INITIAL INFILTRATION AND INFLOW REDUCTION PROJECT ALTERNATIVES ANALYSIS REPORT

Regional Infiltration and Inflow Control Program
King County, Washington

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King County
Department of Natural Resources and Parks
Wastewater Treatment Division

King County

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King County

Initial Infiltration and Inflow Reduction Project Alternatives Analysis Report

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GLOSSARY

TERMS

20-Year Peak Flow—A level of wastewater flow expected to be reached once every 20 years, on average, based on statistical analysis of historical rainfall and system flows; the 20-year peak flow is the design flow that King County conveyance facilities should be built to accommodate

Benefit/Cost Ratio—The ratio of savings associated with reduction or elimination of a conveyance system improvement project to the cost of the I/I reduction project that allows the reduction or elimination

Cost-Effective—Having a benefit/cost ratio of 1.0 or greater

Infiltration—Groundwater that enters a wastewater conveyance system through cracks or other defects in the buried infrastructure

Inflow—Precipitation runoff that enters a wastewater conveyance system through manholes, roof drains or other surface openings connecting to the system

Lateral—The portion of a pipe connecting a private property to the public sewer system that is in the public right of way

Mini-Basin—A drainage basin (geographic area encompassing all portions of the wastewater collection system draining to a single point) defined by King County's Regional I/I/ Control Program in order to establish manageable target areas for sewer system evaluation and rehabilitation. Mini-basins typically include about 20,000 feet of sewer main pipeline.

Side Sewer—The portion of a pipe connecting a private property to the public sewer system that is on the private property

ABBREVIATIONS

B/C—Benefit/cost

CCTV—Closed circuit television

cfs—Cubic feet per second

CMP—Corrugated metal pipe

CSI—Conveyance System Improvements

CSU—Concrete segments, unbolted

CT—Clay tile

E&P Subcommittee—Engineering and Planning Subcommittee

gpm—Gallons per minute

I/I—Infiltration and Inflow

IMAP—Interactive Mapping System

KCDNRP—King County Department of Natural Resources and Parks

MG—Million gallons

mgd—Million gallons per day

MWPAAC—Metropolitan Water Pollution Abatement Advisory Committee

NGPA— Native Growth Protection Area

NGPE— Native Growth Protection Easement

NRCS—Natural Resource Conservation Service

PVC—Polyvinyl chloride

ROE—Right of entry

RWSP—Regional Wastewater Services Plan

SSES—Sanitary sewer evaluation survey

WDFW—Washington Department of Fish and Wildlife

WDNR—Washington Department of Natural Resources

WTD—Wastewater Treatment Division

EXECUTIVE SUMMARY

BACKGROUND

The *Initial Infiltration and Inflow Reduction Project Alternatives Analysis* report presents recommendations for projects to reduce infiltration and inflow (I/I) in portions of King County's regional wastewater conveyance system. Reducing I/I, which consists of stormwater and groundwater entering a sanitary sewer system from various sources, makes more capacity available for sewage in the county's wastewater system. This increased capacity helps prevent overflows and reduce the need for capital projects to add system capacity. King County is engaged in a long-term program to reduce I/I when cost-effective to do so, and the projects outlined in this alternatives analysis represent an early test of the effectiveness of I/I reduction measures over a large area.

Previously, King County conducted a six-year study on I/I control, which included pilot-testing in several small areas of the county and a detailed benefit/cost analysis. The benefit/cost analysis outlined a general process for assessing whether the cost of I/I reduction measures can be recaptured through savings associated with elimination or reduction in size of capital projects that otherwise would be needed to increase system capacity. Specifically, the process looks at potential savings in the cost of projects planned under King County's Conveyance System Improvement (CSI) Program. The 2007 update to the CSI Program identifies 33 needed projects, assuming no broad I/I reduction across the service region. Successful I/I reduction projects may eliminate the need for an identified CSI project, reduce the required size of the project, or allow for delay in the implementation of the project. Any of these results can lead to cost savings in the CSI Program.

The initial I/I reduction projects fulfill the key components of the Executive's recommendation based on the six-year study:

- Select, implement, and evaluate two or three initial I/I reduction projects to test the cost-effectiveness of I/I reduction on a larger scale than the pilot projects.
- After completion of the initial projects, make recommendations to the King County Council regarding long-term I/I reduction and control.

Mini-Basin—A drainage basin (geographic area encompassing all portions of the wastewater collection system draining to a single point) defined by King County's Regional I/I/ Control Program in order to establish manageable target areas for sewer system evaluation and rehabilitation. Mini-basins typically include about 20,000 feet of sewer lines.

PