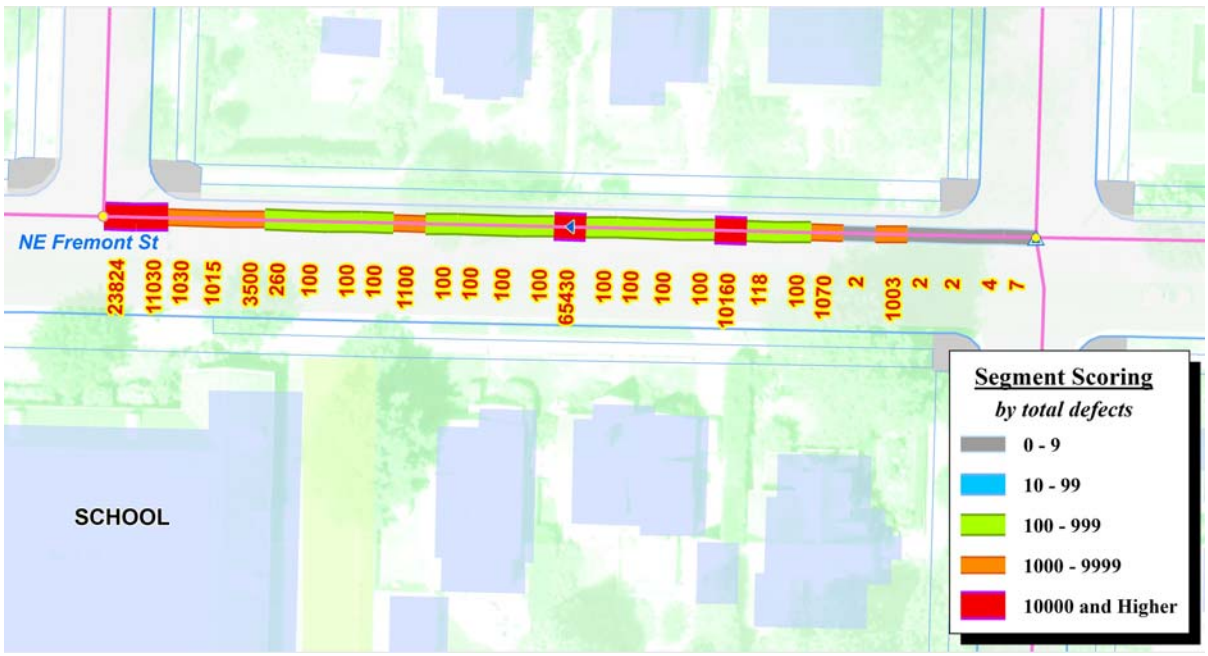


FIGURE 4-3
Example of Discretized Pipe Segment Scoring

The condition grades were used in conjunction with literature-based, remaining-useful-life tables to estimate a remaining useful life (RUL) for each segment (see *TM 3.1—Approach to Pipe Remaining Useful Life [Brown and Caldwell, 2008]*). Figure 4-4 shows an example of an RUL curve for a condition Grade 3 pipe segment.

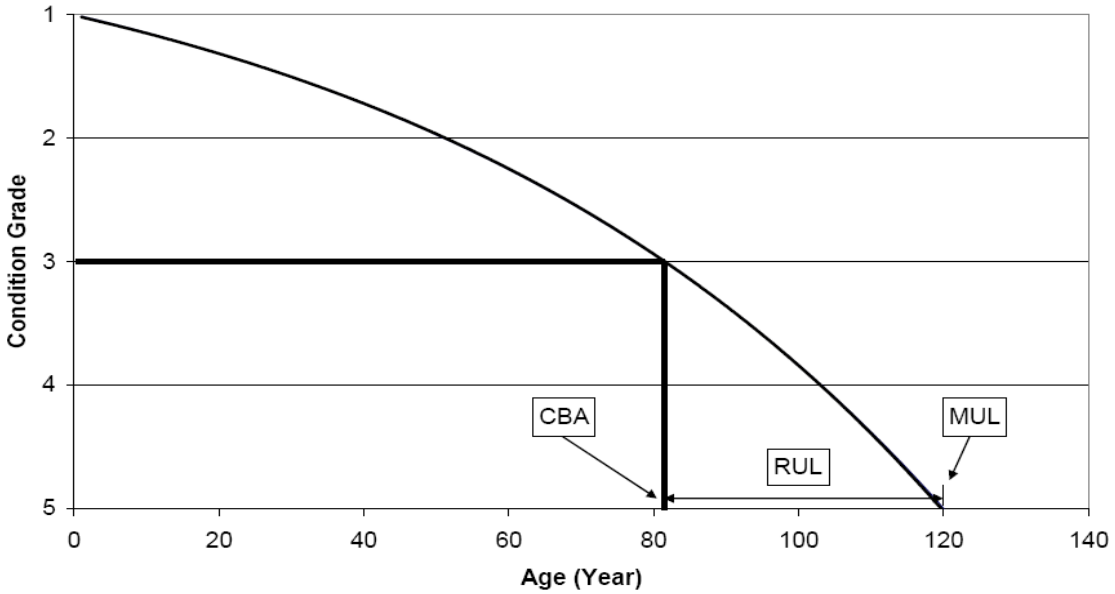


FIGURE 4-4
Example of Remaining Useful Life Curve
Determining remaining useful life and mean failure year of whole pipe from literature curves. CBA = condition based assessment; MUL = maximum useful life; RUL = remaining useful life

The mean failure year was estimated for each segment by adding the RUL to the CCTV inspection date:

Mean Failure Year = Inspection Date + RUL

For the example pipe segment, the CCTV inspection date is 2011 and it has a score of 100 (condition Grade 3). Therefore, the mean failure year would be calculated as follows:

2011 + 38 years = year 2049.

A normal probability distribution was assumed about the mean failure year with a standard deviation to reflect the confidence in the mean failure year estimate. The standard deviation is calculated as:

Standard Deviation = 0.1 x RUL + 0.15 x Years Since Last Inspected

The second term of this equation increases the standard deviation (decreases confidence in the RUL estimate) as the inspection becomes dated.

For the example pipe segment with a score of 100 (condition Grade 3), the standard deviation would be calculated as follows:

0.1 x 38 years + (0.15 x 0 years since last inspection) = 3.8 years

Figure 4-5 shows the probability distribution for the example 10-foot segment of pipe with a segment score of 100 (condition Grade 3).

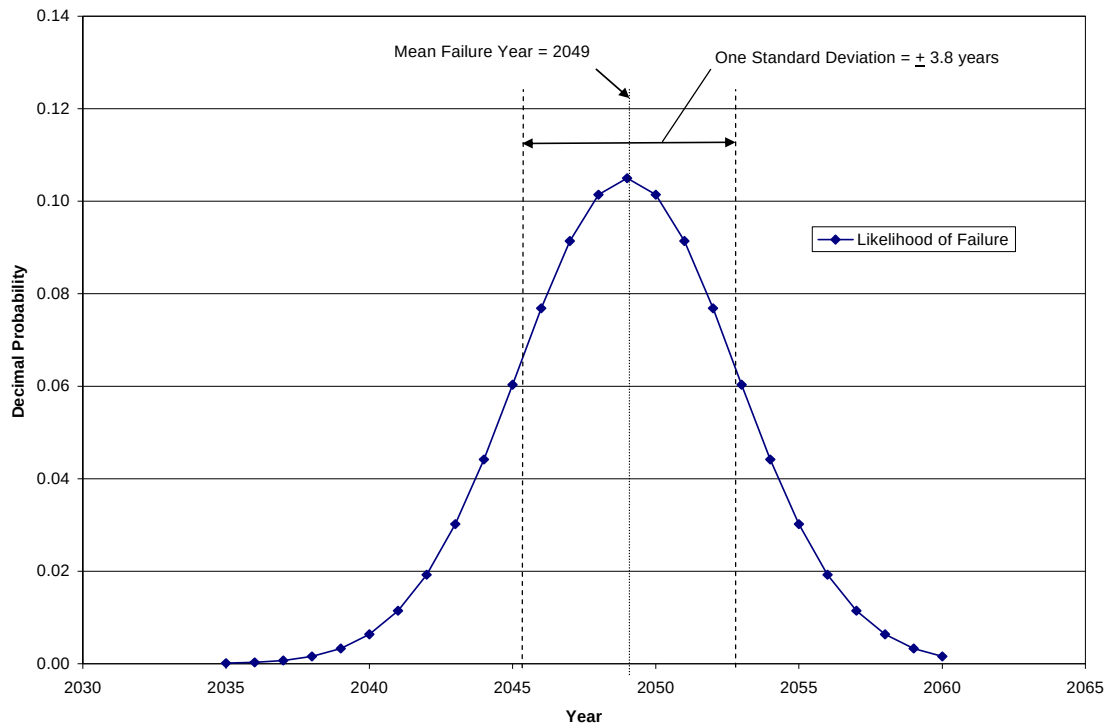


FIGURE 4-5
Example Probability Distribution for Single 10-foot Pipe Segment in Fair Condition (Grade 3)

4.2.2.3.3 Risk of Structural Deficiency Failures

The risk of structural deficiency failures is distributed in time by multiplying the likelihood of failure times the consequence of failure. The risk distribution for the example pipe (aggregation of the twenty-nine 10-foot segments) is shown in Figure 4-6.

The risk shown in Figure 4-6 is the base line risk that assumes the pipes will not be repaired or replaced, but allowed to fail as they deteriorate. The first peak of costs corresponds with failure of the very poor condition (Grade 5) 10-foot segments shown in Figure 4-3.

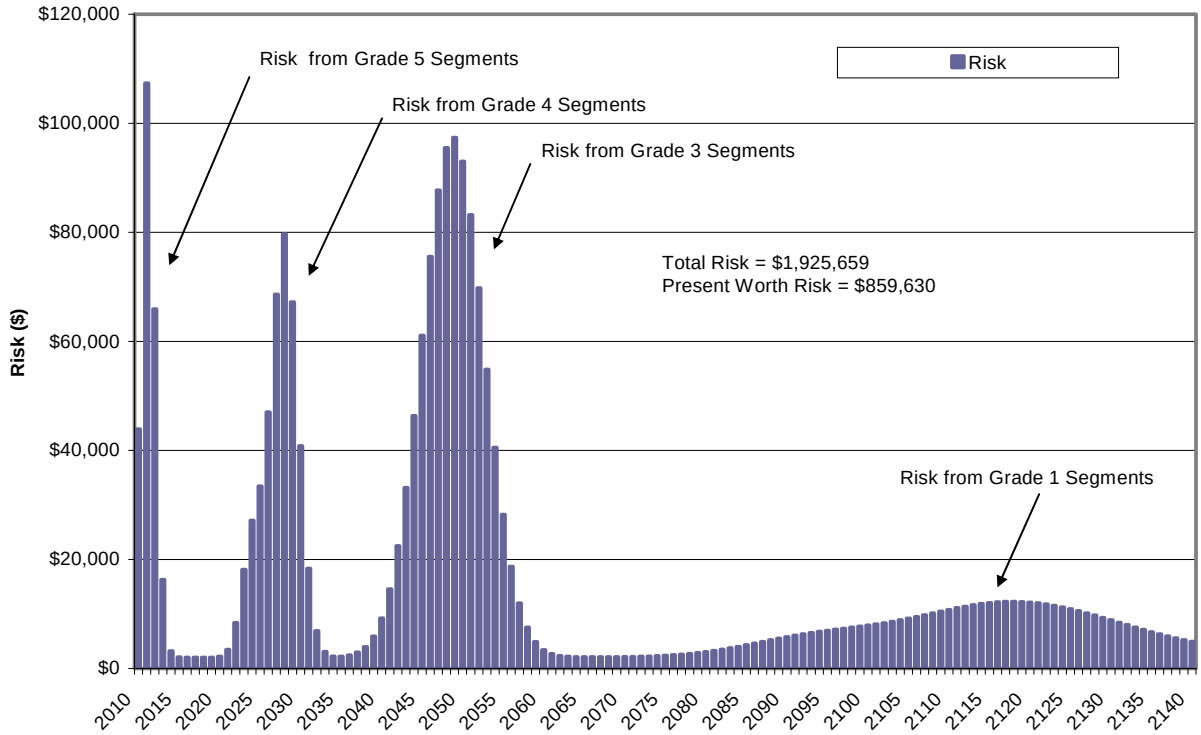
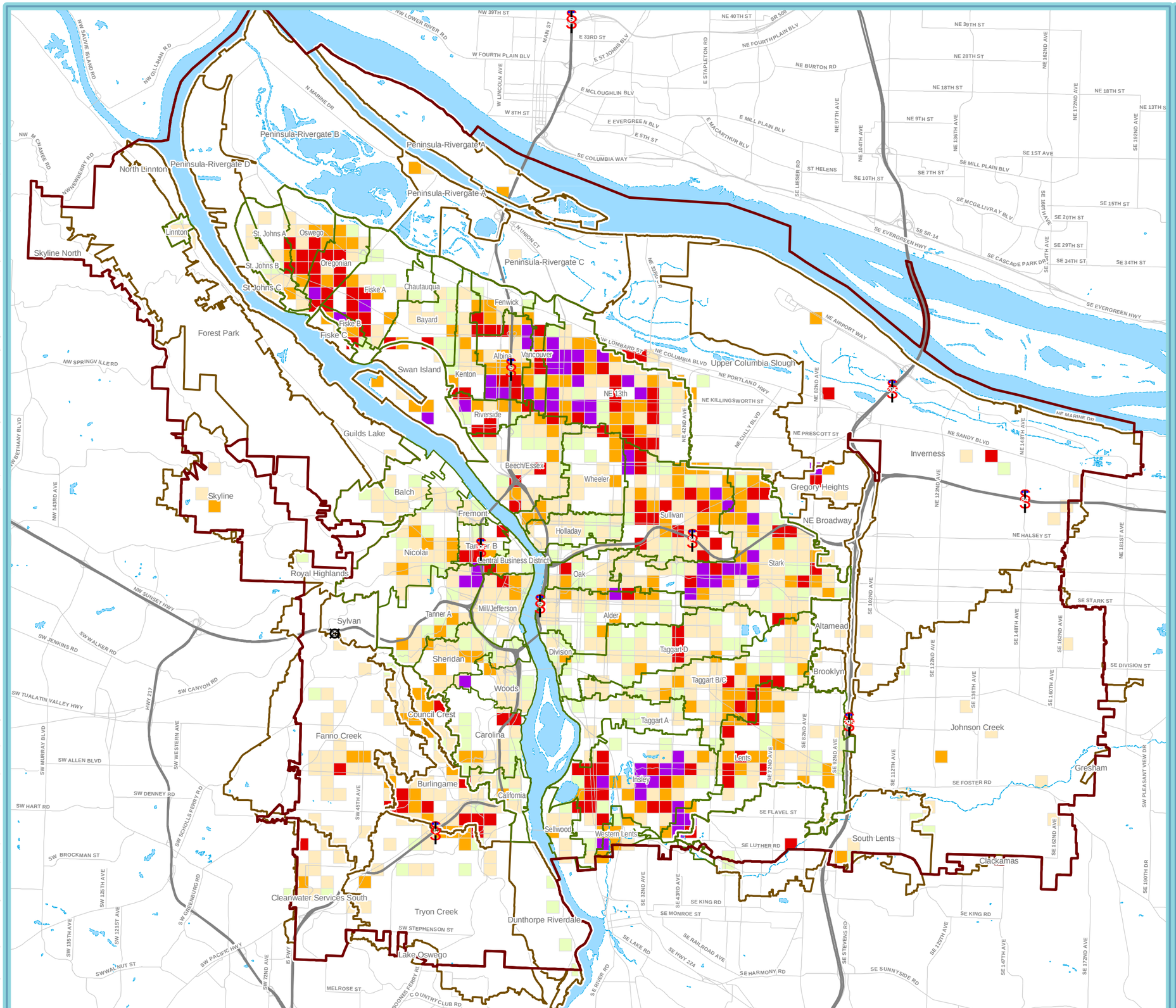


FIGURE 4-6
Risk Distribution for Structurally Deficient Pipe Example
(Example shown in Figure 4-3)

To assess structural deficiency risk for the entire sewer system, the process described above was applied to every 10-foot pipe segment in the City's service area. Figure 4-7 shows the 100-year present worth value of structural deficiency risk for all condition Grade 4 and 5 pipes summed by 25-acre grid cells. Only the Grade 4 and 5 pipes are shown in Figure 4-7 because they represent immediate pipe rehabilitation needs within the 20-year planning horizon.



Map Elements

- Urban Services Boundary
- Combined Sewer Basin Boundary
- Sanitary Sewer Basin Boundary

Risk in Dollars per Acre

- $1,000 to $5,000
- $5,000 to $25,000
- $25,000 to $50,000
- $50,000 to $100,000
- $100,000 and Greater

1 in = 1.5 miles

Figure 4-7

Present Worth of Structural Deficiency Risk

March 2012 - System Plan

Environmental Services
City of Portland
working for clean rivers

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4.3 Combined Sewer System Hydraulic Capacity Deficiencies

4.3.1 Analysis Tools

To support the capacity and performance analyses of the sewer systems, BES staff developed a highly detailed simulation technique called *explicit modeling*. The technique is *explicit* in that it models public and private facilities (manholes, pipes, green streets, onsite vegetated facilities, etc.) and impervious surfaces at the tax lot (parcel) level. Explicit modeling enables BES to more clearly define the sources of basement sewer backup risk and capacity problems throughout the basins, to efficiently calibrate to flow monitoring data with more certainty than traditional models, and to evaluate the cumulative benefits of street, parking area, and roof stormwater controls. BES used explicit modeling to prepare this combined sewer system characterization.

4.3.2 Model Calibration

BES developed and calibrated thirty-one basin explicit models and three interceptor explicit models. Nineteen of the basin models and the three interceptor models were developed and calibrated for the CSO Sizing and Flow Management Predesign Project. A detailed review of the calibration process for these basins and the interceptors is included in the *CSO Sizing and Flow Management Predesign Project TM 2.3* (*CSO Model Systemwide Calibration Report)*. The twelve Northside basin explicit models were developed and calibrated for this Combined Sewer System Plan Update Project. Reviews of the calibration processes for these basins are included in the basin calibration memoranda that were produced for each basin.

The basin model calibrations were performed by comparing basin model results against flows measured by temporary flow monitors that were installed within the basins. The interceptor calibrations were performed by comparing model results from the interceptor models against the monitoring data collected by the City of Portland Hydrological Data Retrieval and Alarm (HYDRA) system sewer level remote telemetry (SLRT) monitors in the collections system and HYDRA flow monitors located at the major pump stations and treatment plant. Examples of both basin and interceptor calibration are presented in Figures 4-8 and 4-9. These are examples of the good correlation between the model predictions and physical measurements at the monitors. The overall calibration results have provided BES confidence that the EMGAATS modeling system is predicting the hydrologic response from rainfall events fairly well. Additional flow monitoring and calibration typically occurs before the design of capital improvement projects in order to check the accuracy of the model predictions at the project-level scale.

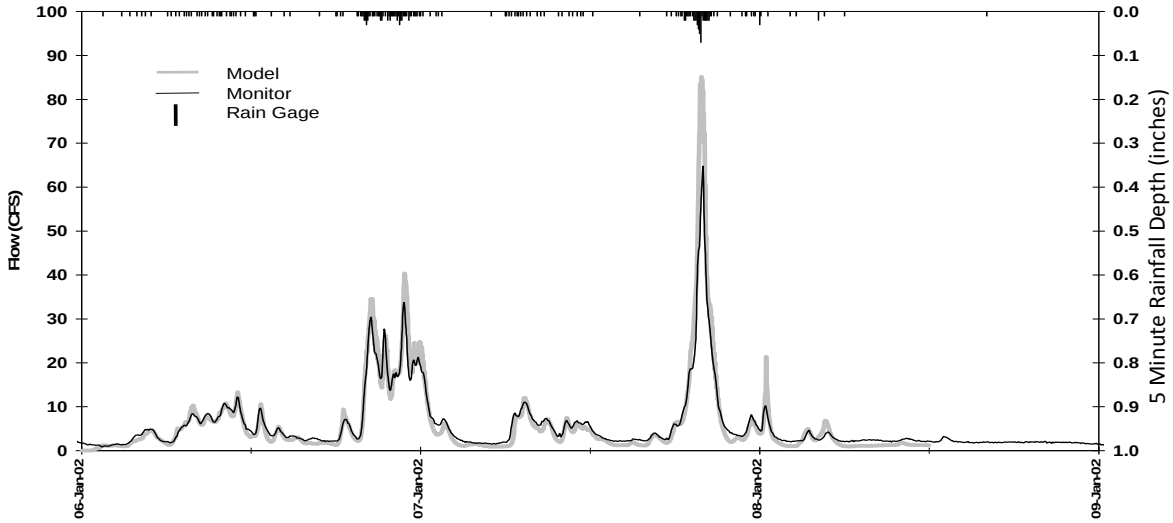


FIGURE 4-8
Alder Combined Basin Calibration at SE 23rd and Belmont

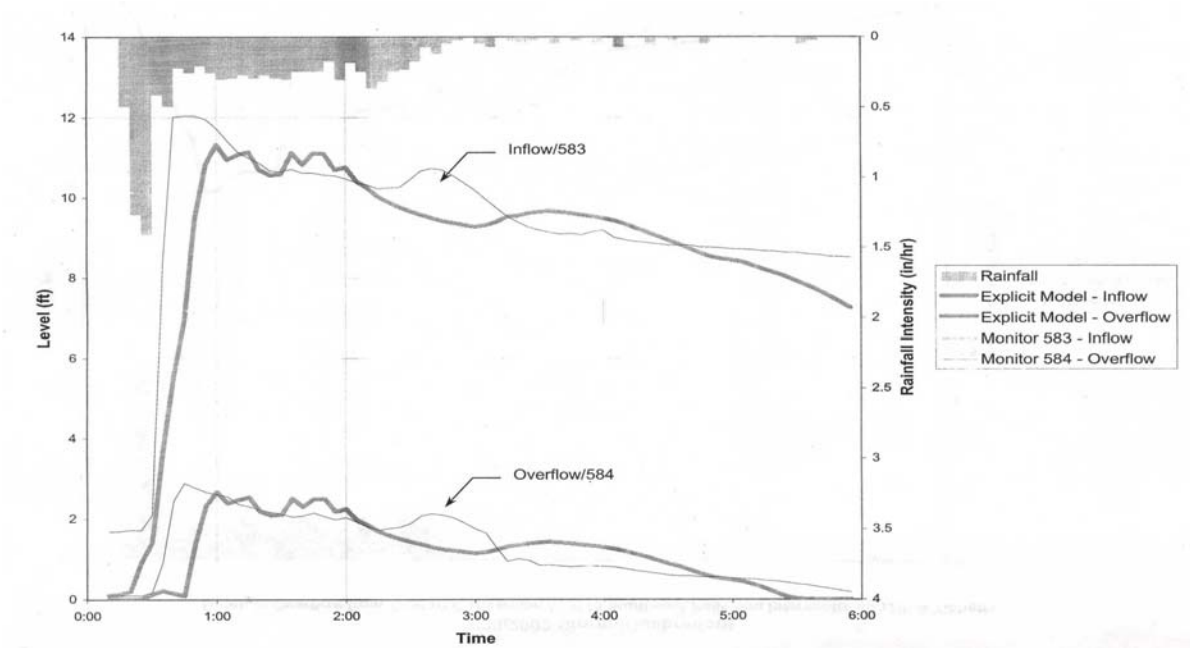


FIGURE 4-9
Interceptor Calibration Results at Alder Basin Diversion SE46
SE 9th Avenue and SE Madison Street (inflow to diversion structure and overflow from diversion structure)

4.3.3 Capacity Problem Identification

The hydraulic capacity characteristics of the combined sewer system were evaluated for four different design storm scenarios: three storms for existing conditions and one storm for future conditions. In addition, the 3-year summer storm was run to test the likelihood of a CSO occurring when the full CSO tunnel system becomes operational. For each of the four

design storms, Table 4-2 lists the design storms and their return frequencies, likelihood of occurrence, consequence (cost per basement sewer backup), and the risk expressed in dollars per basement over the 100-year analysis period. The dollar values shown in Table 4-2 coincide with those shown in Table 2-3 for pipe capacity failures and are the basis for the combined sewer capacity risk shown in Figure 4-10.

TABLE 4-2
Combined Sewer Capacity Risk

Design Storm (Land Use Condition)	Likelihood of Occurrence	Consequence	Risk as 100-Year Present Worth Value
2-year (existing condition)	50% chance each year (areas of highest risk)	$5,000/occurrence*	$91,535/basement
5-year (existing condition)	20% chance each year (areas of high risk)	$5,000/occurrence*	$36,614/basement
25-year (existing condition)	4% chance each year (Does not currently meet level of service)	$5,000/occurrence*	$7,323/basement
25-year (future condition)	Projected to not meet level of service in future	Used results from this design storm to size pipes and stormwater control facilities based on future land use conditions.	

*This dollar value only represents the consequence of a basement sewer backup occurring; based on costs outlined in Table 2-3 for capacity failures.

Each of the three existing-condition design storms represents a different level of risk. The levels of risk are determined from the likelihood of the failure occurring and the triple-bottom-line dollar value resulting from the consequence of that failure. The results from the future-condition 25-year storm scenario were used to size pipes and stormwater facilities in areas that did not meet the technical levels of service performance measures.

The risk of increasing CSO volume is estimated to be $3/gallon of stormwater runoff generated during the 3-year summer design storm.[10] As described in the *Post-2011 Combined Sewer Overflow Facilities Plan* (BES, 2010a), it is predicted that 22.4 million gallons of new stormwater runoff from future development will flow to the Willamette River CSO tunnels by 2050. Therefore, the dollar value related to the consequence of that risk is approximately $67.2 million.

In addition to basement sewer backup risk and CSOs, there is a risk of surcharging of trunk sewers that leads to degradation of pipe material. Each of the three existing-condition design storms represents a different frequency of surcharging that could shorten the life of

[10] Adapted from *CSO Sizing and Flow Management Final Predesign Report*, Figure 6-1 (BES, 2005); value was estimated as $4/gallon, but because these projects were not needed until 2025, the credit was discounted through a present worth analysis and was assumed to be worth $3/gallon at the time that this system planning work was completed.

the pipe segments. This plan incorporated surcharging risk for the NE 33rd Avenue and the Sullivan's Gulch trunk lines since there has been a history of pipe failure along the lower portion of this trunk line. The dollar value of that risk is approximately $11.6 million.

Figure 4-10 shows the geographic distribution of capacity deficiency risk within the BES service area (combined and sanitary sewer basins) in terms of 100 year present worth value. This capacity deficiency risk includes basement sewer backup risk, the risk of future CSOs, and the risk related to surcharging the NE 33rd Avenue and Sullivan's Gulch trunk lines.

The performance measures used to predict capacity deficiency risk are discussed in Section 3.4.2. The characterization of the combined sewer system is documented in the *Combined Sewer Basin Hydraulic Characterization Technical Memoranda* (BES, 2006b), the *Combined Sewer System Plan Characterization Summary* (BES, 2006c), and in the *Basin Characterization Atlas* (BES, 2006a).

4.4 Sanitary Sewer System Hydraulic Capacity Deficiencies

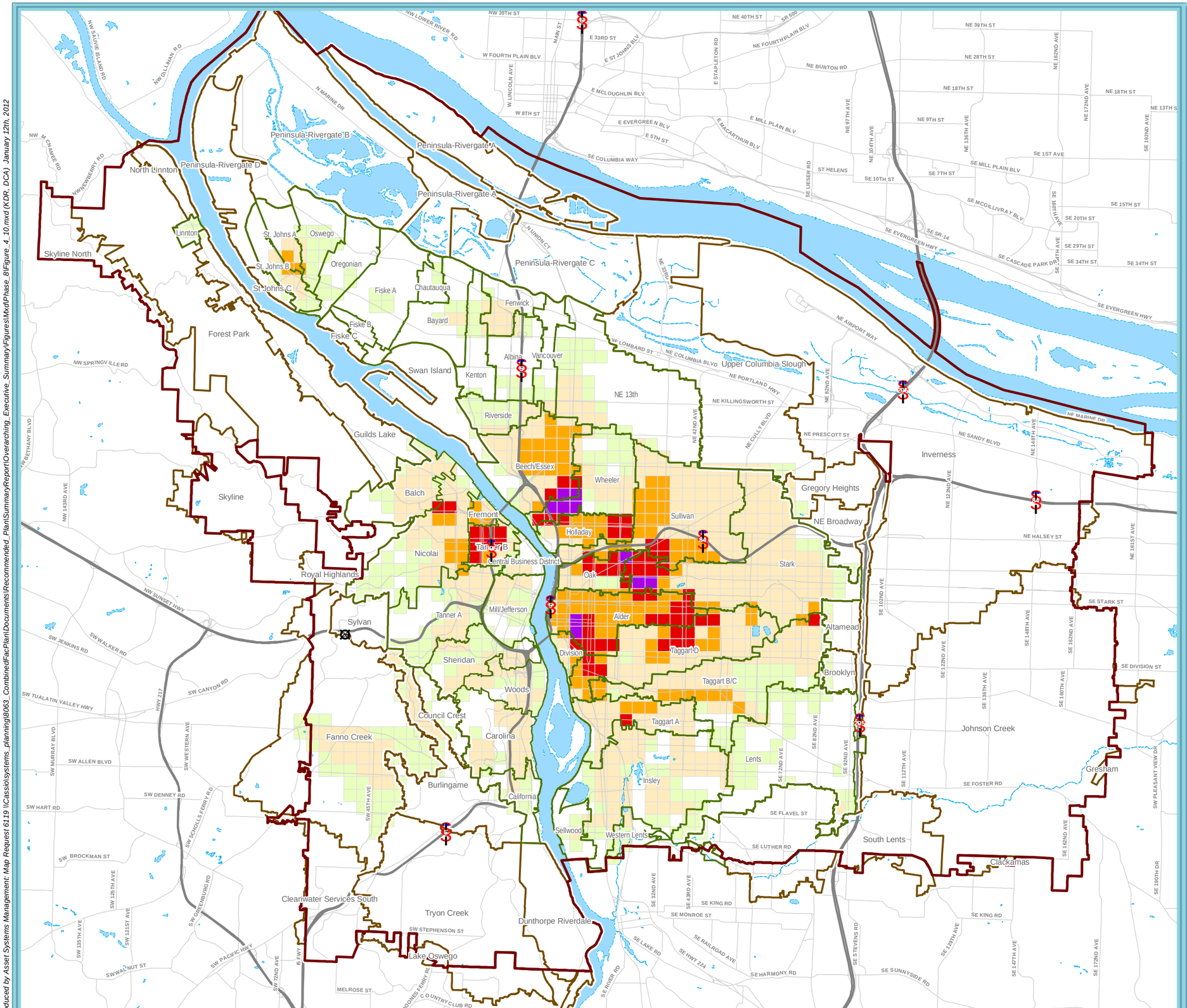
4.4.1 Analysis Tools

BES adapted the explicit modeling techniques used in the combined sewer system analysis to characterize sanitary collection system performance. The hydraulic model was largely unchanged.

However, the nature of sanitary sewer flow required a different hydrologic model than what was used for the combined sewer system. During the process of selecting the appropriate model, it was determined that the Fanno Creek basin required greater emphasis on accuracy than the other sanitary basins because of known deficiencies in pumping and conveyance that compelled development of a near-term solution. With this in mind, it was decided to apply and calibrate the Fanno Creek, Burlingame, and Tryon Creek basin models using some of the latest hydrologic and hydraulic modeling software.

4.4.2 Model Calibration

Twenty-four sanitary sewer basin models were developed using off-the-shelf tools and the latest modeling software. Flow monitoring was performed during the winter months of 2003/04, 2004/05, 2005/06, 2008/09, and 2009/10. The monitoring plan was designed to monitor major catchments of each basin. Areas with significant RDII were sub-divided by performing additional monitoring to obtain greater detail about where sources of RDII might be concentrated.



Map Elements

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- Combined Sewer Basin Boundary
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Risk in Dollars per Acre

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- $100,000 and Greater

1 in = 1.5 miles

Figure 4-10

Present Worth of Capacity Deficiency Risk

March 2012 - System Plan

Environmental Services
City of Portland
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The basin models were calibrated against flow monitor and pump station cycle data and documented in the *Sanitary Sewer System Model Development and Calibration Technical Memoranda* (BES, 2010b). Roughly two-thirds of the sanitary sewer service areas were calibrated to flow monitor or pump station run-time data. The monitoring and calibration effort was greatest for the Fanno Creek, Burlingame, and Tryon Creek basins because these basins had higher RDII and thus more monitoring sites to analyze and calibrate.

Figures 4-11 and 4-12 are examples of model calibration results for the Fanno Creek and Tryon Creek discharge locations. The plots show measured flow data and model predictions for the December 1–4, 2007, storm, an event that was approximately a 5-year, 24-hour storm.

4.4.3 Flow Characterization

The total flow hydrograph in the separated sanitary system was characterized as two components: base flow and RDII.

Base flow was defined as domestic and industrial wastewater plus infiltration from groundwater that is not influenced by rainfall.

RDII was defined as the total flow hydrograph minus the base flow. This includes infiltration from seasonally elevated groundwater that enters sewer pipes through holes, breaks, joint failures, etc. Inflow sources include yard and footing drains, catch basins, directly connected downspouts, and holes in manhole covers.

A base flow hydrograph and a model for creating an RDII hydrograph were developed for each catchment. The monitors showed that measured base flow was commonly less than what would be predicted by the *Sewer and Drainage Facilities Design Manual* (Design Manual) (BES, 2007) while the RDII flow was considerably higher.

RDII flow rates are typically expressed on a per-unit basis, such as gallons per day per acre (gpd/acre). The 5-year storm peak RDII rate is of interest because it is the flow component that causes most capacity failures. The peak RDII rates for sanitary *basins* range from 500 to 22,000 gpd/acre. To put this in perspective, the Design Manual specifies that a peak RDII rate of 1,000 gpd/acre is to be used when designing new sanitary sewer systems. (In comparison, a typical residential combined sewer system basin will generate approximately 175,000 gpd/acre during a 5-year storm.)

Figure 4-13 shows the basinwide RDII rates ranked by 5-year storm peak RDII rate. Although Fanno Creek is ranked third, *individual catchments* within this basin have calibrated peak RDII rates as high as 100,000 gpd/acre. When the ranking is applied to individual catchments, the Fanno Creek and Burlingame basins have ten catchments with peak rates in excess of 30,000 gpd/acre.

Table 4-3 summarizes how development assumption categories shown in Figure 3-1 were applied to sanitary flow characterization.

TABLE 4-3
Application of Connection and Development Assumptions to Flow Characterization

Connection and Development Assumption	Existing Flow		Future Flows	
	Base Flow	RDII	Base Flow	RDII
Will Not Connect	None	None	None	None
Connected, No Changes	Base flow pattern measured or assumed during model development and calibration	5-year winter storm applied to RDII model created during model development and calibration	Same as existing	Maximum of 110% of existing or 1,000 gpd/acre
Connected, Future Redevelopment	None	None	Design Manual	Maximum of 110% of existing or 1,000 gpd/acre
Future New Connection	None	None	Design Manual	2,000 gpd/acre*

*Flow monitoring showed that basins were more likely to have RDII rates greater than the Design Manual value, so a more conservative value was assumed to estimate flows.

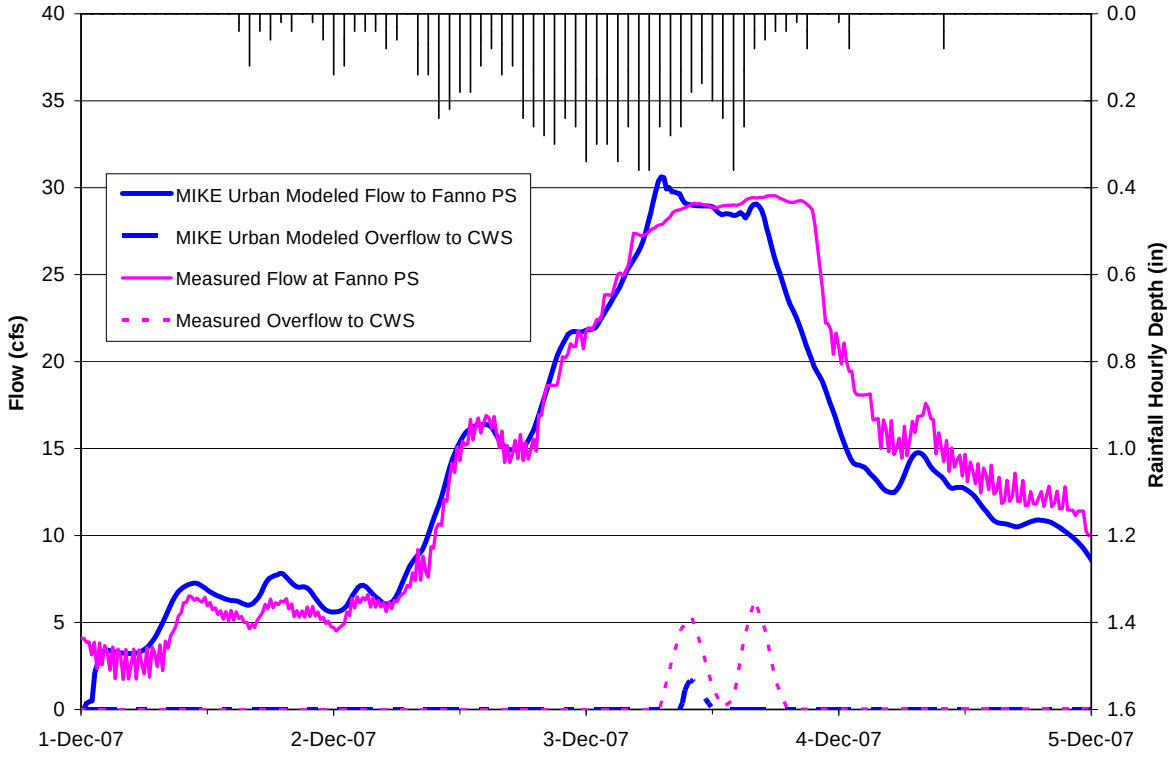


FIGURE 4-11
Fanno Creek Sanitary Basin Calibration

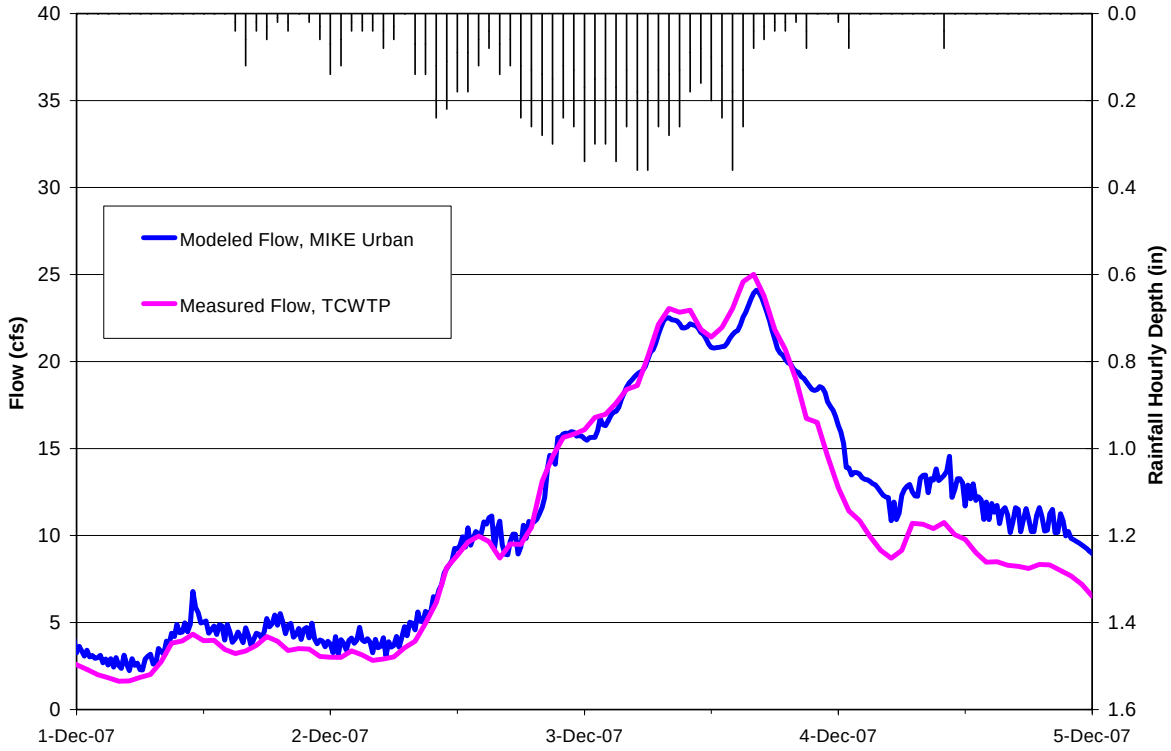


FIGURE 4-12
Tryon Creek Sanitary Basin Calibration

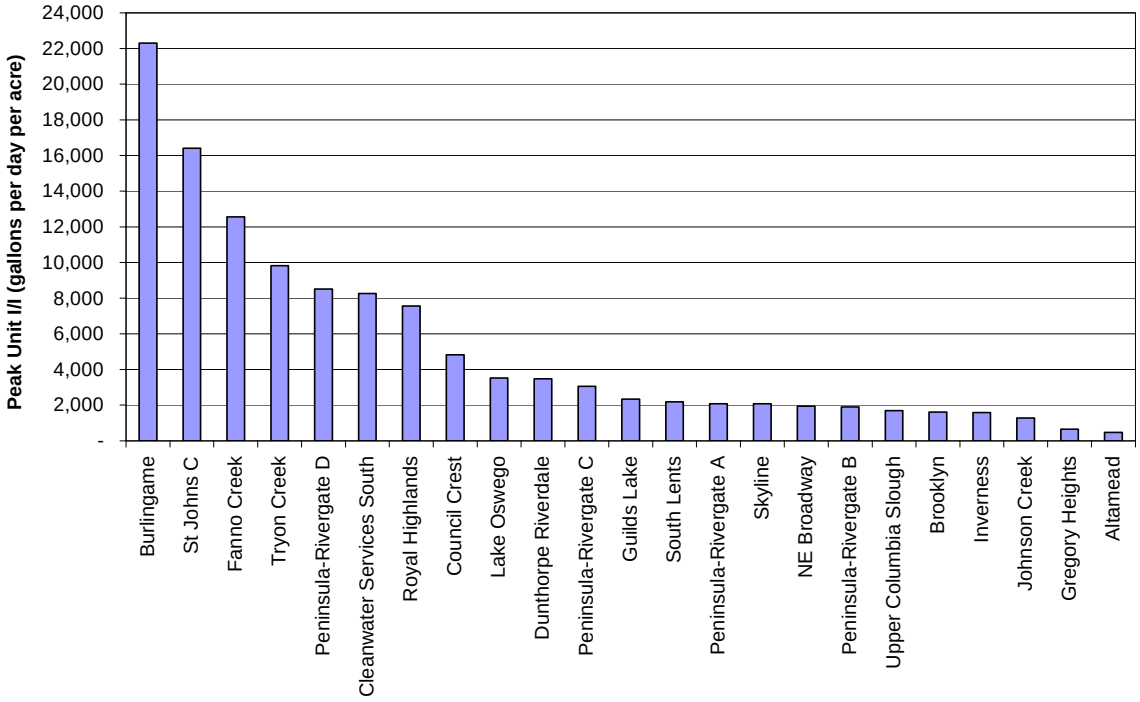


FIGURE 4-13
Sanitary Basin Peak RDII Flow Rates

4.4.4 Capacity Problem Identification

BES performed hydraulic modeling of the sanitary sewer area to characterize collection system performance relative to service levels, as discussed in Section 3.4.3. If the sanitary components cannot adequately convey the design storm flow, the options for meeting this service level are to either reduce the flow (RDII reduction) or increase the capacity of the conveyance system (upsize pipe diameters, increase pump station capacity, and/or expand the wastewater treatment plant capacity). The risk may be a local risk that only requires pipe upsizing or it may be a basin risk that requires increasing pump station capacity or perhaps even treatment plant expansion.

Most of the sanitary sewer basins meet the BES service levels for conveyance.[11] Exceptions are the Fanno Creek and Burlingame basins where street flooding and basement sewer backups may occur during storms smaller than the service level design storms.

During intense storms, the Fanno Basin Pump Station is unable to keep up with the additional flow from RDII. A CIP project is currently underway to address the capacity issues at the Fanno Basin Pump Station, so the associated risk is excluded as part of this problem identification. Similarly, capacity issues regarding the Burlingame Trunk are being addressed by an existing CIP project and therefore the associated risk is excluded from this problem identification.

The Tryon Creek collection system has adequate capacity, but the TCWTP is approaching the maximum plant capacity. The consequence of not meeting the levels of service at TCWTP has not been estimated at this time and thus is not shown in Figure 4-10. The dollar values shown in Table 4-4 coincide with those shown in Table 2-3 and are the basis for the sanitary sewer capacity risk shown in Figure 4-10.

TABLE 4-4
Sanitary Sewer Capacity Risk

Type of Failure, Design Storm, and Condition	Likelihood of Occurrence	Consequence*	Risk over 100-Year Analysis Period
Basement Backup 5-year (existing condition)	20% chance each year	$5,000/occurrence	$36,600/basement
Surface Flooding 5-year (existing condition)	20% chance each year	$48,000/subbasin	$334,600/subbasin
Surface Flooding near School 5-year (existing condition)	20% chance each year	$53,000/subbasin	$369,200/subbasin
Surface Flooding near School 1-year (existing condition)	100% chance each year	$53,000/subbasin	$1,940,500/subbasin
Failure to Provide Sewer Service	100% chance each year	$700/dwelling unit	$28,800/dwelling unit

*Refer to Table 2-3 for additional details and footnotes.

[11] See Section 3.4.3 for discussion regarding design storm frequency.

4.4.5 Identification of Areas Requiring Sewer Service Connections

BES identified tax lots requiring future sewer service connections in two steps.

The first step was to place tax lots into development categories described in Section 3.2.2. Tax lots were placed in the "will not connect" category if they fit any of the following categories: parks and open spaces; properties within an environmental protection zone (p-zone); golf courses; publicly owned property set aside as nature reserves, including BES Willing Seller Program and Metro Green Space Initiative properties; transportation corridors; cemeteries; and large swaths of low density residential (RF) areas that are currently served or would likely be served by septic systems, such as the Skyline North and North Linnton Basins.

The second step was to determine whether the tax lots met the following conditions that are required for sewer service connection:

- No gravity sewer currently exists close enough to allow a lateral to connect to the sewer.
- It must be feasible to provide service to the tax lot. Where connection was not feasible, no alternatives were identified or recommended plan developed. These difficult locations will need to be evaluated at the site level, instead of at this planning level. Pump stations were not considered feasible for fewer than five properties.
- The tax lot is not in an area where a sewer system is currently in design or under construction.

There are significant areas currently unserved by sanitary sewers within the USB, primarily in the Johnson Creek and Skyline basins. These properties are generally undeveloped or will be redeveloped based on the planning assumptions discussed in Section 3.2.2. The *Sewer and Drainage Design Manual* (BES, 2007) guidelines were used as the basis for estimating base flow from new connections. Flow caused by RDII was assumed to be 2,000 gpd/acre. Table 4-5 shows the total unserved areas and estimated peak flows.

TABLE 4-5
Estimate of Future Sanitary Sewer System Peak Flow from Unserved Areas

Sanitary Sewer Basin	Unserved Service Area (acres)	Peak Flow (cfs)
Johnson Creek	475	3.7
South Lents	14	0.7
Tryon Creek	86	0.4
Royal Highland	47	0.4
Skyline	322	2.4

cfs = cubic feet per second.

At the time of this report, the analysis of unserved areas in the Columbia Slough was not completed. This analysis will be documented in the *Sanitary Sewer System Recommended Plan for Un-served Areas* (BES, 2012d) scheduled for completion in March 2012. The locations of the Columbia Slough unserved areas are shown on Figure 6-2.

Chapter 5: Development and Analysis of Alternatives

5.1 Overview

BES developed and evaluated alternatives to address the structural and capacity pipe deficiencies that were identified during the characterization of the system. The alternatives were developed to meet the levels of service that are summarized in Section 3 of this report.

For the pipes with structural deficiencies, the alternatives consisted of performing a whole pipe replacement or a spot repair at the location of the deficiency. Ongoing monitoring was recommended as an alternative when the defects did not warrant rehabilitation.

For the combined sewer system, the primary capacity alternatives were conveyance or stormwater control. The conveyance alternative provided the traditional pipe upsizing approach, whereas the stormwater control alternative provided a green infrastructure approach with stormwater runoff being infiltrated into vegetated stormwater facilities.

For the sanitary sewer system, the capacity alternatives included pipe upsizing, pump station expansion, RDII removal, and wastewater treatment plant expansion. In areas currently unserved by any sewer system, alternatives were developed and evaluated to provide new sanitary sewer service.

The development and evaluation of alternatives is described separately below for pipe structural deficiencies and pipe hydraulic deficiencies for both the combined sewer system and the sanitary sewer system.

5.2 Pipe Structural Deficiencies

The process for development, evaluation, and selection of preferred rehabilitation/ replacement alternatives to address structural deficiencies (pipes with condition Grades 4 or 5) is discussed below.

5.2.1 Development and Evaluation of Alternatives

BES identified three viable actions to manage the risk associated with pipe structural deficiencies and used these to develop three system-wide alternatives for evaluation. The three viable actions were as follows:

- **Monitor by Inspection**. This action is appropriate when rehabilitation work is not recommended, but the observed defects warrant CCTV inspection to ensure the likelihood of failure does not rapidly increase.

- **Perform Spot Repair**. Spot repairs are appropriate when only a portion of the pipe is in poor structural condition. Spot repairs can be made with spot liners or by digging and replacing portions of the pipe.
- **Rehabilitate the Whole Pipe**. Whole pipe rehabilitation is appropriate for pipes with a significant portion in poor condition. Whole pipe rehabilitation may be performed by digging and replacing the pipe or with trenchless technologies such as lining or pipe-bursting. BES currently uses a guideline for whole pipe rehabilitation: Grade 4 and 5 pipes are selected for whole pipe rehabilitation when a large portion of the pipe is in poor condition or when the fourth spot repair is due.

Applying these actions in different combinations, BES developed the following system-wide pipe rehabilitation alternatives:

- **System Alternative 1: Whole Pipe Rehabilitation and Monitor by Inspection**. With this alternative, all pipes requiring rehabilitation are assumed to require *whole pipe rehabilitation* and are replaced without upsizing. Those pipes that do not require rehabilitation are placed on a *monitor by inspection* list.
- **System Alternative 2: Whole Pipe Rehabilitation, Spot Repair, Monitor by Inspection**. This alternative reduces the number of pipes designated for *whole pipe rehabilitation* in situations where the severe defect occurs in a small segment of the pipe, and that defect can be addressed by a *spot repair*. The spot repair changes the structural condition of the pipe to a grade that extends its useful life. The remaining pipes are placed on a *monitor by inspection* list.
- **System Alternative 3: Whole Pipe Rehabilitation Accounting for Laterals, Spot Repair, and Monitor by Inspection**. This alternative is the same as System Alternative 2, except that pipes designated for *spot repairs* or *monitor by inspection* are re-examined to determine if the laterals connecting to the pipe are defective (dropped or offset lateral). If four or more laterals on the pipe are defective, the pipe is re-designated for *whole pipe replacement*.

To evaluate these system alternatives, BES applied each of the system alternatives to the structurally deficient pipes (condition Grades 4 and 5) identified during the system characterization (described in Section 4) and defined three sets of preferred pipe rehabilitation alternatives. The process preformed to evaluate the pipes and select the preferred rehabilitation action for each pipe is illustrated for System Alternative 3 in Figure 5-1 and discussed below.

5.2.1.1 Reference Asset Inventory

The Hansen Maintenance Management Database inventory of sanitary and combined sewers, including combined sewer outfalls, was referenced to begin the evaluation process.

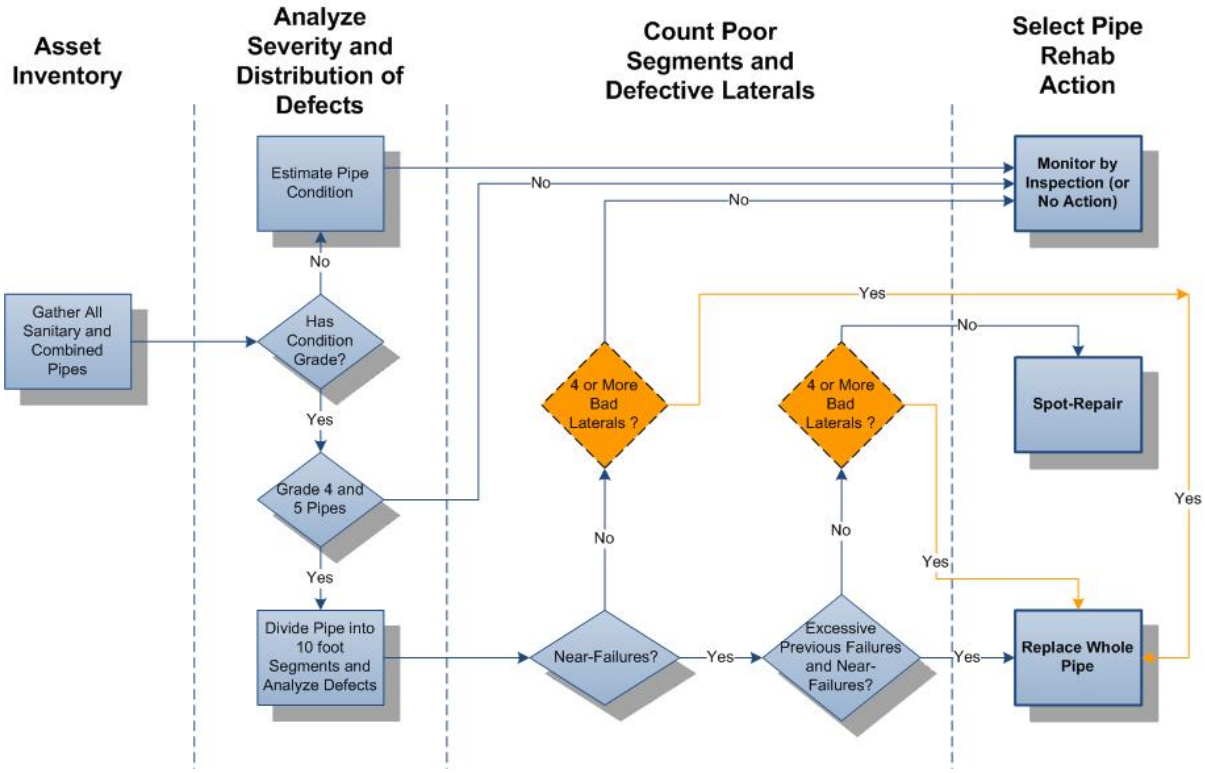


FIGURE 5-1
Development of Preferred Pipe Rehabilitation Actions for System Alternative 3

5.2.1.2 Analyze Severity and Distribution of Defects

The defects of condition Grade 4 and 5 pipes were analyzed to determine their severity and distribution by dividing the pipes into 10-foot segments and then determining the condition grade of each segment as discussed in Section 4.

Pipes with no condition grade or good condition grade (Grades 1, 2, or 3) do not require actionable rehabilitation and were designated to be monitored by inspection.

5.2.1.3 Count Poor Segments and Defective Laterals

Segments with structural scores greater than or equal to 1,000 (condition Grade 4) were deemed "near failure." Segments that had been previously repaired (via spot repairs) were counted as "previously failed."

Defective laterals identified by CCTV inspection crews were also counted. This included laterals with holes or cracks or laterals dropped at the tee to the main line. If four or more defective laterals were identified, then replacement of the whole pipe was recommended because the level of effort was judged to be approaching that of whole pipe replacement and because of the increased risk. Also, it is easier to replace laterals after replacement of a main line.

5.2.1.4 Select Pipe Rehabilitation Action

Monitor by Inspection was selected for pipes that do not appear to currently warrant either whole pipe replacement or spot repairs.

Spot Repairs were assumed for pipes with less than 10 percent near-failed or previously-failed segments, with at least one near-failed segment.

Whole Pipe Replacement was the preferred alternative for pipes with more than 10 percent of the segments near failure and previously failed, with at least two near-failed segments. This 10 percent cutoff represents the BES guideline that after three spot repairs, a pipe should be replaced. In addition, all Grade 4 or 5 pipes with four or more defective laterals were assigned to be replaced in whole.

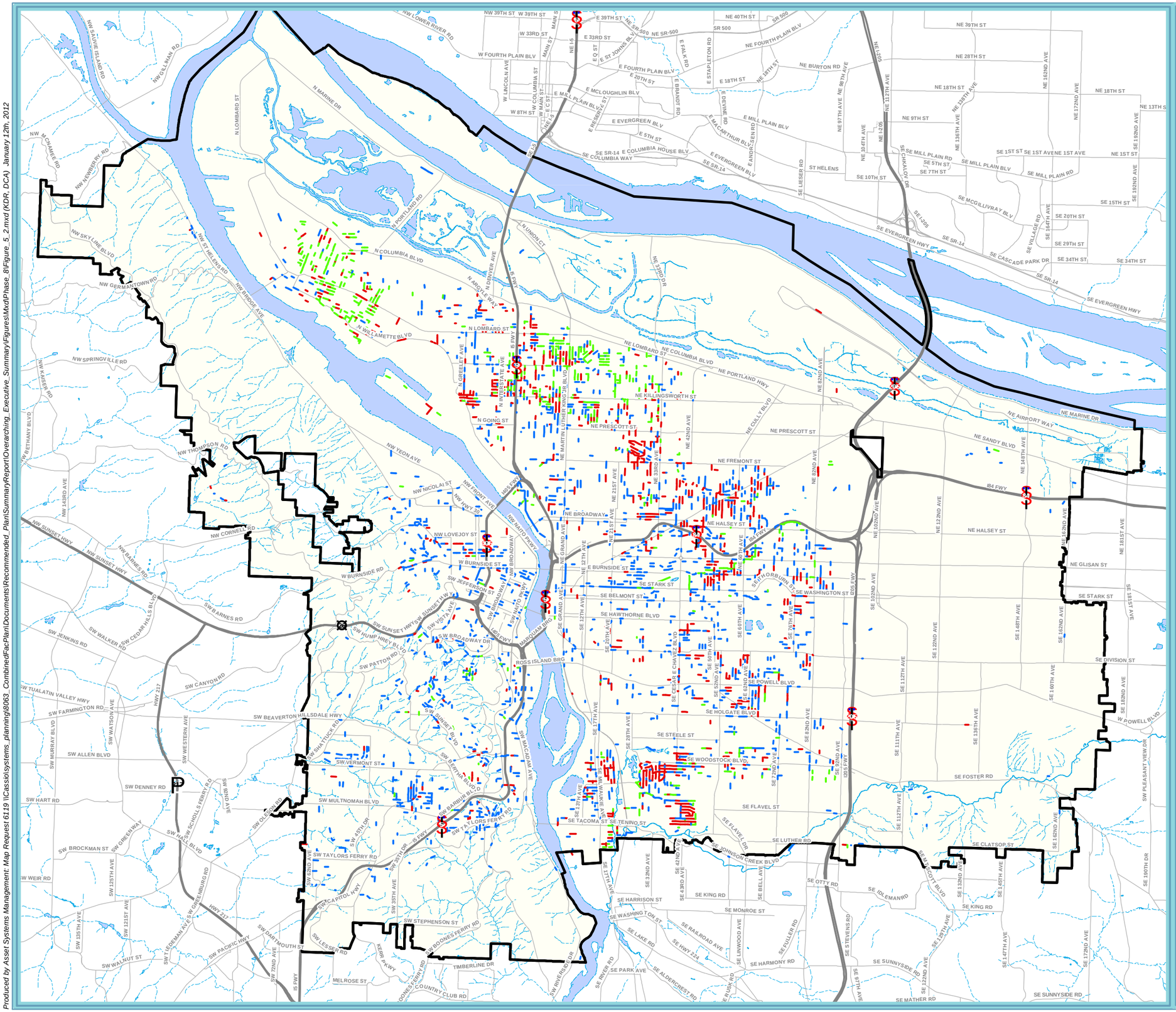
The resulting cost estimates for the three system alternatives are shown in Table 5-1 for comparison.

TABLE 5-1
Cost Comparison of Pipe Rehabilitation System Alternatives

System Alternative	Components	Total Cost Estimate ($ in thousands)
1	Whole pipe rehabilitation and monitor by inspection	$637,992
2	Whole pipe rehabilitation, spot repair, and monitor by inspection	$128,053
3	Whole pipe rehabilitation accounting for laterals, spot repair, and monitor by inspection	$149,499

5.2.2 Selection of Preferred Alternatives

System Alternative 3 was found to represent the most complete, reliable, and cost-effective combination of pipe alternatives that addresses the structurally deficient pipes and extends their economic useful life. This alternative accounts *for known factors that result in* whole pipe replacement versus spot repairs or monitoring by inspection only, and should result in projects that are reliable in terms of scope. Therefore, System Alternative 3 was selected as the preferred alternative. The pipe rehabilitation actions of the preferred alternatives are shown on the map provided in Figure 5-2. The monitor by inspection actions shown in Figure 5-2 are for pipes with condition Grade 4 that do not currently require spot repairs or whole pipe replacement.



Map Elements

Urban Services Boundary

Pipe Alternative Action

Spot Repair

Monitor by Inspection

Whole Pipe Rehabilitation

1 in = 1.5 miles

Figure 5-2

Preferred Pipe Rehabilitation Alternative

March 2012 - System Plan

Environmental Services
City of Portland
working for clean rivers

Produced by Asset Systems Management: Map Request 6119 \\Cassio\systems_planning\8063_CombinedFacPlan\Documents\Recommended_Plan\SummaryReport\Overarching_Executive_Summary\Figures\Mxd\Phase_8\Figure_5_2.mxd (KDR, DCA) January 12th, 2012

The cost breakdown of the preferred alternative pipe rehabilitation actions is presented in Table 5-2.

TABLE 5-2
Cost Breakdown of Preferred Alternative Pipe Rehabilitation Actions

Action	Pipe Count	Number of Spot Repairs	Capital Cost ($ in thousands)
Monitor by Inspection	45,790		Not applicable
Spot Repair	1,802	2,317	$19,396
Whole Pipe Rehabilitation	907		$130,103
Total Capital Cost			$149,499

5.3 Combined Sewer System Hydraulic Capacity Deficiencies

The process for development, evaluation, and selection of preferred alternatives in the combined sewer system is outlined in Figure 5-3. The elements of this process are discussed below.

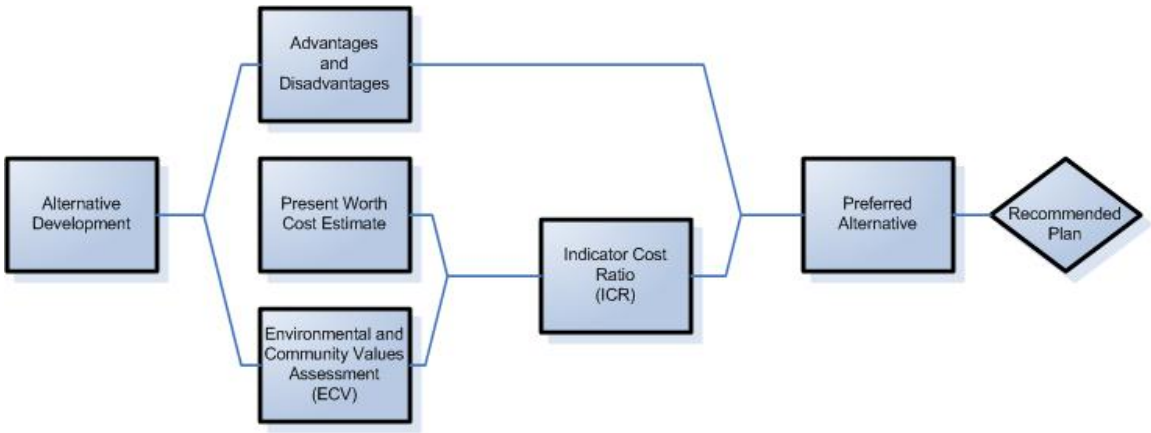


FIGURE 5-3
Combined Sewer System Alternatives Development and Evaluation Process

5.3.1 Development of Alternatives

Alternatives were developed to address capacity problems in the combined sewer system basins, excluding those with recent, applicable predesign projects (Taggart D, Northwest Neighborhoods, and Lents 2). The Oak basin predesign was re-evaluated during the alternative development phase, but only for the purposes of updating the predesign. In the Beech-Essex basin, a recently completed predesign had to be significantly altered when it was determined that the proposed sewer separation trunk line was infeasible, and the East Side CSO Tunnel design was modified to address the resulting CSO problem. As a result, a new stormwater control alternative was developed as part of this sewer system planning process.

The two primary types of alternatives developed and evaluated for most basins were conveyance and the stormwater control alternatives. The conveyance alternatives only included upsized pipe segments, while the stormwater control alternatives included mitigating flows by using roof, parking, and street stormwater controls, as well as upsized pipe segments when necessary to meet the level of service.

Other types of alternatives such as storage, flow diversion, and stormwater separation were considered and evaluated as opportunities were identified in the basins.

For example, four stormwater separation alternatives were evaluated in detail for the Westside Streams basins; these included collection of surface runoff in the Carolina subbasin, collection of flow from Ivy Creek (eliminating transport of sediment from the creek drainage to the tunnel system), collection of flow from Mitchell Creek, and restoration of the creek channel in George Himes Park. Similarly, in the Northwest Neighborhoods basin, a stormwater separation alternative was evaluated to reroute an average of 9.6 million gallons of annual stormwater runoff from the combined sewer system to a new separated stormwater system that will discharge to the Willamette River via the Tanner Creek stormwater line.

The alternatives were primarily developed to mitigate local basement sewer backup risk and street flooding risk during the 25-year, future conditions design storm. Those alternatives that included stormwater controls or stormwater separation provided the secondary benefit of reducing the risk of unpermitted CSOs by either infiltrating stormwater or routing flows to a separated stormwater system that discharges to the Willamette River. Structurally deficient pipes were also included in the alternatives so that the benefit of replacing a pipe segment that was both structurally deficient and capacity deficient would be accounted for in the evaluation.

5.3.2 Evaluation of Alternatives

Planning level present worth cost estimates were developed to evaluate and compare the alternatives developed for areas within each of the combined sewer basins. The present worth cost estimates account for the benefit that the alternatives provide by removing volume from the tunnel system, the annual cost that BES would incur for O&M of the alternative, and the capital cost.

The watershed benefits, implementation risks, and neighborhood impacts of each of the alternatives were also considered when evaluating alternatives. These are presented in Table 5-3 and are collectively referred to as the environmental and community values (ECVs). Each of these values was assigned a score. Some of the scores were determined through quantitative methods (for example, number of impervious drainage area acres)

while others were determined on a qualitative basis (for example, minimize construction risk).

TABLE 5-3
Environmental and Community Values

Watershed Benefits	Implementation Risks	Neighborhood Impacts
Infiltrate on public and private property to the level consistent with the 2007 Green Streets Policy Reduce the level of water quality pollutants in non Municipal Separate Storm Sewer System (MS4) areas from 2007 levels Protect and improve terrestrial habitat conditions from 2007 levels Protect and improve aquatic habitat conditions from 2007 levels	Minimize construction risk Minimize work on private property	Limit duration of street closure and other short-term impacts Limit loss of street parking and other long-term impacts Provide a consistently reliable solution for a broad range of conditions Provide other community benefits

The alternatives were evaluated based on the total ECV indicator score, present worth cost, and an indicator to cost ratio (ICR). The ICR provided a way to evaluate the level of ECV per dollar expended for the project. The highest ICR for each project area represents the alternative that has the greatest level of environmental and community value per dollar invested.

5.3.3 Selection of Preferred Alternatives

Preferred alternatives were selected for each project area after consideration of the cost information, ECVs, ICRs, and the specific advantages and disadvantages of the alternatives in the project areas.

Also, the alternatives were evaluated in terms of overall basin benefits, recognizing interdependencies and potential total cost savings.

The preferred alternatives were further evaluated and consolidated into a combined sewer system recommended plan. This included (1) revising the initial project area boundaries into new project areas to more closely align with the needs for construction packaging, (2) updating the sewer hydraulic characterization, (3) developing, modeling, and evaluating the hydraulic capacity components of the recommended plan, and (4) incorporating the replacement of nearby structurally deficient pipes.

When the preferred alternatives were presented to the technical review committee for their review, there was a concern about the level of participation that could be expected from private property owners for those projects that propose stormwater controls on private property. In order to address this concern, the BES Bureau Leadership Team decided that if

the preferred alternative projects include stormwater controls on private property, then the final recommended plan for those project areas should be finalized by using a 50 percent factor of safety on the participation level for private facilities. Therefore, when the recommended plans were developed, all the recommended public and private stormwater control facilities were retained, but it was assumed that only 50 percent of the private property facilities would be constructed. The recommended plan also assumes that the project capital costs and O&M costs for those facilities are reduced by 50 percent as well. Downstream pipes were upsized in the plan as needed to accommodate the resulting increased runoff.

The process that was utilized to develop, evaluate, and select alternatives is documented in the *Combined Sewer Basin Recommended Plan Technical Memoranda (*BES, 2012a), and the *Combined Sewer System Plan Recommended Plan Summary* (BES, 2012b).

5.4 Sanitary Sewer System Hydraulic Capacity Deficiencies

5.4.1 Development of Alternatives

Alternatives were developed to eliminate pipeline and pump station capacity deficiencies identified during characterization for the Fanno Creek and Burlingame basins. RDII reduction alternatives were developed to reduce peak hour flow to the TCWTP. In addition, alternatives were developed to extend service to currently unserved areas.

5.4.1.1 Fanno Creek and Burlingame Basins

The alternatives development and evaluation process used for the Fanno Creek and Burlingame basins is shown in Figure 5-4.

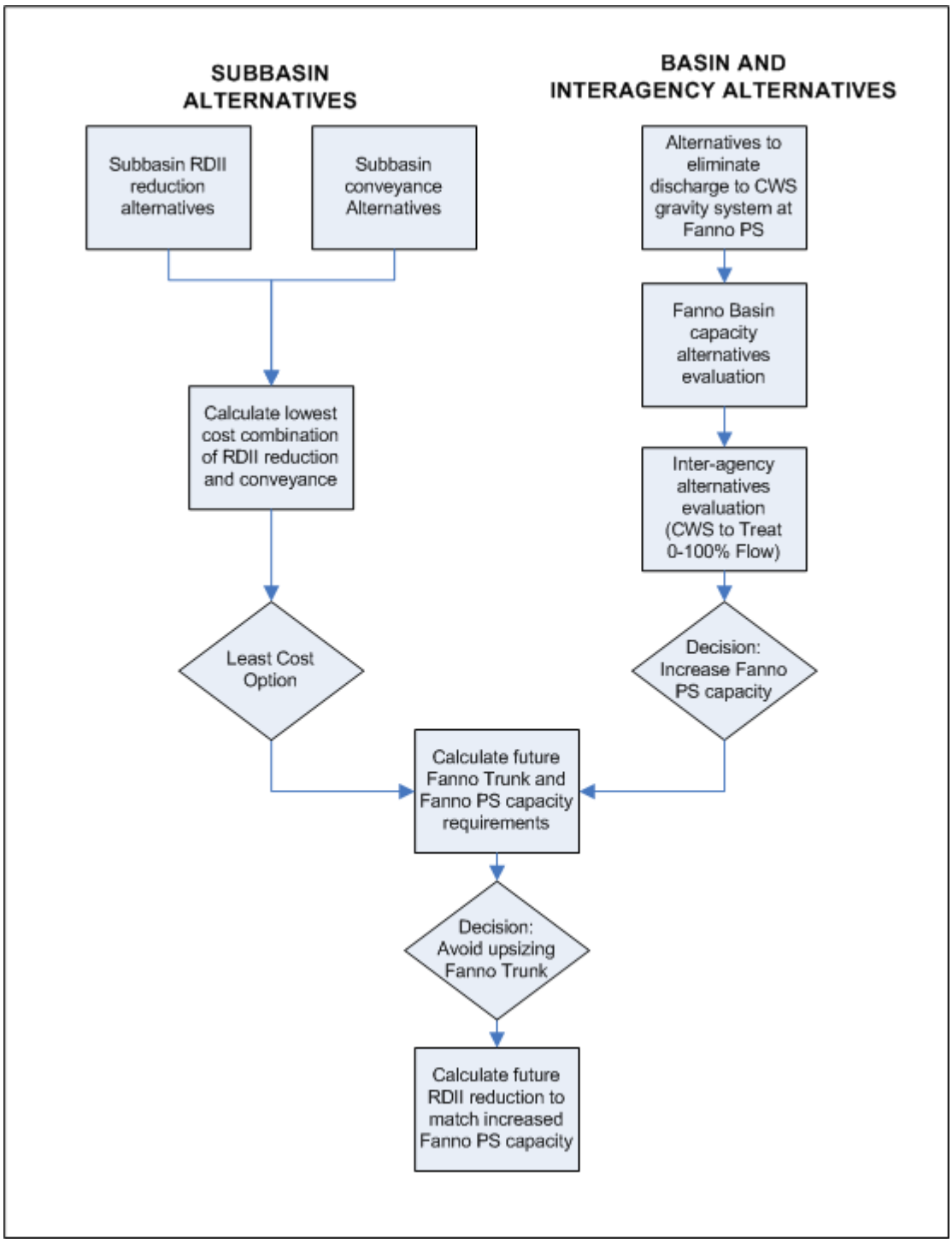


FIGURE 5-4
Alternatives Development and Evaluation Process for the Fanno Creek and Burlingame Basins
CWS = Clean Water Services; PS = pump station.

Subbasin-scale alternatives were developed to address street flooding and basement sewer backup risk. A project was considered subbasin-scale when the project was designed to resolve capacity deficiencies within a single sub-catchment or a small group of sub-

catchments. For the subbasin-scale projects, an iterative process was used to determine the lowest-cost combination of RDII reduction and pipeline upsizing.

RDII Reduction

It was necessary to estimate RDII reduction costs and the corresponding decrease in peak RDII flow rates using planning level assumptions because field investigations to detect actual RDII sources were not done. These assumptions were adapted from an approach documented by King County, Washington (*Benefit/Cost Analysis Report*, November 2005). This approach applies a decision tree to select RDII reduction techniques based on the characteristics of the flow monitoring data. Based on this approach, it was determined that RDII reduction efforts should focus on private property sources. A fixed cost per tax lot was calculated assuming that the laterals would be replaced on 95 percent of the tax lots. It was assumed that the RDII reduction efforts would decrease the peak RDII rate by 60 percent.

Fanno Basin Pump Station Capacity Deficiency

Basin and interagency alternatives were developed to address the capacity deficiency at the Fanno Basin Pump Station. The following options were considered at the basin scale:

- Add pumping capacity by constructing new pump stations at locations other than the existing Fanno Basin Pump Station
- Add pumping capacity at the Fanno Basin Pump Station site
- Reduce peak flows by storing excess volume upstream of Fanno Basin Pump Station
- Reduce peak flows through RDII reduction

Three interagency alternatives were developed that would direct flow from the Fanno Creek basin to Clean Water Services.

5.4.1.2 Tryon Creek Basin

The conveyance system in the Tryon Creek basin does not have local capacity deficiencies that warrant development of collection system improvement alternatives. However, high RDII increases the peak influent flow at the TCWTP. Because the peak influent flow appears to be at or above treatment plant capacity, RDII reduction alternatives will be developed and evaluated as part of the TCWTP facilities planning effort. It is anticipated that three levels of RDII reduction (low, medium, and high) will be developed as alternatives for comparison with treatment expansion alternatives.

5.4.1.3 Unserved Areas

The City followed a standard approach in developing alternatives for providing service to unserved areas. As noted in Section 3.4.3, these alternatives were developed to prepare for

that possibility that the City may construct new sewers to provide service to the unserved tax lots in question; implementation depends on City policy decisions and governmental agreements not addressed by this plan.

The following general prioritization was used to select preferred routes for service to the fringe areas bordering the City of Gresham or other providers such as Clean Water Services:

1. Gravity flow to City of Portland sewer system
2. Gravity flow to other service provider
3. Pumped to City of Portland sewer system
4. Pumped to other service provider

Note that the City will not build a pump station for fewer than five tax lots.

5.4.2 Evaluation of Alternatives

5.4.2.1 Fanno Creek and Burlingame Basins

Alternatives were evaluated in terms of their effectiveness in meeting levels of service listed in Table 5-4. Subbasin alternatives were rejected if they did not meet the levels of service.

Basin capacity issues require design and construction of major pumping and gravity conveyance facilities. These facilities must be designed and built to meet levels of service on an accelerated schedule. For this reason, basin alternatives were evaluated primarily for how they affected downstream facilities and the level of certainty that they would eliminate unplanned discharges to Clean Water Services.

TABLE 5-4
Application of Levels of Service

Levels of Service	Application Scale	
	Subbasin	Basinwide
Convey sewage to prevent releases to streets	✓	
Convey sewage to prevent releases to buildings	✓	
Operate Cambridge Village Pump Station within firm capacity so that BES is in substantial compliance with relevant laws and regulations	✓	
Operate Fanno Basin Pump Station within firm capacity so that BES is in substantial compliance with relevant laws and regulations		✓
Prevent discharges to surface waters (i.e., Fanno Creek) without discharging to Clean Water Services		✓

5.4.2.2 Tryon Creek Basin

The Tryon Creek basin RDII reduction alternatives will be evaluated for cost effectiveness as part of the TCWTP facilities planning effort and compared with treatment capacity improvement alternatives.

5.4.2.3 Unserved Areas

In unserved areas, the preferred (lowest likely cost) alternative was to provide gravity service and connect to the City of Portland's existing sewer system. However, if that alternative was not feasible, the second best alternative was to provide gravity service to another provider's existing sewer system.

Pumped options were considered last because of the expense and long-term maintenance requirements of pumping stations. However, if no gravity alternative was available, then the pumped alternative was considered, with a preference for pumping to the City of Portland's existing sewer system. The final alternative considered, if necessary, was to provide pumped service to another provider's existing sewer system. A minimum of five tax lots was required to consider a pumped option.

Planning-level cost estimates were developed for the alternatives for evaluation. If pumped and gravity alternatives were developed for the same area, the present worth costs were compared and the alternative with the lowest cost was selected. If more than one gravity alternative was identified, costs were prepared and significant constraints were compared, and the most advantageous alternative with the lowest cost was selected. In most cases, a gravity option was developed and selected, with no other alternatives evaluated.

5.4.3 Selection of Preferred Alternatives

Preferred alternatives were selected after consideration of the cost estimates, overall basin benefits, near-term capacity requirements, interagency agreements, and hydraulic interdependencies.

5.4.3.1 Fanno Creek and Burlingame Basins

The preferred alternatives for the Fanno Creek and Burlingame basins were documented in the *Recommended Plan for the Fanno Creek and Burlingame Sanitary Basins* (BES, 2012c).

The preferred alternative was developed based on the selection criteria listed in Table 5-5. Subbasin alternatives were selected based on the lowest cost solution. Basin alternatives for the Fanno Creek basin were narrowed down to three pumping options. Ultimately, the selected alternative was to construct a new pump station to be used in conjunction with the existing Fanno Basin Pump Station. The new pump station (SW 86th Avenue Pump Station) will be located near the existing pump station.

TABLE 5-5
Preferred Alternative Selection Criteria

Criteria	Alternative Scale		
	Subbasin	Basin	Interagency
Lowest cost	✓	✓	✓
Avoid upsizing Fanno Trunk		✓	
Avoid increasing the scope of the Burlingame Trunk Improvement Project		✓	
Implementation timing		✓	✓
Simplify operations and ease of maintenance		✓	

Clean Water Services prepared cost estimates of system improvements that would be required to accept flows from the Fanno Creek basin. BES reviewed these interagency alternatives and found them to cost more and take longer to implement than to increase pumping at Fanno Basin Pump Station.

5.4.3.2 Unserved Areas

For most project areas, a gravity option was developed and selected, with no other alternatives evaluated. In cases where more than one alternative was feasible, the alternative with the lowest present worth cost was selected.

The preferred alternatives were adjusted and further refined after discussions with staff from Portland Development Services. Projects were recommended that would route flow to City of Gresham, Lake Oswego, and Clean Water Services. When the best alternative involved directing flow to another service provider, the alternatives were reviewed with the provider.

The preferred alternatives for unserved areas were documented in the *Sanitary Sewer System Recommended Plan for Un-served Areas* (BES, 2012d).

Chapter 6: Recommended Plan

6.1 Overview

After development and evaluation of collection system improvement alternatives (as described in Chapter 5), preferred alternatives were packaged together into recommended projects to address both structural and capacity risks within the system.

The pipeline rehabilitation, combined sewer system, and sanitary sewer system recommended plans are discussed separately below. These form the basis for the implementation plan of recommended projects presented in Chapter 7.

6.2 Rehabilitation of Structural Pipe Deficiencies

The development of recommended projects included prioritizing spot repairs and whole pipe rehabilitation actions of the preferred alternative based on their nBCRs. This pipe-level prioritization process is outlined in Appendix E.

Four categories of pipe rehabilitation projects were developed based on pipe size, rehabilitation prioritizations, and relative location:

1. **Geographically-based, small-diameter, large-scale projects**. These project areas were drawn around groupings of positive-nBCR, small-diameter (≤ 36 inches), whole pipe replacements. They include small diameter pipes in the project area even if they have negative nBCRs. Also, it was assumed that the spot repairs would be performed along with the whole pipe replacements in these project areas.

2. **Urgent, small-diameter whole pipe rehabilitations/replacements and spot repairs**. This project includes individual small-diameter whole pipe rehabilitations/replacements and spot repairs that did not fall within a geographic area. Only whole pipes with positive nBCRs were selected. Spot repair pipes were included in this project if they contained at least one spot with a defect total of 5,000 points (a hole in the pipe). Whole pipes with negative nBCRs were also included on the spot repair list if they included a segment with a defect total of 5,000 points. It was assumed that all of the near-failed segments (1,000 points or greater) would also be repaired on these spot repair pipes.

3. **Urgent, large-diameter, whole pipe rehabilitations/replacements and spot repairs**. This project includes all large-diameter (> 36 inches) whole pipe rehabilitations/replacements and spot repairs. Whole pipe rehabilitation/replacement pipes were included with both positive and negative nBCRs, with the understanding

that the negative whole pipe replacements might become spot repairs. All large-diameter spot repair pipes were also included in this project.

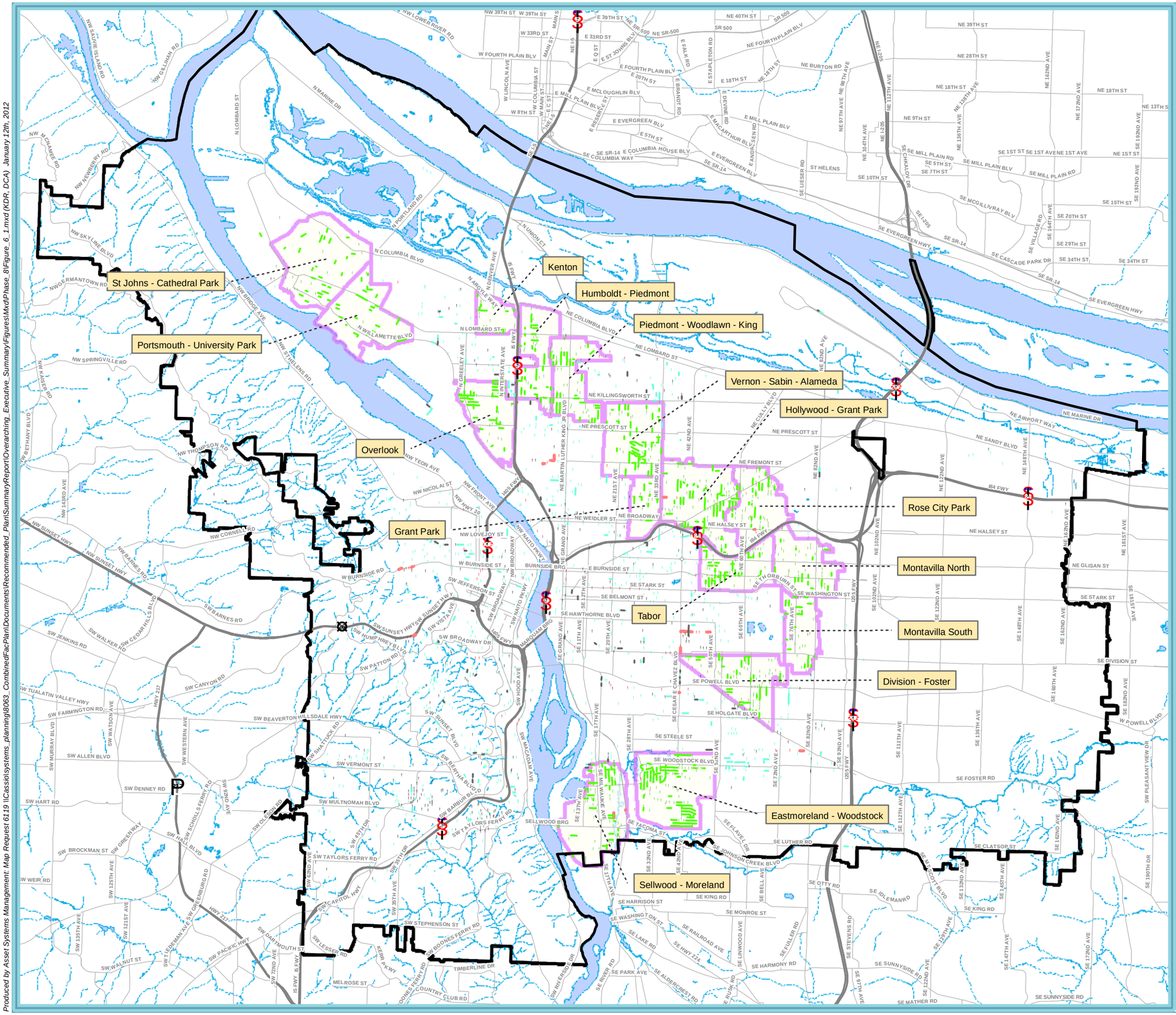
4. **Remainder**. This project includes all, small-diameter, Grade 4 and 5 pipes that are a part of the preferred alternative, but were not included in the other previously described projects. These include small-diameter, whole pipe rehabilitation/replacement pipes with negative nBCRs and no 5,000-point segments, and spot repair pipes with no 5,000-point segments.

Both the BES construction and design services groups were consulted during the development of the recommended plan project boundaries. This input allowed for the delineation of project boundaries that made sense for both the design and construction of projects. The characteristics of the recommended projects are summarized in Table 6-1. The locations of the recommended projects are shown on Figure 6-1.

TABLE 6-1
Pipe Rehabilitation Recommended Plan Project Characteristics

Project Category/Pipe Rehabilitation Action[a]	Number of Pipe Segments in Project Areas					
	North Willamette	West Willamette	Columbia Slough	East Willamette	Sanitary Areas	Total
Geographically-Based, Small-Diameter, Large-Scale Projects						
Number of Projects	*1*	*0*	*4*	*11*	*0*	*16*
Whole Pipe Rehabilitation/ Replacement	4	0	206	482	0	692
Spot Repair	10	0	119	475	0	604
Urgent, *Small*-Diameter, Whole Pipe Rehabilitations/Replacements and Spot Repairs						
Whole Pipe Rehabilitation/ Replacement	0	13	9	29	9	60
Spot Repair	1	60	27	112	111	311
Urgent, *Large*-Diameter, Whole Pipe Rehabilitations/Replacements and Spot Repairs						
Whole Pipe Rehabilitation/ Replacement	0	3	0	9	0	12
Spot Repair	0	22	4	52	2	80
Remainder						
Whole Pipe Rehabilitation/ Replacement	1	31	24	65	20	141
Spot Repair	5	243	61	323	175	807
Totals						
Actions[a]	21	372	450	1,547	317	2,707
Cost-Beneficial Actions[b]	15	98	365	1,159	122	1,759

[a]Pipe rehabilitation actions shown in this table are whole pipe rehabilitation or spot repair.
[b]nBCR ≥ 0.



Map Elements

Urban Services Boundary

Geographic Pipe Rehabilitation Project Areas

Types of Projects

Geographic

Whole

Spot

Urgent Small

Whole

Spot

Urgent Large

Whole

Spot

Remainder

Whole

Spot

1 in = 1.5 miles

Figure 6-1

Recommended Plan
Pipe Rehabilitation Projects

March 2012 - System Plan

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Table 6-2 summarizes the present worth of the base structural deficiency risk for the recommended plan projects within the combined and sanitary sewer system that was presented in Section 4 in Figure 4-7. It also summarizes the present worth of the alternate risk provided by the rehabilitation projects and their capital costs. Risk reduction equals the base risk minus the alternate risk.

TABLE 6-2
Pipe Rehabilitation Recommended Plan Risk and Cost Summary
Risk or Cost within Service Areas in Units of $1,000

	North Willamette	West Willamette	Columbia Slough	East Willamette	Sanitary Areas	Total
Recommended Plan Projects						
Base Structural Risk	$1,914	$22,416	$84,948	$204,741	$22,910	$337,929
Alternate Structural Risk	$1,147	$21,398	$47,029	$148,474	$15,377	$233,424
Risk Reduction	$767	$1,018	$37,919	$57,267	$7,534	$104,505
Capital Cost	$655	$11,737	$32,822	$97,912	$6,457	$149,585
Cost-Beneficial* Projects						
Base Structural Risk for Cost-Beneficial* Projects	$1,695	$9,260	$77,844	$184,809	$9,897	$283,506
Alternate Structural Risk for Cost Beneficial* Projects	$954	$9,012	$42,127	$126,054	$6,338	$184,486
Risk Reduction for Cost-Beneficial* Projects	$742	$247	$35,717	$58,755	$3,559	$99,020
Capital Cost for Cost-Beneficial* nBCR Projects	$555	$5,231	$29,911	$84,577	$2,417	$122,690

*nBCR ≥ 0.

6.3 Combined Sewer System Improvements

The recommended plan for the combined sewer system includes projects that reduce basement sewer backup risk, replace structurally deficient pipes, reduce surcharging in major trunk lines, and contribute to CSO reduction through the incorporation of stormwater control facilities. The primary focus of these projects is to provide adequate capacity in the combined sewer system to convey the design flow and resolve basement sewer backup risk. For the most part, this is completed by either increasing pipe capacity through the upsizing of pipe diameter or by routing stormwater runoff to stormwater control facilities to reduce the runoff that enters the system. However, in a few basins the resolution of basement sewer

backup risk is achieved through stormwater separation, redirection of flow, or underground pipe storage facilities.

As for pipe rehabilitation, both the BES construction and design services groups were consulted during the development of the recommended plan project boundaries.

Recommended projects were developed for all combined sewer basins except the Taggart D, Lents, and Northwest Neighborhood basins, which were recently addressed by separate predesigns. The predesign recommendations for these basins are incorporated by reference into the combined sewer system recommended plan. This combining of plans is possible because the predesigns were developed using similar approaches, including explicit modeling and the similar future development assumptions. The process used to develop recommended projects is documented in the *Combined Sewer Basin Recommended Plan Technical Memoranda* (BES, 2012a), and the *Combined Sewer System Plan Recommended Plan Summary* (BES, 2012b).

An overview of the types of projects recommended by the plan is provided in Table 6-3. There are four types of projects:

1. Conveyance
2. Stormwater Control
3. Stormwater Separation
4. Storage

Table 6-3 indicates how many of these types of projects were recommended and their distribution among the CSO service areas. The four project types were selected to indicate a significant component or primary focus of a project. For instance, a project that is designated as a "Storage" project includes an underground storage facility but also includes pipe upsizing and may include stormwater controls. Table 6-3 also shows (in parentheses) the number of recommended projects that were determined to be cost beneficial either as stand-alone projects or when combined with hydraulically dependent projects. Also, the Oak A Basin Phase 2 project was included even though it is not cost beneficial, because uncertainty about the future of this project. The combined sewer system recommended plan capacity projects outlined in Table 6-3 are shown on Figure 6-2. The types of projects are indicated and those that are cost beneficial are identified with blue cross hatching.

TABLE 6-3
Combined Sewer System Recommended Plan Project Characteristics

Projects	Number of Projects (Number of Cost-Beneficial[a] Projects)				
	North Willamette	West Willamette	Columbia Slough	East Willamette	Total
Projects developed through the *Combined Sewer System Plan*[b]	2	14	8	72	96
Projects developed through the Taggart D, Northwest Neighborhoods and Lents Predesign Projects	0	22	0	40	62
Conveyance Projects	2 (0)	27 (7)	5 (5)	42 (6)	76 (18)
Stormwater Control Projects	0	3 (0)	2 (0)	65 (19)	70 (19)
Stormwater Separation Projects	0	5 (2)	1 (0)	0 (0)	6 (2)
Storage Projects	0	1 (0)	0 (0)	5 (0)	6 (0)
Total Projects	2	36	8	112	158
Total Cost-Beneficial[a] Projects	(0)	(9)	(5)	(25)	(39)

[a]nBCR ≥ 0.

[b]During development of this Wastewater Sewer System Plan, the Combined Sewer System Plan (BES, 2012a) projects with a pipe rehabilitation focus were replaced by similar projects in the pipe rehabilitation recommended plan component of this Wastewater Sewer System Plan.

Table 6-4 summarizes the base risk for the recommended plan projects within the combined sewer system that was presented in Figure 4-11. It also includes the capital cost and present worth cost to design, construct, and maintain the facilities.

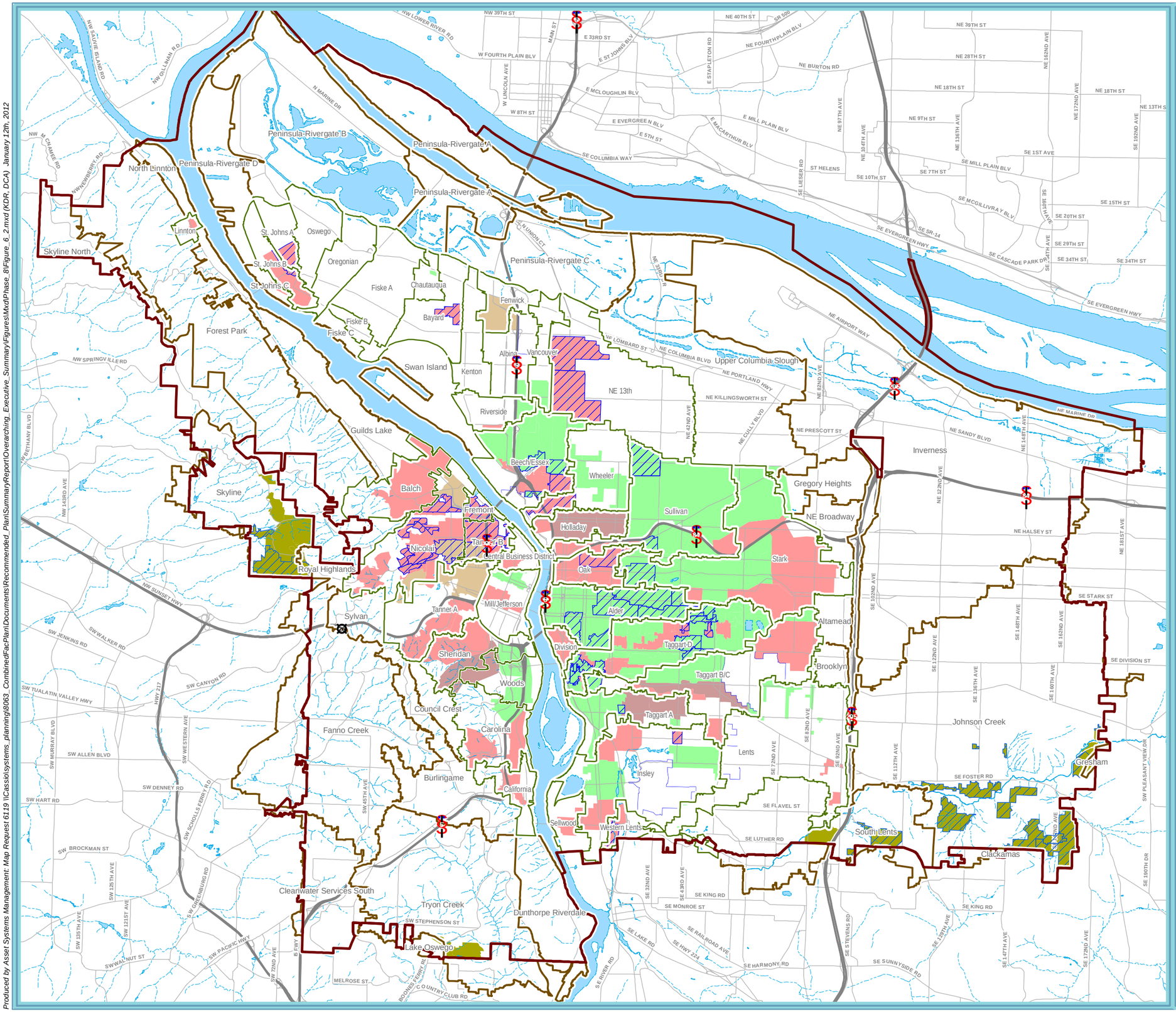
TABLE 6-4
Combined Sewer System Recommended Plan Risk and Cost Summary
Risk or Cost within Service Areas in Units of $1,000

Item	North Willamette	West Willamette	Columbia Slough	East Willamette	Total
Recommended Plan Projects					
Structural Risk	$5,572	$120,375	$71,193	$335,510	$532,650
Capacity Risk	$1,285	$42,743	$11,149	$264,046	$319,223
Risk of CSOs to the Willamette River		$17,580		$49,620	$67,200
Risk of Surcharging the Sullivan's Gulch Trunk Line	$0	$0	$0	$11,661	$11,661
Total Base Risk	$6,857	$180,698	$83,342	$680,837	$930,734
Capital Cost	$9,109	$224,641	$58,405	$736,801	$1,028,956
Present Worth Cost	$9,171	$229,091	$58,347	$768,118	$1,064,727
Cost Beneficial[a] Projects					
Structural Risk	$0	$24,740	$23,742	$54,668	$103,150
Capacity Risk	$0	$23,949	$6,894	$118,399	$149,242
Risk of CSOs to the Willamette River	$0	$3,196	$0	$18,372	$21,568
Risk of Surcharging the Sullivan's Gulch Trunk Line	$0	$0	$0	$1,430	$1,430
Total Base Risk	$0	$51,885	$30,636	$192,869	$275,390
Capital Cost[b]	$0	$34,938	$21,138	$137,638	$193,714
Non-CIP Costs[c]	$0	$0	$333	$4,661	$4,994
Present Worth Cost	$0	$36,182	$21,508	$145,080	$202,770

[a]nBCR ≥ 0.

[b]Capital costs include non-CIP costs as a conservative assumption for budgeting purposes because of uncertainty about construction of stormwater control facilities on private property. If private property facilities are not feasible, then they must be replaced by facilities of comparable capacity in the public right of way.

[c]Refers to capital costs for stormwater control facilities on private property, which cannot be funded via CIP.



Map Elements

- Urban Services Boundary
- Combined Sewer Basin Boundary
- Sanitary Sewer Basin Boundary

Types of Projects*

- Conveyance
- Stormwater Control
- Stormwater Separation
- Storage
- Rainfall Dependent Infiltration and Inflow Reduction
- Sewer Extension
- Cost Beneficial Projects (>= 0 nBCR) Recommended for Inclusion into CIP

*These categories describe the primary focus of the project. Nearly all projects have conveyance (pipe upsizing) components.

1 in = 1.5 miles

Figure 6-2

Recommended Plan
Sewer System Capacity Projects

March 2012 - System Plan

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Table 6-4 shows that the recommended combined sewer system plan has identified $1,064,727,000 in present worth costs for projects to resolve capacity and structural risks in the combined area. This compares against a total identified risk value of $930,734,000. Because this amount is less than the present worth costs, asset management principles indicate that as a whole, the total set of projects is not cost-beneficial. The sub-set of projects that are cost-beneficial is put forth as the recommended projects. The total present worth of the cost-beneficial projects is about $200 million, which compares well to the total risk of these projects, which is about $275 million. By this comparison, asset management would indicate these projects should go forward because they cost-beneficially reduce the risk within the combined sewer system.

The recommended plan assumes that because of limited private property owner participation only 50 percent of the private property facilities incorporated in the recommended projects will actually be constructed. This assumption should be reviewed during the predesign of projects to maximize private property owner participation and minimize the BES stormwater control facility maintenance obligation.

6.4 Sanitary Sewer System Improvements

The recommended plan for the sanitary sewer system consists of projects to resolve capacity deficiencies and extend sewer service to unserved areas. Capacity deficiencies are resolved through a combination of gravity sewer improvement projects, pump station expansions, and an RDII reduction program. Associated private property work would not be funded via the CIP; it is likely this work would be funded through the Private Property Retrofits Program. Table 6-5 summarizes the types of projects and their distribution among the sanitary service areas. The locations of these projects are shown in Figure 6-2.

TABLE 6-5
Sanitary Sewer System Recommended Plan Project Characteristics

Types of Projects	Number of Projects (Number of Cost-Beneficial* Projects)					
	West Side	Tryon Creek	Durham	CSO Fringe	Southeast	Total
Conveyance/Pump Station		1 (0)				1 (0)
RDII Control (may have conveyance elements)	5 (0)	1 (0)				6 (0)
Sewer Extension		2 (0)	6 (2)	1 (0)	11 (8)	20 (10)
Total Projects	5	4	6	1	11	27
Total Projects that are Cost Beneficial*	(0)	(0)	(2)	(0)	(8)	(10)

*nBCR ≥ 0.

Note that projects designed to eliminate capacity risk had negative nBCRs and thus did not cost-beneficially reduce the risk within the sanitary sewer system, even though the selected alternative represents the lowest-cost alternative to meet the level of service performance measures. Some of these projects have already been funded in the CIP because the consequences of repeated releases to Fanno Creek or uncontrolled releases at TCWTP likely carry a risk of enforcement action that is not captured in the value assumptions about consequences of failure presented in Table 2-3.

Table 6-6 summarizes the base risk for the recommended plan projects within the sanitary sewer system that was presented in Figure 4-11. It also includes the capital cost to design and construct the facilities, and maintenance costs to maintain the facilities. Since the O&M of new pipes and RDII reduction efforts are minimal, the capital costs and present worth costs are essentially the same.

TABLE 6-6
Sanitary Sewer System Recommended Plan Risk and Cost Summary
Risk or Cost within Service Areas in Units of $1,000

Description	West Side	Tryon Creek	Durham	CSO Fringe	Southeast	Total
Recommended Plan Projects						
Structural Risk	$1,185	0	0	0	0	$1,185
Capacity Risk	$8,419	0	0	0	0	$8,419
Failure to Provide Sewer Service	0	2,303	27,674	950	$58,978	$89,905
Total Base Risk	$9,604	$2,303	$27,674	950	$58,978	$99,509
Capital Cost	$28,489	$4,804	$27,673	$2,278	$33,478	$96,722
Present Worth Cost	$28,489	$4,804	$27,673	$2,278	$33,478	$96,722
Cost-Beneficial Projects						
Structural Risk	0	0	0	0	0	0
Capacity Risk	0	0	0	0	0	0
Failure to Provide Sewer Service	0	0	$16,617	0	$56,819	$73,436
Total Risk Reduction	0	0	$16,617	0	$56,819	$73,436
Capital Cost	0	0	$4,619	0	$30,148	$34,767
Present Worth Cost	0	0	$4,619	0	$30,148	$34,767

*nBCR ≥ 0.

6.4.1 Sanitary Sewer System Capacity Improvements

The most critical issues in the sanitary sewer system are the capacity-related deficiencies in the Fanno Creek and Burlingame basins. Significant wet weather flow and capacity problems (described in Section 4.4) require a system-based solution that combines capacity upgrades with RDII reduction.

The March 2008 failure of the Fanno Basin Pump Station force main and the wet weather capacity issues necessitated an accelerated schedule for the design and construction of new pumping capacity, replacement force mains, and new gravity pipe to meet existing and projected build-out capacity needs of the Fanno Creek basin. The draft *Recommended Plan for Fanno Creek and Burlingame Sanitary Basins* was developed during 2008-09 and approved by the BES Technical Review Committee in May 2009. The *Recommended Plan for Fanno Creek and Burlingame Sanitary Basins* was developed in accordance with the Mutual Agreement and Order (MAO) from Oregon DEQ, which required Portland to develop improvements to control all flows associated with the 5-year design storm at Fanno Basin Pump Station. The recommended plan was designed to achieve this level of control without discharging to Clean Water Services (or Fanno Creek in the short-term) as well as meeting basin capacity requirements in the long-term.

Major elements of the *Recommended Plan for Fanno Creek and Burlingame Sanitary Basins* include constructing a SW 86th Avenue Pump Station to be used in conjunction with the nearby Fanno Basin Pump Station, constructing a surge tank facility to protect recently constructed force mains, near-term RDII reduction and pipe upsizing to resolve subbasin capacity issues, long-term RDII reduction to reduce the risk of flows exceeding the capacity of the Fanno Creek Interceptor and the Fanno Basin Pump Station, increasing the capacity of the Burlingame Trunk sewer (currently under construction) that receives discharge from the Fanno force mains, and increasing the capacity of a short section of the Southwest Parallel Interceptor.

6.4.2 Providing Sewer Service to Unserved Areas

Since 1995, the Sewer Extension Program has been guided by *Sewer Extension Master Plan* (Crane and Merseth, 1995). The recommended plan for sanitary sewers proposes additional projects for the Sewer Extension Program. Net benefit cost ratios were developed to prioritize projects for the Sewer Extension Program. The project nBCRs were calculated using the present value of revenues from new customers (benefits) and the capital costs of construction (costs). These projects are located in the following sanitary sewer basins: Johnson Creek, South Lents, Tryon Creek, Skyline, and Royal Highlands.

6.4.3 Rainfall Dependent Infiltration and Inflow Reduction Program Plan

The Sanitary Sewer System Plan recommends RDII reduction projects in the Fanno Creek, Burlingame, and Tryon Creek basins. The benefit-cost analysis for RDII reduction was based on analysis of monitoring data without field investigations. Consequently, initial efforts need to focus on a comprehensive source detection program to determine the number and type of actual RDII sources.

Two CIP projects were initiated in 2010 that will identify specific sources of RDII and develop plans to redirect stormwater away from sanitary sewers and direct it to streams, stormwater sewers, and groundwater. It is recommended that these projects be considered the first phases of a large-scale RDII Reduction Program Plan. The recommended RDII Reduction Program Plan includes the following elements:

- **Program Management:** RDII reduction activities should be coordinated by a Program Plan Manager to provide continuity across projects and time periods that exceeds typical maintenance or project cycles. Several RDII studies have been conducted in the Fanno Creek and Tryon Creek basins since the 1970s. One of the short-comings of past RDII reduction efforts was that there was no process to track and monitor identified sources over time. In the future, program management should include performance measures and a data management system to track RDII sources as they are identified and removed. This is essential to the success of the program.
- **Private Property Access and Repair Policy**: The benefit-cost analysis assumed 60 percent removal of peak flow due to RDII. In order to reach this reduction goal, it will be necessary to have the ability to inspect facilities on private property and verify that sources are removed. It is recommended that the Program Plan Manager take action early to develop and propose a clear statement of legal authority and City policy to guide decisions about when, how, and for what purposes the City may choose to enter private property for inspection or repair. A related issue is whether or not the City will provide funding for repairs on private property.
- **Field Investigation:** Field assessment will include phone contacts to property owners; field surveys similar to the Downspout Disconnection Program; and source detection through smoke testing, dye testing, TV inspection, and manhole inspection. Follow-up inspections will be performed to verify that RDII sources have been removed. The field investigations will involve contact with customers. Program goals and implications for property owners should be thought out before the field investigations so that clear answers can be provided to customers' questions.
- **Alternatives Development:** RDII sources resulting from deteriorated laterals and pipes have straightforward solutions for repair or replacement. Inflow sources from area drains, roof downspouts, and even depressed manholes may require more extensive alternatives analysis. One of the challenges in the Fanno Creek, Burlingame, and Tryon Creek basins is that many areas do not have adequate conveyance for stormwater and

there may not be a safe discharge point for disconnecting downspouts and storm inlets. In some cases the alternatives analysis may include the design and construction of stormwater facilities.

- **Review and Update Recommended Plan**: The planning level benefit-cost analysis and alternative evaluation will be revised based on source detection results. The revised benefit-cost analysis will provide the basis for adjusting existing project budgets and creation of new projects.
- **Benefit-Cost Analysis**: The planning level benefit-cost analysis and RDII reduction goals should be revised based on source detection results.
- **Project Implementation:** The revised benefit-cost analysis will likely require adjustments to existing project budgets and creation of new projects.
- **Evaluation of RDII Reduction Projects:** Post project flow monitoring and modeling will be done to verify the effectiveness of RDII projects. The calibrated pre-rehabilitation models will be used to simulate post-rehabilitation storms. RDII reduction is demonstrated when the simulated flows from the pre-rehabilitation model are higher than the post-rehabilitation flows.

Chapter 7: Implementation Plan

7.1 Introduction

BES applied asset management methods to prioritize the implementation of recommended projects and develop short-term and long-term implementation plans.

As the recommended projects go forward, it will be necessary to review and finalize recommended changes to the CIP and a proposed special predesign process for pipe rehabilitation projects. Other implementation considerations include recognition of hydraulic dependencies in the sequencing of projects and coordination of projects to preserve the stormwater control facilities essential to the effectiveness of related projects and sustainable reduction of flows to the CSO tunnel system.

In support of the implementation plan, BES identified next steps to be pursued regarding associated policy issues. These are discussed in Section 8.1.

7.2 Methods for Priority Ranking of Projects

The primary reason to implement a project or program is to reduce business risk, which is considered for the purposes of priority ranking of projects to be the chief benefit. Because risk is estimated in dollars, the reduction in risk is estimated in dollars. Therefore, cost effectiveness can be measured in terms of the amount of risk reduction obtained for a given project cost. As described in Section 2.4, the ratio of risk reduction (as the benefit) versus the project cost is called the net benefit cost ratio or nBCR. To prioritize projects systemwide, BES calculated nBCRs for the recommended pipe rehabilitation, combined sewer system, and sanitary sewer system projects and compared them. Other factors considered in the prioritization of projects are discussed below.

7.2.1 Pipe Rehabilitation

The recommended pipe rehabilitation projects were mainly prioritized based on nBCRs. Exceptions were large-diameter whole pipe replacement and spot repair projects. These large diameter projects were recommended because of their high base business risks, without regard to their nBCRs, to ensure the business risks for difficult-to-rehabilitate pipes were not underestimated and that significant potential pipe failures were addressed—for example, Project E10220 (Structural Rehabilitation of Taggart Outfall 30) and Project E10030 (SE Interceptor Rehabilitation).

7.2.2 Combined Sewer System

BES calculated nBCRs for the projects recommended through the Combined Sewer System Plan and those recommended through the previously completed basin predesign projects for Taggart D, Lents, and Northwest Neighborhoods. Some basin predesign projects currently in the CIP do not have positive nBCRs. Many of these projects are recommended here for reevaluation for CIP priority. Some projects with negative nBCRs have been recommended here in this plan to proceed with predesign because the nBCR calculation does not take into account that the projects are hydraulic predecessors and need to be implemented before implementing a hydraulically connected project with a positive nBCR. An nBCR was not calculated for the Sandy Storage project; since the scope of that project is currently under development and without defined project components, there is no way to calculate risk or project costs.

7.2.3 Sanitary Sewer System

Many of the projects that were recommended as a part of the Sanitary Sewer System Plan update have already been added to the CIP and are in the predesign or design stages. For example, the recent failure of the Fanno Basin Pump Station force main raised the priority of projects related to Fanno Creek basin pumping capacity. Therefore, the recommended construction of the SW 86th Avenue Pump Station to be used in conjunction with the nearby Fanno Basin Pump Station and the upstream projects to reduce RDII in the Fanno Creek basin were moved forward in the CIP and are now in the predesign or design phases.

The RDII Reduction Plan recommended for the Tryon Creek, Fanno Creek, and Burlingame basins is under development through three predesign projects that have been initiated in the CIP. The RDII projects for these basins were prioritized for inclusion into the CIP for different reasons:

- The **Tryon Creek** basin project (E10258) is considered a priority because of concerns about the wet weather flows potentially exceeding the capacity of the TCWTP in the near future. There is no capacity (basement or street flooding) risk within the Tryon Creek basin collection system and the risk of a permit violation at the plant has not been assigned a value in dollars. Thus, no nBCR was calculated for this project. If Portland is responsible for 100 percent of construction costs and risks associated with permit violations, then RDII reduction is likely lower in cost than increasing plant capacity. Final determination of whether this project is cost-beneficial will require an evaluation of the risk to Portland for permit violations and an estimate of RDII reduction costs based on identification of actual RDII sources.
- The **Fanno Creek** basin project (E10259) is considered a priority because of the need to meet the MAO requirements for the Fanno Creek basin.

- The **Burlingame** project (E10273) is considered a priority because of local sanitary sewer system capacity issues.

There is also a desire to identify the potential RDII sources in these basins at the same time to take advantage of the programmatic aspects described under the recommended plan discussion in Section 6.4.3.

7.3 Review of CIP Projects

As part of the wastewater sewer system planning effort, BES reviewed the existing CIP to ensure its project list is consistent with the updated sewer system characterization, more recent evaluations of improvement alternatives, and the current list of Wastewater Sewer System Plan recommended projects.

The primary purpose of this review was to evaluate the existing CIP projects and make recommendations about whether they should remain in the CIP and proceed to predesign, be reevaluated for CIP priority, or be removed from the CIP. The resulting CIP Action Plan is summarized in Appendix B.

7.4 Short-Term Implementation Plan

The short-term planning horizon is approximately 10 years. The short-term implementation plan is composed primarily of recommended plan projects with positive nBCRs and CIP projects with a recommended action to proceed to predesign (refer to Appendix B). In addition, the plan includes projects with negative nBCRs that are considered critical to the BES mission. The recommended short-term projects are listed in Table 7-1 in order of nBCR, with highest-nBCR projects first. Projects previously submitted to the CIP have project numbers beginning with "E." Fact sheets with additional information and project area maps are provided in Appendix C for each of the new projects listed in Table 7-1. The fact sheets in Appendix C are grouped into three categories: pipe rehabilitation, combined sewer, and sanitary sewer. Within each category, the fact sheets are arranged in alphabetical order by project name or project number.

See the fact sheets in Appendix C for recommended project characteristics, benefits, and costs.

The short-term implementation plan projects address structural deficiencies, capacity deficiencies, RDII, and odor control issues. The total value of the projects presented in Table 7-1 is approximately $450 million. Pipe rehabilitation projects total approximately $175 million; combined sewer capacity improvement projects total approximately $205 million; sanitary sewer capacity improvement projects total approximately $70 million. The value of the non-CIP work to be completed in the combined sewer basins is approximately $5 million.

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
SKY 01	Skyline Basin – Sewer Extension Project, 513 Dwelling Units **Description**: Sanitary sewer improvements include construction of 5,600 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$3,019	3.89
SLE 03	South Lents Basin – Sewer Extension Project, 243 Dwelling Units **Description**: Sanitary sewer improvements include construction of 2,500 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$1,673	3.18
E08391	Oak basin - Oak Basin CP-F. **Description**: Combined sewer improvements include roof and parking stormwater control facilities. **Implementation**: This project is recommended for implementation through the Stormwater Retrofits program since it only includes stormwater control facilities on private properties.	$142	1.68
E10215	Taggart Basin - TGA-06 **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 15 to 18 inches and roof, parking, and street stormwater control facilities. **Implementation**: There are no known implementation issues with this project.	$900	1.57
Refer to by Project Title[c]	St Johns-Cathedral Park Pipe Rehabilitation Action Area **Description**: This project consists of 6,832 linear feet of whole pipe rehabilitation ranging in diameter from 8 to 30 inches, and 23 spot repairs on pipes 8 to 36 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$4,603	1.53
E08667	Taggart Basin - SE 41st Recon and GRST (TGD-22) **Description**: Combined sewer improvements include local pipe upsizing to 12-inch diameter pipe and roof, parking, and street stormwater control facilities. **Implementation**: This project is hydraulically dependent on E08668 (SE Hawthorne Recon GRST [23]).	$979	1.37
Refer to by Project Title[c]	Piedmont-Woodlawn King Pipe Rehabilitation Action Area **Description**: This project consists of 12,251 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 12 inches, and 46 spot repairs on pipes 6 to 30 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$8,067	1.35
JCR 06	Johnson Creek Basin – Sewer Extension Project, 604 Dwelling Units **Description**: Sanitary sewer improvements include construction of 10,400 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$7,430	1.34

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
Refer to by Project Title[c]	Small Diameter Urgent Pipe Rehabilitation **Description**: This project consists of 13,663 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 36 inches, and 491 spot repairs on pipes 6 to 36 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$14,028	1.21
E10219	Wheeler Basin - Wheeler WHE-04 **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 30 inches. **Implementation**: There are no known implementation issues with this project.	$9,859	1.18
Refer to by Project Title[c]	Piedmont-Humbolt Pipe Rehabilitation Action Area **Description**: This project consists of 9,274 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 36 inches, and 26 spot repairs on pipes 8 to 18 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$6,800	1.11
Refer to by Project Title[c]	Sellwood-Moreland Pipe Rehabilitation Action Area **Description**: This project consists of 14,169 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 39 inches, and 64 spot repairs on pipes 6 to 32 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$9,878	1.10
E10184	Vernon-Sabin-Alameda Pipe Rehabilitation Action Area **Description**: This project consists of 18,217 linear feet of whole pipe rehabilitation ranging in diameter from 8 to 14 inches, and 33 spot repairs on pipes 8 to 24 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$10,938[d]	1.09
JCR 02	Johnson Creek Basin – Sewer Extension Project, 352 Dwelling Units **Description**: Sanitary sewer improvements include construction of 8,200 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$4,906	1.07
NWN-CNC	Nicolai Basin – NWN-CNC **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 24 inches and pipe rehabilitation of local 8-inch pipe. **Implementation**: There are no known implementation issues with this project.	$820	1.04
E08401	Nicolai Basin - Far North Nicolai (NWN-FNN) **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12- to 30-inch diameters and pipe rehabilitation on local 8-inch diameter pipe. **Implementation**: There are no known implementation issues with this project.	$3,912	1.04

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
E10269	Eastmoreland-Woodstock Pipe Rehabilitation Action Area **Description**: This project consists of 28,617 linear feet of whole pipe rehabilitation ranging in diameter from 8 to 24 inches, and 97 spot repairs on pipes 6 to 36 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$19,333	1.04
Refer to by Project Title[c]	Portsmouth-University Park Pipe Rehabilitation Action Area **Description**: This project consists of 7,633 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 15 inches, and 7 spot repairs on pipes 6 to 30 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$5,341	1.00
Refer to by Project Title[c]	Tabor Pipe Rehabilitation Action Area **Description**: This project consists of 10,720 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 14 inches, and 65 spot repairs on pipes 8 to 27 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$7,136	0.96
E10261	Overlook Pipe Rehabilitation Action Area **Description**: This project consists of 13,604 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 18 inches, and 29 spot repairs on pipes 8 to 30 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$9,111[e]	0.91
Refer to by Project Title[c]	Kenton Pipe Rehabilitation Action Area **Description**: This project consists of 4,175 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 36 inches, and 26 spot repairs on pipes 8 to 36 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$3,427	0.81
Refer to by Project Title[c]	Rose City Park Pipe Rehabilitation Action Area **Description**: This project consists of 6,544 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 36 inches, and 72 spot repairs on pipes 8 to 36 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$4,998	0.78
TGD_27	Taggart D Basin – TGD-27 **Description**: Combined sewer improvements include local pipe upsizing to diameters of 12 inches. **Implementation**: E08669 and E08670 are hydraulic predecessors. E08669 has been constructed and E08670 is in 60% design as of June 2011.	$821	0.75

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
N13_04	NE 13th Basin – N13_04 **Description**: Combined sewer improvements include local pipe rehabilitation with diameters ranging from 8 to 10 inches, local pipe upsizing with diameters ranging from 12 to 15 inches, and a re-routing of flow to an adjacent sub-basin. **Implementation**: There are no known implementation issues with this project.	$4,441	0.68
JCR 09	Johnson Creek Basin – Sewer Extension Project, 15 Dwelling Units **Description**: Sanitary sewer improvements include construction of 450 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$261	0.65
E10028	Tanner A Basin - Southwest Tanner **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 24 inches, pipe rehabilitation on local pipe with diameters ranging from 8 to 10 inches, new stormwater separation pipe ranging in diameter from 12 to 24 inches and water quality treatment facilities. **Implementation**: This project is hydraulically dependent on E09019 (Southeast Tanner).	$6,460	0.59
JCR 07	Johnson Creek Basin – Sewer Extension Project, 181 Dwelling Units **Description:** The project area lies between Jenne Road and the Springwater trail. This project is currently outside of the Portland City Boundary but within the urban services boundary. Sanitary sewer improvements include construction of 1,900 linear feet of gravity pipe, a 70 gallon per minute capacity pump station, and 500 feet of force main. **Implementation:** The pump station force main would be hung off of an existing bridge crossing Johnson Creek. Alternatively, the pump station could discharge to the Jenne Road Trunk and flow to Gresham. Note that the Jenne Road Trunk is constructed but not currently in service.	$2,810	0.58
ALD_08	Alder Basin – ALD_08 **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 18 inches and roof, parking, and street stormwater control facilities. **Implementation**: This project is hydraulically dependent upon a trunk line being upsized on SE Yamhill between SE 31st and SE 35th. The trunk line is in ALD_05, which is not cost effective (nBCR = -0.10). Recommend repackaging this project to include the eastern portion of ALD_05.	$2,791	0.56
E08671	Taggart D Basin - SE Salmon Reconstruction & GRST (TGD-26) **Description**: Combined sewer improvements include local pipe upsizing to 12-inch diameter pipe, new 12-inch diameter pipe, pipe rehabilitation of local 8-inch pipe and street stormwater control facilities. **Implementation**: This project is hydraulically dependent on E08668 [SE Hawthorne Recon GRST (23)].	$1,652	0.52

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
E08656	Beech-Essex Basin - Beech-Essex CP-J **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 30 inches and pipe rehabilitation on local 6- to 8-inch diameter pipe. **Implementation**: There are no known implementation issues with this project.	$7,647	0.51
STJ_02	St Johns A Basin – STJ_02 **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 24 inches, local pipe rehabilitation on two 8-inch diameter pipes and street stormwater control facilities. **Implementation**: This project is hydraulically dependent upon upsizing two segments of trunk sewer along N. Philadelphia Avenue that are in STJ_01. Recommend repackaging this project to include these two pipe segments.	$3,760	0.48
ALD_06	Alder Basin – ALD_06 **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 30 inches, and roof, parking, and street stormwater control facilities. **Implementation**: The project is dependent upon the implementation of stormwater controls on private property so the Stormwater Retrofits group should assess the potential of private property stormwater control before initiation of design. In addition, upsizing the 48-inch trunk line in ALD_05 is required before implementing ALD_06.	$6,165	0.47
E08659	Taggart D Basin - SE Powell Recon and GRST (01) **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 24 inches, major and local pipe rehabilitation with diameters ranging from 16 to 120 inches and roof, parking, and street stormwater control facilities. **Implementation**: Four major pipe segments associated with the Taggart D outfall line have been removed from this project and E10220 has been opened as a project to rehabilitate those pipe segments. Recommend repackaging this project without those outfall line segments. New capital cost is for project without 4 outfall segments.	~~$7,212~~[f] $3,124	0.45
Refer to by Project Title[c]	Grant Park-Hollywood Pipe Rehabilitation Action Area **Description**: This project consists of 19,537 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 36 inches, and 99 spot repairs on pipes 6 to 36 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$13,465	0.44
E08386	Beech-Essex Basin - Beech-Essex CP-K **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 21 inches, and roof and parking stormwater control facilities. **Implementation**: Some recommended pipe sizes are dependent on the implementation of stormwater controls on private property so the Stormwater Retrofits group should assess the potential of private property stormwater control prior to the initiation of the design.	$1,396	0.41

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
JCR 05	Johnson Creek Basin – Sewer Extension Project, 298 Dwelling Units **Description**: Sanitary sewer improvements include construction of 2,700 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$6,081	0.41
N13_03	NE 13th Basin – N13_03 **Description**: Combined sewer improvements include local pipe rehabilitation with diameters ranging from 8 to 12 inches, local pipe upsizing ranging from 12 to 21 inches, re-routed of flow through new 12- to 18-inch diameter pipe and roof, parking, and street stormwater control facilities. **Implementation**: There are no known implementation issues with this project.	$7,365	0.40
E10216	Stark Basin - Stark HSS-17 **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 8 to 21 inches and street stormwater control facilities. **Implementation**: The street stormwater controls will need to be field located before initiation of design.	$11,777	0.38
E08660	Taggart D Basin - SE 9th Green Street (TGD-02) **Description**: Combined sewer improvements include street stormwater control facilities. **Implementation**: There are no known implementation issues with this project.	$505	0.36
Refer to by Project Title[c]	Division-Foster Pipe Rehabilitation Action Area **Description**: This project consists of 11,575 linear feet of whole pipe rehabilitation ranging in diameter from 8 to 30 inches, and 82 spot repairs on pipes 6 to 30 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$8,190	0.35
Refer to by Project Title[c]	Montavilla North Pipe Rehabilitation Action Area **Description**: This project consists of 4,656 linear feet of whole pipe rehabilitation ranging in diameter from 8 to 12 inches, and 65 spot repairs on pipes 8 to 18 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$3,192	0.33
E08402	Tanner A Basin - North Tanner (NWN-NT) **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 42 inches and re-routing of flow away from streets with streetcar tracks by adding new 12- to 24-inch diameter pipe. **Implementation**: There are no known implementation issues with this project.	$8,879	0.33

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
ALD_01	Alder Basin – ALD_01 **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 27 inches, and street stormwater control facilities. **Implementation**: A portion of this project is being built through the SE Clay Green Street project (E10007). Recommend reevaluating risk after completion of that project.	$9,792	0.29
ALD_09	Alder Basin – ALD_09 **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 18 inches, local pipe rehabilitation with diameters ranging from 8 to 10 inches, and roof, parking, and street stormwater control facilities. **Implementation**: There are no known implementation issues with this project.	$6,393	0.28
Refer to by Project Title[c]	Grant Park Pipe Rehabilitation Action Area **Description**: This project consists of 4,865 linear feet of whole pipe rehabilitation ranging in diameter from 6 to 14 inches, and 25 spot repairs on pipes 8 to 30 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$3,440	0.27
TGD_20	Taggart D Basin – TGD-20 **Description**: Combined sewer improvements include local pipe rehabilitation with diameters ranging from 8 to 12 inches, pipe rehabilitation of a 340 foot segment of 54-inch trunk line, pipe upsizing to ≤ 12-inch diameter, and street stormwater control facilities. **Implementation**: The project consists of pipe rehabilitation and street stormwater control facilities. Recommend splitting the project so that the stormwater control facilities are independent of the pipe rehabilitation work.	$2,480	0.25
HSS_18	Sullivan Basin – HSS-18 **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 18 inches, local and major pipe rehabilitation with diameters ranging from 8 to 30 inches, and street stormwater control facilities. **Implementation**: Need to check that the 30-inch diameter pipe crossing of I-84 at NE 29th Avenue has adequate capacity if the proposed new trunk line down NE Sandy Boulevard in E10074 (Oak A Phase 2) is not competed first, because this project is upstream of that project.	$4,136	0.25
SIW_01	Insley Basin – SIW_01 **Description**: Combined sewer improvements include local pipe upsizing to 12-inch diameters and street stormwater control facilities. **Implementation**: This project is recommended for packaging with project TGA_05 when submitting to the CIP.	$1,209	0.21

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
ALD_07	Alder Basin – ALD_07 **Description**: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 24 inches, local pipe rehabilitation of 8-inch diameter pipe, and roof, parking, and street stormwater control facilities. **Implementation**: There are no known implementation issues with this project.	$4,383	0.20
BAY_02	Bayard Basin – BAY_02 **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 15 inches and local pipe rehabilitation with diameters ranging from 8 to 10 inches. **Implementation**: There are no known implementation issues with this project.	$1,306	0.20
E08658	Nicolai Basin – East Nicolai (NWN-EN) **Description**: Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 21 inches, pipe rehabilitation on 48-inch diameter pipes, and new stormwater separation pipe to deliver flow to the Tanner Creek stormwater line and water quality facilities. **Implementation**: There are no known implementation issues with this project.	$6,416	0.18
JCR 01	Johnson Creek Basin – Sewer Extension Project, 171 Dwelling Units **Description**: Sanitary sewer improvements include construction of 7,122 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$4,241	0.16
SKY 04	Skyline Basin – Sewer Extension Project, 64 Dwelling Units **Description**: Sanitary sewer improvements include construction of 2,600 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$1,600	0.15
JCR 04	Johnson Creek Basin – Sewer Extension Project, 109 Dwelling Units **Description**: Sanitary sewer improvements include construction of 2,700 linear feet of gravity pipe. **Implementation**: There are no known implementation issues with this project.	$2,751	0.14
E07165	Taggart B/C Basin – TG-3 **Description**: Combined sewer improvements include local pipe upsizing from 12- to 18-inch diameter pipe and street stormwater control facilities. **Implementation**: There are no known implementation issues with this project.	$2,931	0.13

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
HSS_07	Sullivan Basin – HSS_07 **Description**: Combined sewer improvements include local pipe rehabilitation with diameters ranging from 8 to 14 inches, local pipe upsizing to 12-inch diameter pipe, and street stormwater control facilities. **Implementation**: Some pipes in this project area are being rehabilitated under E10184 (Vernon-Sabin-Alameda Replacement Project). The street stormwater control facilities are primarily for risk mitigation for the Sullivan's Gulch Trunk Line. Reassess risk in HSS_07 once E10184 is completed.	$8,056	0.13
Refer to by Project Title[c]	Montavilla South Pipe Rehabilitation Action Area **Description**: This project consists of 5,439 linear feet of whole pipe rehabilitation ranging in diameter from 8 to 14 inches, and 32 spot repairs on pipes 8 to 18 inches in diameter. **Implementation**: There are no known implementation issues with this project.	$3,511	0.12
SIW_06	Western Lents Basin – SIW_06 **Description:** Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 21 inches and local pipe rehabilitation with diameters ranging from 6 to 8 inches. **Implementation:** There are no known implementation issues with this project.	$2,698	0.09
E07391	Holladay Basin - HAN/SCH/GR to 16 (HO6) **Description:** Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 18 inches. **Implementation:** There are no known implementation issues with this project.	$1,213	0.09
NWN-NNC	Nicolai Basin – NWN-NNC **Description:** Combined sewer improvements include local pipe upsizing with diameters ranging from 10 to 12 inches and local pipe rehabilitation with diameters ranging from 8 to 12 inches. **Implementation:** There are no known implementation issues with this project.	$718	0.07
TGD-21	Taggart D Basin – TGD-21 **Description:** Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 15 inches, major pipe rehabilitation of 650 feet of 54-inch diameter trunk line, and street stormwater control facilities. **Implementation:** TGD-34 is listed as a hydraulic predecessor.	$2,723	0.05
NWN-CNB	Nicolai Basin – NWN-CNB **Description**: Combined sewer improvements include local pipe rehabilitation with diameters ranging from 8 to 12 inches with pipe upsizing for many of the structurally deficient pipes to diameters ranging from 12 to 18 inches. **Implementation**: There are no known implementation issues with this project.	$1,466	0.04

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
E09018	Nicolai Basin - Central Nicolai A (NWN-CNA) **Description:** Combined sewer improvements include local pipe upsizing with diameters ranging from 12 to 18 inches and pipe rehabilitation on local pipe with diameters ranging from 8 to 18 inches. **Implementation:** There are no known implementation issues with this project. It has a slightly negative nBCR, but since it is already in the CIP; leave it in, but schedule for the later years**.**	$3,960	-0.04
E09019	Tanner B Basin - Southeast Tanner **Description:** Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 30 inches and pipe rehabilitation on local pipe with diameters ranging from 8 to 12 inches. **Implementation:** It has a negative nBCR, but it is a hydraulic predecessor to E10028. The nBCR is positive (0.36) when considering E09019 and E10028 together.	$3,402	-0.08
E08668	Taggart D Basin - SE Hawthorne Recon GRST (TGD-23) **Description:** Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 24 inches, pipe rehabilitation of local 12-inch pipe, and street stormwater control facilities. **Implementation:** The project has a negative nBCR, but is a hydraulic predecessor to E08667. When the two projects are combined, they have a positive nBCR (0.34).	$2,299	-0.10
ALD_05	Alder Basin – ALD_05 **Description:** Combined sewer improvements include major and local pipe upsizing ranging from 12 to 48 inches, pipe rehabilitation of two 8-inch diameter pipes, and roof, parking, and street stormwater control facilities. **Implementation:** It has a negative nBCR but it is a hydraulic predecessor to ALD_08 and ALD_06. The nBCR is positive (0.18) when considering ALD_08, ALD_06 and ALD_05 together.	$10,553	-0.10
E10074	Oak Basin - Oak A Basin Phase 2 (OAK_A) **Description:** Combined sewer improvements include major and local pipe upsizing with diameters ranging from 12 to 48 inches. Includes new trunk line down NE Sandy Boulevard and NE Davis Street from NE 29th Avenue to NE 12th Avenue. **Implementation:** The new trunk line down NE Sandy Boulevard may need to be constructed before 30-inch diameter pipe under I-84 at NE 29th Avenue that conveys flow to the Sullivan's Gulch Trunk Line can be abandoned. About $2.3 million in Sullivan's Gulch Trunk Line surcharge risk is mitigated by constructing the new trunk line down Sandy. The trunk line is approximately 5,300 feet long, an average of 19 feet deep, and estimated to have a capital cost of $13.3 million. Suggest splitting the Phase 2 project into a trunk line project and a local combined sewer improvements project and then reevaluating the nBCR for both projects.	$23,916	-0.10

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
E08385	Beech-Essex Basin - Beech-Essex CP-G	$8,321	-0.14
	Description: Combined sewer improvements include local pipe upsizing with diameters ranging from 8 to 18 inches, pipe rehabilitation on 39- to 49-inch diameter pipes, and roof parking and street stormwater control facilities.		
	Implementation: The 39- to 49-inch trunk lines proposed for rehabilitation have negative nBCRs. If these are removed from the project, it has a positive nBCR (0.01). It is most likely that the spot repairs required for these brick and stone trunk line pipes would be completed under another contract, so it is reasonable to consider them as a separate project. Recommend removing these spot repairs from the project.		
Refer to by Project Title[c]	Large Diameter Urgent Pipe Rehabilitation	$16,063	-0.46
	Description: This project consists of 2,910 linear feet of whole pipe rehabilitation ranging in diameter from 38 to 60 inches, and 129 spot repairs on pipes 36 to 96 inches in diameter.		
	Implementation: Bypass pumping may be challenging on large diameter pipes.		
E10035	Fanno Creek Basin and Burlingame Basins – Fanno Creek RDII		
	Subbasin		
	Beaverton Hillsdale	$1,083	-0.02
	Pendleton Creek	$3,439	-0.63
	SW Maplewood	$1,656	-0.21
	SW Idaho/Vermont	$4,522	-0.46
	Burlingame Basin & Cambridge Village (Top Priority)	$8,422	-0.58
	TOTAL	**$19,122**	
	Description: Project E10035 is the primary budget for RDII investigation and mitigation in the Fanno and Burlingame basins. Projects E10259 (Fanno Creek) and E10273 (Burlingame RDII) were recently opened for predesigns of the Burlingame and Fanno Creek basins. The five subbasin areas listed above were analyzed as stand-alone projects and nBCRs were calculated for each project.		
	Implementation: These projects will implement the RDII program plan elements described in Section 6.4.3. Major challenges include developing a private property access and repair policy and the lack of a cohesive stormwater collection system in the Burlingame and Fanno Creek basins. Despite the negative nBCR, the Burlingame/Cambridge Village project is a top priority to eliminate frequent sanitary sewer overflows at SW Dewitt.		
E07818	Sullivan Basin – Sandy Storage (SU6)	$13,678	No nBCR
	Description: Combined sewer improvements include major and local pipe upsizing with diameters ranging from 10 to 120 inches. This includes the construction of a 2,000-foot long, 120-inch diameter storage tunnel along NE Sandy Boulevard and NE Broadway Street. Much of the local pipe upsizing was completed under project E07817 (Hollywood Relief and Reconstruction).		
	Implementation: A work plan is currently being developed to change the scope to a stormwater control approach. Leave CIP funding in the project and adjust once the scope of work is defined.		

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
E10030	Oak and Taggart D Basins – SE Interceptor Rehabilitation **Description:** Rehabilitation of the SE Interceptor from the intersection of SE Grand and SE Pine north to NE Davis and west in NE Davis to NE 3rd. This 2,038-foot length of 72-inch by 74-inch monolithic concrete sewer is between 41 and 53 feet deep. Also rehabilitation between SE Caruthers and SE 12th. This section is 1,330 feet long, 66-inch by 54-inch, and approximately 30 feet deep. This work is predicated on further condition assessment and subsequent engineering recommendations. The consequence of failure for this sewer would be very high. **Implementation:** This work cannot be completed until the Eastside Tunnel is operational and fully tested so that it can be used for flow diversion.	$8,322	No nBCR
E10220	Taggart Basins – Structural Rehabilitation of Taggart Outfall 30 **Description:** Taggart Outfall 30. Structural rehabilitation of the Taggart outfall between SE 16th Avenue and the outfall. The outfall is a brick sewer ranging in diameter from 64 to 118 inches, with depths from 20 feet to 63 feet. The consequence of failure of this sewer would be very high. **Implementation:** Rehabilitation will be performed in accordance with results of further condition inspection and engineering recommendations. Diversion pumping during construction may be an issue during construction, as the outfall carries up to 900 cubic feet per second during the 25-year storm.	$14,805	No nBCR
E10034	Tryon Creek Basin – Tryon Creek RDII **Description:** This is the primary budget for RDII investigation and mitigation in the basin. Planning level cost estimates indicate that RDII reduction would be less expensive than upgrading TCWTP capacity. Project E10258 was recently opened for the predesign project. The project originally focused on elimination of RDII from the Tryon Creek Interceptor (TCI). Additional analysis has since shown that the TCI has little RDII and that the highest RDII sources are at the upper end of the basin near 31st and Multnomah. **Implementation:** A revised benefit-cost analysis should be completed Fiscal Year 2011/12 and coordinated with the TCWTP facilities plan project.	$11,030	No nBCR
E10121	Fanno Creek Basin – SWPI Odorous Air Control and Treatment **Description:** The project will design and construct odorous air treatment system for the Southwest Parallel Interceptor (SWPI) and the Burlingame Trunk. **Implementation:** Project should be constructed before completion of E09051 (construction of the SW 86th Avenue Pump Station).	$1,247	No nBCR

TABLE 7-1
Short-Term Implementation Plan Recommended Projects Prioritized by nBCR

Project Number	Project Title, Description, and Implementation Considerations[a]	Capital Cost[b] $1,000	nBCR
E09016	Dunthorpe-Riverdale Basin – Willamette Interceptor Upgrade **Description:** Sanitary sewer improvements include the replacement of 3,500 linear feet of 15-inch pipe with 24-inch pipe. **Implementation:** A closer analysis of the hydraulic conditions that led to proposing this project found that it may be more effective to upsize the Tryon Basin Pump Station or target RDII removal instead of upsizing the interceptor. The recommended plan will be updated by the end of fiscal year 2013. Leave funding in the project, but change the scope of the project.	$2,020	No nBCR
Total Capital Cost		$448,283	

[a]Refer to fact sheets provided in Appendix C for more information about each project, including project area maps. The fact sheets are organized by these categories—pipe rehabilitation, combined sewer, and sanitary sewer—in alphabetical order by project name or project number.

[b]Class 3 estimates as defined by the Association for the Advancement of Cost Engineering International (AACE, 2011) with an expected accuracy range of +40 percent to -20 percent. Capital costs include direct construction cost plus indirect costs such as engineering, legal, administrative, and construction inspection.

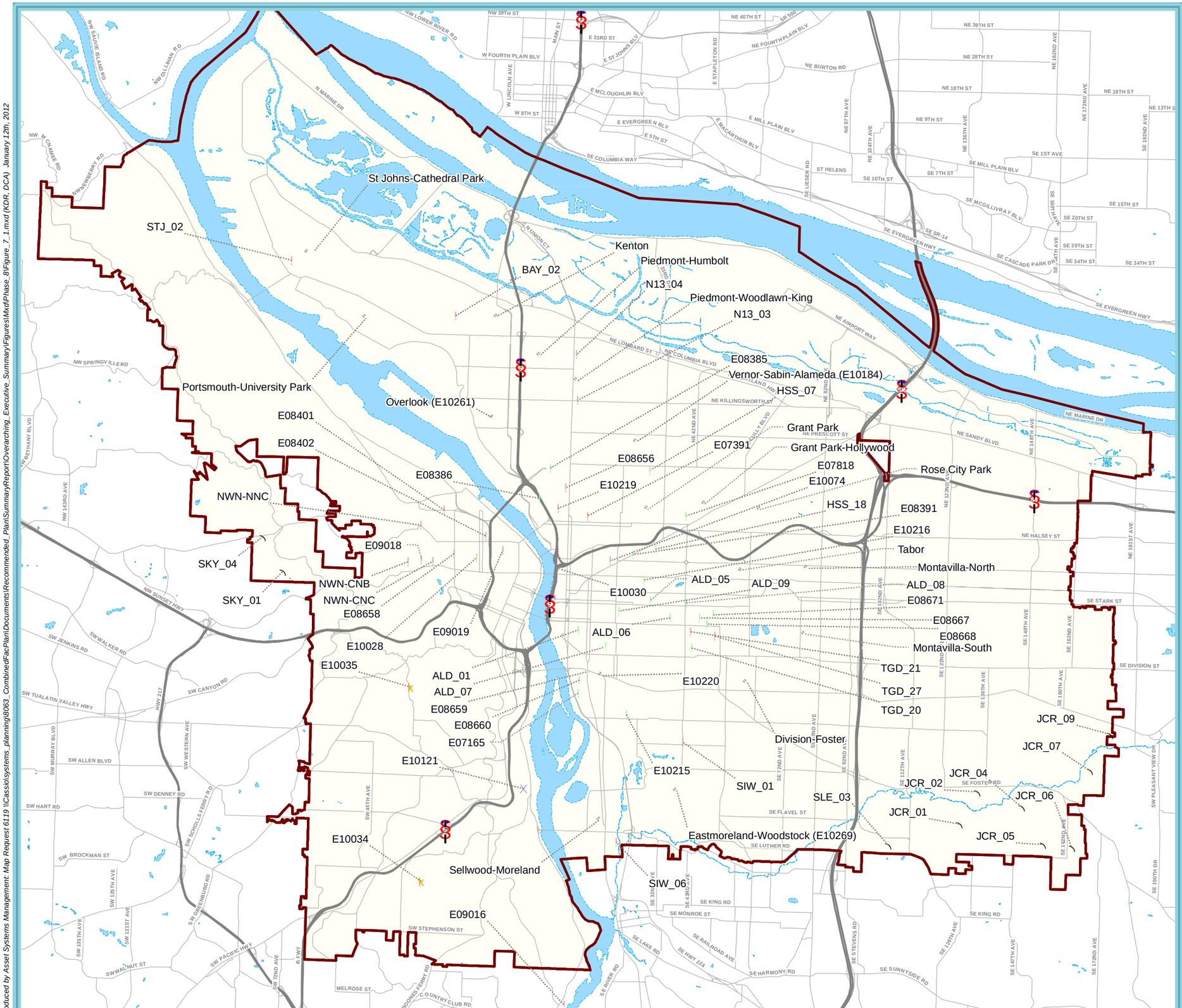
[c]Pipe rehabilitation projects were not numbered for the recommended plan and do not yet have CIP Project Numbers.

[d]Engineering Design Group estimate for the CIP Project E10184 = $9,075,000.

[e]Engineering Design Group estimate for the CIP Project E10261 = $7,241,000.

[f]Original CIP estimate updated by this report.

The locations of the major short-term implementation plan projects are shown in Figure 7-1. All of the short-term combined sewer and sanitary sewer capacity improvement projects are shown in Figure 7-1. The geographically-based pipe rehabilitation projects are also shown in Figure 7-1, but not the large-diameter, urgent pipe rehabilitation projects, or the small-diameter, urgent pipe rehabilitation projects, which are listed in Table 7-1.



Map Elements

Urban Services Boundary

Types of Projects

- Conveyance
- Stormwater Controls
- Stormwater Separation
- Pipe Rehabilitation
- Odor Control
- Rainfall Dependent Infiltration and Inflow Reduction
- Sewer Extension

1 in = 1.5 miles

Figure 7-1

Recommended Short-Term Projects

March 2012 - System Plan

ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

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7.5 Long-Term Implementation Plan

The long-term planning horizon is approximately 20 years. The short-term implementation plan covers the first 10 years; the long-term implementation plan covers the next 10 years.

7.5.1 Pipe Rehabilitation

The pipe rehabilitation portion of the long-term implementation plan includes the following:

- R*emainder* category of projects from the recommended plan. Currently, the whole pipes identified for rehabilitation/replacement in the remainder project have negative nBCRs, and the spot repairs are less urgent (< 5,000 structural points). It is assumed, however, that these remainder pipes will be rehabilitated/replaced in the long term (10 to 20 years out), when their conditions worsen, and their nBCRs become positive.
- Uninspected pipes with unknown condition grades that fail and require rehabilitation/replacement.
- Pipes that will receive spot repairs in the short term, but will require whole pipe rehabilitation/replacement in the long term when it becomes cost beneficial.
- Pipes monitored by inspection whose conditions worsen such that whole pipe rehabilitation/replacement or spot repair becomes cost beneficial.

The long-term pipe rehabilitation costs for the combined and sanitary sewer system were estimated by distributing rehabilitation about an estimated failure date as described in Appendix F. The estimated rehabilitation costs from this analysis are shown in Figure 7-2. The whole pipe rehabilitation/replacement cost shown for 2011 represents projects identified for implementation under the short-term (10-year) plan. The average short-term rehabilitation costs incorporating these projects and spot repairs over the next 10 years would be approximately $20.1 million per year. The long-term rehabilitation costs between the years 2020 and 2030 drop to an average of $9.3 million per year, and then rise again to $20 million per year in the year 2040.

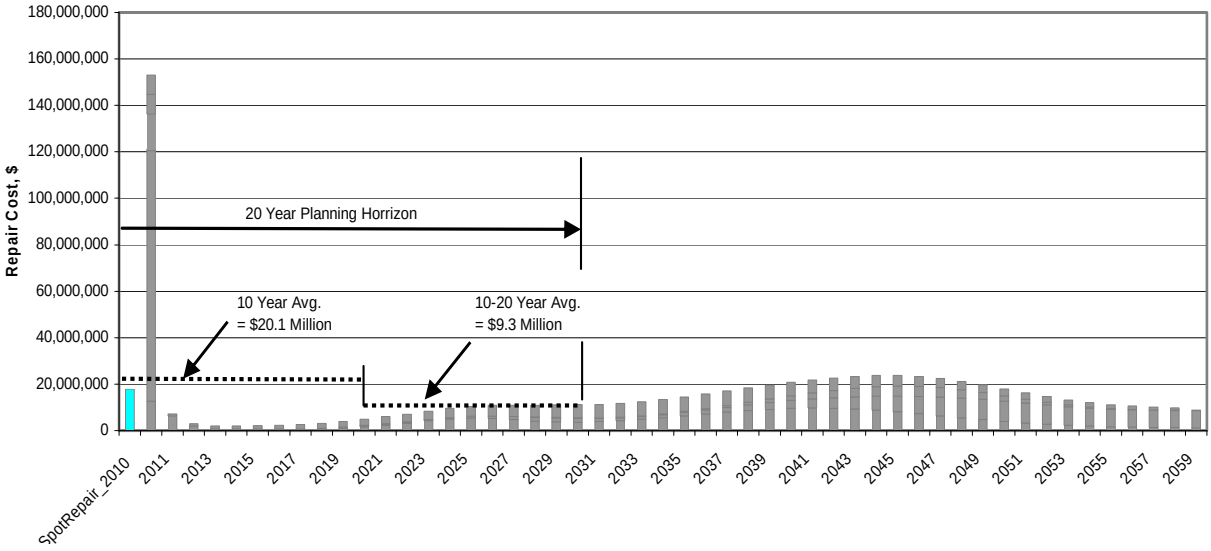

FIGURE 7-2
Estimated Long-Term Pipe Rehabilitation Costs

7.5.2 Combined Sewer System Capacity Improvements

The combined sewer system capacity improvement portion of the long-term implementation plan will be drawn primarily from the remaining (negative-nBCR) projects identified in the combined sewer system recommended plan. In the long-term, it is expected that some of these projects may become cost beneficial to implement due to one or more of the following factors:

- The sewer system is aging so pipe segments proposed for upsizing will have a higher risk of having a structural failure. Therefore, those segments proposed for replacement will be credited with resolving a higher dollar value of risk.
- The dollar value of basement sewer backup risk increases to be more than the $5,000 per basement sewer backup due to a change in regulations.
- The dollar value of risk of CSOs to the Willamette River will be re-evaluated and the dollar value of that risk will increase.
- More stormwater control facilities will be implemented on private property through the stormwater retrofits program and this will reduce the maintenance costs assumed in the system plan because maintaining the facilities will be the responsibility of the property owners.
- The Bureau of Planning and Sustainability modifies the zoning in a way that changes the future base assumptions that were used to predict capacity deficiencies and more properties are predicted to be at risk of BSBR as a result.

If projects that were focused on capacity deficiencies were funded in the long-term at the same level as they are in the short-term, about $20 million per year would be allocated for these projects. This would allow for implementation of approximately 30 long-term projects. This includes 15 projects with a focus on pipe upsizing, 13 projects that have a focus on stormwater controls, 1 project with a focus on stormwater separation, and 1 project that focuses on underground storage.

7.5.3 Sanitary Sewer System RDII Control

Within the sanitary system, the focus of the long-term plan is the control of RDII. The long-term plan for Fanno Creek basin must include the implementation of RDII reduction measures to offset increased RDII that is due to system degradation. Failing to reduce RDII in the Fanno Creek basin will eventually result in a risk of sewage releases at Fanno Basin Pump Station even with the planned pumping capacity upgrades.

Implementing the short-term RDII reduction projects within the context of an RDII program as discussed in Section 6.4.3 will build the foundation for ongoing flow management in the Fanno Creek, Burlingame, and Tryon Creek basins.

7.6 Implementation Considerations

7.6.1 Hydraulic Dependencies

Some of the recommendations proposed provide local capacity relief either through upsizing small diameter pipes and/or constructing stormwater control facilities. The construction packages that provide local relief through the primary use of stormwater control facilities are considered to be hydraulically interdependent since they remove stormwater flows from the basin network. Other pipe upsizing projects depend upon prior completion of downstream projects so that construction of the upstream projects does not increase basement sewer backup risk. These packages are considered to be hydraulically dependent upon the downstream projects and so their implementation is recommended in a sequentially phased approach. In addition, there may be projects composed wholly of constructing stormwater control facilities that provide flow relief for downstream areas. Therefore, some downstream projects are considered to be hydraulically dependent upon the upstream projects.

In general, projects with higher nBCRs will be selected first for submission into the CIP. If, however, a project with a higher nBCR is hydraulically dependent on a downstream project with a lower nBCR, the downstream project will be submitted into the CIP first for sequential implementation. Hydraulic dependencies within the combined sewer system are described in the *Combined Sewer System Plan Recommended Plan Technical Memoranda* (BES,

2012a). There are no hydraulic dependent collection system projects proposed in the sanitary sewer system.

Typically, private property (roof and parking) stormwater controls will be completed before beginning design of the complementary street stormwater controls and sewer pipe upsizings to ensure sufficient capacity is provided in the area.

7.6.2 Coordination

The large number of stormwater control facilities in this recommended plan, combined with traditional pipe projects to solve sewer capacity problems, necessitates a more coordinated implementation program than typical BES maintenance and reliability projects require. Many of the recommended pipe diameters are based on the assumption that a certain amount of runoff will be removed by these stormwater control facilities. Thus, the ability of the stormwater facilities to achieve their expected stormwater reduction collectively is a major element of this recommended plan. If these levels cannot be achieved, a different design scheme is required to mitigate sewer backup and CSO flow management problems.

Coordination with BES non-CIP projects to build stormwater control facilities on private property (roof and parking stormwater controls) is necessary to ensure that design schemes are fully implemented. Such coordination will require continued integration of multiple internal functions that BES currently conducts. These include ongoing programs (e.g., Stormwater Retrofit Programs), research and demonstration projects (e.g., Sustainable Stormwater Program), CIP projects (e.g., Design Services staff), financial planning (e.g., Business Services), and Stormwater Management Manual updates (e.g., System Development Services). The benefits of this coordination include identifying (1) the appropriate time when BES design/construction projects should begin, and (2) the available resources to construct stormwater control facilities on private property.

7.7 Review and Finalization of Recommendations

7.7.1 Review Recommended CIP Action Plan

One initial step in implementation is to review the recommended actions for the CIP (Appendix B) with the CIP Development/Stakeholder Team members and Engineering Services managers to finalize recommendations. It is expected that this team will use the nBCR values and the results from their review to reprioritize the projects in the CIP.

The boundaries and scopes of work for the various pipe repair projects included in the Phase 2 Pipe Rehab – Early Action Plan Project (E10031) (Phase 2 Pipe Rehab Project) will be finalized through implementation of the Predesign Process presented below.

7.7.2 Pipe Rehabilitation Implementation Processes

As noted previously in this report, the Pipe Rehabilitation Plan was prepared in two phases. Phase 1 focused on identifying and rehabilitating/replacing critical pipes in poor condition. Phase 2 focused on comprehensive analysis of the City's pipe rehabilitation needs and the development of a recommended rehabilitation plan, which is summarized as a component of this Wastewater Sewer System Plan.

7.7.2.1 Need for Different Implementation Process

The Phase 2 Pipe Rehab Project is essentially a program shell composed of high-priority pipe rehabilitation actions. The contents of this program shell are identified in a set of GIS coverages showing the specific pipes, risks and conditions, recommended rehabilitation methods, and repair priorities according to cost-beneficial risk reduction. The overall Phase 2 Pipe Rehab Project GIS coverages provide much of the information needed to assign pipes to small or large project packages for implementation in a prioritized manner. However, the complete information needed to finalize project boundaries, sizes, and scopes of work requires additional investigation beyond facilities planning. Specifically, finalizing pipe rehabilitation project packages to ensure a reliable scope and successful implementation requires:

- Additional CCTV pipe inspection of the recommended pipes (that have old investigations) and their neighboring pipes
- Inspection of laterals and their condition
- Determination of party or non-conforming sewers

This level of field investigation and additional review is best done in the predesign phase after the Phase 2 Pipe Rehab Project recommendations have been approved by the CIP process. Therefore, it is necessary to establish a Pipe Rehab Predesign process to review, select, and package the Phase 2 Pipe Rehab Project actions (including pipes needing repair when discovered later during field investigations) all into efficient and practical project packages.

7.7.2.2 Recommended Pipe Rehab Predesign Team

This Wastewater Sewer System Plan recommends BES establish a cross-functional predesign team to investigate, review, and assign pipes to specific project and maintenance programs. This Pipe Rehab Predesign Team will implement the Phase 2 Pipe Rehab Project by determining the optimal packaging for single pipes and large collections of pipes that have been recommended for rehabilitation.

As illustrated in Figure 7-3 below, the Pipe Rehab Predesign Team will receive the full list of pipes recommended for rehabilitation by the Wastewater Sewer System Plan and recommendations from the Maintenance District Engineers. The Pipe Rehab Predesign Team will develop the project packages by relying on the set of GIS Pipe Rehab coverages that indicate the condition, priority, recommended solution, and cost-benefit of the individual pipe projects.

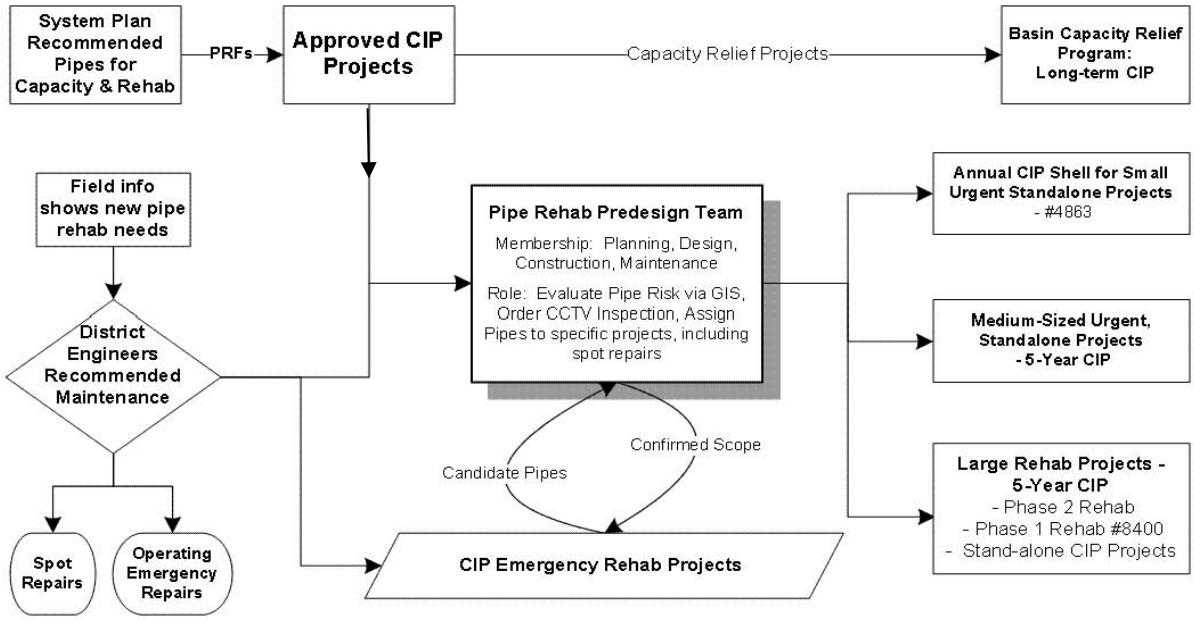

FIGURE 7-3
Pipe Rehab Predesign Team & Implementation Process

The Pipe Rehab Predesign Team will strategically request additional field investigations for priority pipes, and review available data to configure project packages that enable BES to successfully implement the work. The project packages will take the form of:

- Spot repairs recommended by the District Engineers to be done by contractors or through the City's Maintenance group.
- Small but urgent standalone projects that match the criteria for the Maintenance Capital Program Shell - CIP #4863.
- Medium-size but urgent standalone projects that are too large for the #4863 program.
- Large, geographically-based projects.

The Pipe Rehab Predesign Team will also review Emergency Projects to ensure the scope (list of pipes) is right and identify changes needed to account for potential overlapping work being done by other rehabilitation projects.

The real value of the Pipe Rehab Predesign Team is that it centralizes the critical functions necessary to efficiently and strategically assign pipes to specific projects that can be executed successfully without excessive scope change due to new information typically found during predesign.

7.7.3 Capacity Relief Project Implementation Process

7.7.3.1 Need for a Different Implementation Process

Many capacity relief projects that are proposed in both the short-term implementation and long-term implementation plans include stormwater control facilities. These facilities are proposed to be constructed both within the public right-of-way and on private property. It has been demonstrated by past projects that when stormwater control facilities are included in a project, a greater level of community outreach must be completed during the design process. An alternative project delivery model that achieved a greater level of community outreach and met multiple BES objectives has been pioneered in the Tabor to the River (T2R) program. The founding principles of the T2R delivery model are thoroughly described in the program charter (BES, 2009). Through the design of several projects for the T2R program it has been ascertained that there is a need to involve a broader group of BES staff than there is for the traditional capacity relief project that only involves pipe upsizing. The purpose of the following section is to present the organization of the T2R team, discuss the T2R charter that was endorsed by leaders of BES and make a recommendation to utilize this charter as a guide for the design of capacity relief projects recommended through the Wastewater Sewer System Plan.

7.7.3.2 Recommended Capacity Relief Project Design Team

This Wastewater Sewer System Plan recommends that BES adopt the approach that the T2R program utilizes for the design of all sewer capacity relief projects that use stormwater management methods. It is assumed that projects that do not include stormwater control facilities, stormwater separation, or other stormwater management methods will follow the traditional BES design process. The T2R program represents an alternative project delivery model that implements integrated solutions to achieve BES's multiple objectives. These objectives include the mitigation of basement sewer backup risk, reduction of flow volume directed to the CSO tunnel systems, rehabilitation of poor condition pipe, mimicking of natural hydrologic processes, improved water quality treatment of stormwater runoff, improved watershed habitat, vegetation management, and community engagement that will lead to a healthier urban watershed.

Since the T2R program is structured to meet multiple objectives, the team management organization is set up to meet these objectives. The organization structure is shown in Figure 7-4.

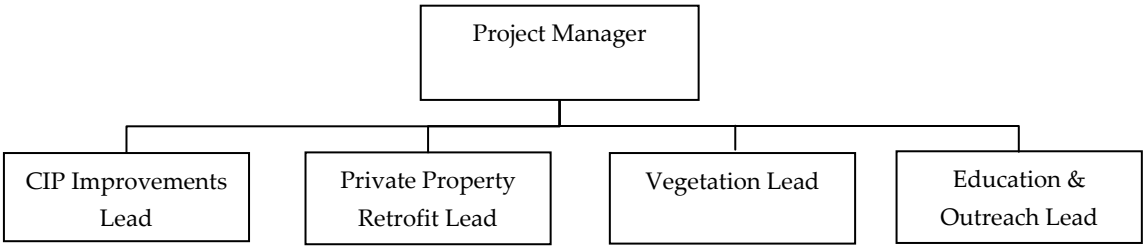

FIGURE 7-4
Capacity Relief Project Design Team Organization

The ***Project Manager*** is responsible for managing the overall project and is supported by the four leads. The manager ensures that the leads work together to meet the project objectives.

The ***CIP Improvements Lead*** is responsible for managing the work that is directly related to public work improvements. This lead is responsible for the development of a recommended alternative and implementation of that alternative into a final design. This is a common role that is required for all capacity relief projects.

The ***Private Property Retrofit Lead*** is responsible for identifying locations where private property retrofits are possible, contacting property owners about participation in the program, and developing signed partnership agreements with the property owners to implement the retrofits. This lead works with the CIP Manager to site retrofits in locations that will help mitigate basement sewer backup risk and reduce flow volume to the tunnel system. A valuable service provided by the Private Property Retrofit Program involvement is the review of modeling assumptions about sewer connections on larger parcels through as-built research and field evaluation.

The ***Vegetation Lead*** is responsible for identifying street tree deficiencies and coordinating the planting of street trees. In addition, this lead identifies revegetation opportunities and coordinates the implementation of revegetation activities.

The ***Education and Outreach Lead*** is responsible for coordinating detailed research of the community characteristics within the project area, coordinating media outreach, acting upon outreach opportunities, and supplying the materials for that outreach. This has proven to be a vital role for these projects that change the appearance and use of the public right-of-way within a project area through the implementation of stormwater control facilities.

The T2R program charter describes the coordination and timing of the four different program elements that are essential for projects to be administered in an effective and efficient manner. It is important to note that certain activities such as the development of partnerships for stormwater controls on private property, coordination of tree opportunities, and initial community outreach need to occur in advance of the initiation of the predesign phase. Therefore, there will need to be a mechanism for individuals to charge their time to a design project before official kickoff of that project.

It is recommended that the T2R charter serve as the guide for the design of capacity relief projects that this Wastewater Sewer System Plan recommends for implementation.

7.8 Financial Planning Considerations

7.8.1 Funding and Financial Planning Process

The projects recommended in this Wastewater Sewer System Plan will be implemented with financing provided by BES's standard financial planning process. All BES operations, maintenance, and capital projects are financed with revenues from sewer rates and system development charges, revenue bond proceeds, or with ending fund balances. Beyond the 5-year forecast interval, BES financial plans rely on knowledge of longer-term sewer and water quality program costs and estimates of the impacts of potential regulatory requirements over a longer horizon. BES assumes that it will continue to rely on revenue bond financing for capital expenditures (decreasingly over the next 15 years).

7.8.2 Financial Affordability

Portland has consistently raised sewer rates to pay for CSO control program and other CIP projects since 1990. The current financial model requires the City to continue to raise rates to retire the substantial debt incurred to finance the CSO control program. Portland ratepayers have shouldered this financial burden and it will continue to grow past 2016 when it is projected that 30 percent of households will exceed the 2.0 percent U.S. Environmental Protection Agency (EPA) affordability guideline for sewer rates.

Based on EPA's Financial Capability Assessments, Portland's financial burden is considered in the upper range of a "Medium Burden" on the community.

Chapter 8: Conclusion

8.1 Next Steps

In conjunction with implementation of the recommended projects, BES will take steps to address associated issues related to the implementation of this Wastewater Sewer System Plan. These are described below.

8.1.1 Comprehensive Pipe Rehabilitation Program

A comprehensive program for locating and rehabilitating defective service laterals in the right of way and manholes must be developed to supplement the main-line pipe rehabilitation plan described herein. Laterals and manholes are typically rehabilitated at the same time the main-line sewer is rehabilitated, and this work is included in the project cost estimates of this report. However, the risk associated with a lateral or manhole failure is not yet included in the base risk of the main-line failure. Moreover, the citywide risk of structural failure of manholes and laterals, and the potential rehabilitation costs, are not well understood at this time.

Additional work must be performed to assess the risk associated with pipe operational deficiencies such as roots, grease, and sediment. Once this risk is quantified, it can be used to prioritize cleaning programs and inform rehabilitation decisions.

The current rehabilitation program also does not address pressure mains. Condition assessment, risk analysis, and prioritization for pressure line rehabilitation needs are under development.

8.1.2 Basement Sewer Backup Risk Business Case

BES will develop a business case for management of basement sewer backup risk to help ensure customer revenues are being spent wisely and to help control costs and limit customer service rate increases.

As with the asset management approach employed in the development of this Wastewater Sewer System Plan, the business case will take into account social, economic, and environmental risks to establish limits to investment in projects to reduce basement sewer backup risk and identify alternatives to sewer system improvements. It will address, for example, those instances where the cost to resolve the basement sewer backup risk is equal to or greater than the property value.

The business-risk consequences considered during development of this Wastewater Sewer System Plan are outlined in Table 2-3. Other consequences should be evaluated, such as BES service reputation and potential permit violations.

Questions that will be considered include:

- Is there a more cost-effective break-point for level of service?
- Does it, for example, make more sense to protect for a 10-year storm instead of a 25-year storm?
- When should the City consider funding or providing a private plumbing service program to homes with significant sewer backup risk?

8.1.3 Operations and Maintenance of Stormwater Control Facilities

BES will continue to investigate ways to ensure new stormwater control facilities are adequately maintained for continued successful operation. This is necessary because although these types of facilities are recommended for implementation on the basis of higher benefits-to-cost ratios and estimated lowest life-cycle (present-worth) costs, they require maintenance and this increases the annual maintenance cost for the sewer system. This has been accounted for in the present-worth cost estimates, but is an on-going challenge for the annual budgeting process.

Current and future potential approaches include:

- Amending budgeting process to improve links between proposed 5-year CIP and 5-year Operating Budget Plan to address necessary funding increases for O&M of new stormwater control facilities.
- Applying cost-benefit risk analysis in a business case to justify adequate maintenance budget.
- Committing to investigation of optimal maintenance cycles, work planning, and procedures with monitoring of how maintenance affects facility functionality.
- Considering alternative maintenance delivery methods, including voluntary maintenance and/or financial compensation for maintenance as provided in a stormwater discount on the offsite portion of the sewer fee.

8.1.4 Stormwater Control Facilities on Private Property

As discussed in the *Combined Sewer System Plan Recommended Plan Summary* (BES, 2012b), the Bureau Leadership Team expressed concern about the feasibility of implementing the significant number of roof and parking stormwater control facilities proposed for development on private property. To address this concern, it was assumed for planning purposes that only 50 percent of these facilities would be implemented. The recommended

projects were modified accordingly. It was also recommended that during project design, the potential private-property stormwater control facilities identified should be pursued before upsizing pipes to accommodate the excess stormwater inflow.

To support optimal development of stormwater control facilities, which is especially important to continued reductions in CSOs over the long term, BES has begun searching for mechanisms to allow funding stormwater control facilities on private property. If participation by private property owners is not sufficient to meet onsite stormwater control targets, it is recommended that BES augment the existing Private Property Retrofits Program through additional outreach, technical assistance, and financial incentive programs. The short-term implementation plan recommends completing nearly $5 million worth of private property retrofit work within the next 10 years. Since there are no BES maintenance responsibilities for facilities constructed on private property, the present worth cost of these private property facilities tends to be lower than for facilities constructed in the public right-of-way.

8.1.5 Asset Management Improvement Program

As noted in Section 2.3, the recently initiated BES Asset Management Improvement Program is expected to provide guidance in the future for further integration of asset management principles into the sewer system planning process. It is expected, for example, that the estimated starting values for consequences of failures to meet levels of service will be modified as additional information is collected and analyzed to better represent risk. BES will continue to apply asset management practices in assessment of pipe structural and capacity deficiency risks and in the development, evaluation, and prioritization of sewer system improvements necessary to maintain BES levels of service. As the Asset Management Improvement Program progresses, BES will refine and improve its sewer system planning approaches accordingly.

8.1.6 Future Updates to the Explicit Model and BES Design Storms

8.1.6.1 Updates to the Explicit Model

The explicit model system that was utilized in the analysis of the combined sewer system is highly detailed and includes the modeling of public and private facilities to the tax lot level. In an effort to refine the model system and make more accurate predictions about locations where basement sewer backups would occur, the following model improvements are being considered:

- **Basement Presence:** Currently, it is assumed in the model that all tax lots have basements. When a project is taken to design, the presence of basements is checked through the project survey and those tax lots without basements are not considered in

the basement sewer backup risk assessment. However, at the planning level, when projects are developed and submitted to the CIP, it is assumed that all tax lots have basements. Therefore, the risk predicted in commercial areas, which typically do not have nearly as many basements as residential areas, can be overestimated. This can lead to the submittal of a project to the CIP that has a higher level of risk than is actually present. Asset System Management (ASM) will search for a reliable source of tax lot basement data and if it can be found, these data will be incorporated into future refinements to the explicit model system.

- **Inlet Inflow Restriction and Surface Flow Connectivity:** Another potential refinement is the assumption about how much stormwater enters a manhole during a storm event. The model currently assumes that all stormwater runoff from the contributing drainage area enters the manhole (through inlets connected to that manhole). However, typically during a significant storm event, some flow bypasses the inlet and flows downhill to low areas in the local topography. With this flow bypass, there would be greater risk of basement sewer backups for tax lots near the low areas and less risk for the other tax lots. The variation in risk within these areas could potentially be integrated into the model by making modifications to the model assumptions related to how much stormwater runoff enters the sewer system at each manhole.

These are a couple of examples of possible improvements to the explicit model in the future.

8.1.6.2 Updates to Design Storms

The 6-hour rainfall distribution that is embedded in the 2-, 5-, and 25-year design storms that are utilized for predicting risk in the combined sewer system was developed through the use of rainfall data that were collected at the Portland International Airport (PIA). These data were utilized to build the intensity-duration-frequency (IDF) curves that are presented in Chapter 6 of the *City of Portland Sewer and Drainage Facilities Design Manual*. The rainfall data that were used to build those curves were collected from 1945 to 1990. When the design manual is updated, ASM will make the recommendation to update the IDF curves with the new rainfall data that have been collected at PIA and at other rainfall gages in the City of Portland HYDRA system. The three design storms that are used to predict risk will be updated at the same time.

The literature that is published on the localized effects of climate change on rainfall intensity and rainfall volume will be evaluated when it becomes available. It is not expected that the standard design storm intensities or volumes will be modified to account for any predicted future changes due to climate change. It is the standard within BES to base design storm intensities and volumes on historical data. However, ASM may extrapolate and perform sensitivity analyses based on predicted changes. This will be determined as data become available on the localized effects. There is a more robust set of climate change models expected to become available as a part of the Intergovernmental Panel on Climate Change

Fifth Assessment Report (AR5) due for publication in 2013. AR5 will focus more on extreme events and annual precipitation predictions. It is recommended to review the results of the findings from this report once it becomes available.

8.1.7 Use of Sewage Release Database Records

The Sewage Release Database (SRDB) is a record of sewage releases that have occurred throughout the City. This database, which is managed by the BES Spill Protection & Citizen Response Group, includes records from February 1996 through June 2011 (date of last update). Over this 15 year period, approximately 260 sewage releases attributed to heavy rainfall have been recorded. The database includes sewage releases in both sanitary and combined sewer areas. Most of the records concern combined sewage backing up into basements due to surcharging pipes, but there are also records of discharges of sewage to surface locations. This database only includes the sewage releases that have been reported to the City. However, door to door canvassing of residents during the design of stormwater control projects (e.g., the Stark Street Inflow Control Project [E10003]) has found that many sewage backups are unreported. This canvassing demonstrates that the lack of SRDB records in an area does not mean that sewage backups have not occurred in that area.

ASM modeling staff members currently review the SRDB records during the predesign and design stages of a project when more detailed evaluations of sewer connections and basement elevations are collected. They have also used SRDB records to help guide the submittal of projects for the CIP. A project that has a positive nBCR with significant capacity risk and SRDB records within the project areas is given a higher priority for implementation than a project that shows significant risk but few, if any, SRDB records.

When the explicit model is converted over to the ArcGIS platform in fiscal year 2012, the SRDB records that are caused by heavy rainfall will be added to the standard maps that are published every time the results from a model run are exported. This will make it easier for the modelers to utilize these records in their day to day work. ASM will also continue to work with the BES Spill Protection & Citizen Response Group to ensure that the SRDB is updated on a regular schedule and the cause of the release for each record is clearly stated.

8.2 Final Thoughts

This Wastewater Sewer System Plan identifies critical and cost-beneficial actions to be taken to ensure the BES wastewater sewer system levels of service are sustained. The plan is founded on unprecedented system characterization and extensive explicit modeling efforts that make it possible to execute a reliable asset management approach. The high-priority cost-beneficial wastewater sewer system improvement projects itemized in Table 7-1

address structural and capacity deficiencies in the combined sewer and sanitary sewer systems.

In keeping with CSO reduction and watershed management policies, this plan incorporates green infrastructure solutions alongside traditional approaches to increase the adaptive capacity of the City's built and natural systems. This is accomplished by systematically developing stormwater control alternatives for evaluation and comparison with pipe upsizing alternatives to address capacity deficiencies in most of the combined sewer system basins. The resulting mixture of project types recommended by the short-term implementation plan is summarized in Figure 8-1.

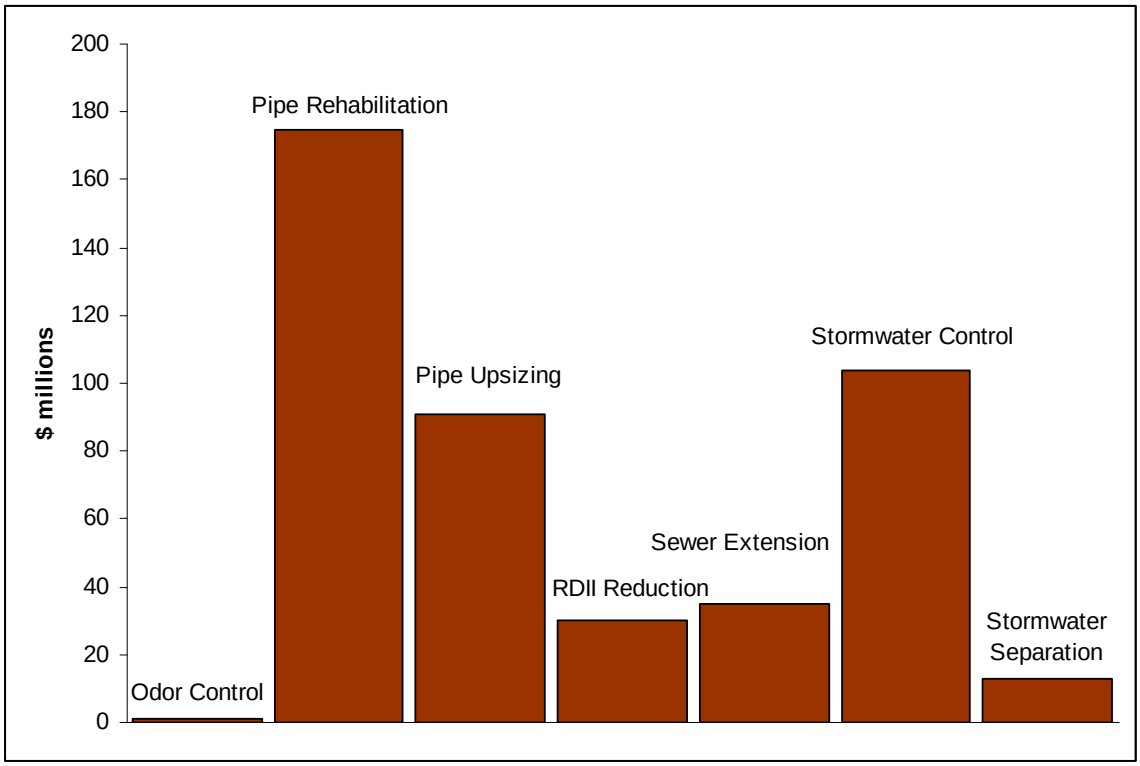

FIGURE 8-1
Short-Term Implementation Plan Breakdown by Type of Project

Because this is the first time a comprehensive asset management approach has been used by the City to prioritize wastewater sewer system projects for implementation, it is expected that recommended projects will be vetted further before being approved for budgeting; the procedures for doing this were proposed above to make certain the best and most important projects are funded and actualized. Also, hydraulic dependencies and coordination issues need to be considered as projects are sorted for implementation.

The next steps described above are recommended to address outstanding issues associated with aspects of the plan that are new to the City and to lay the groundwork for improving the planning process. In combination with the short-term implementation plan projects, these recommended actions will help to make sure the "living" Wastewater Sewer System Plan effectively protects public health, water quality, and the environment.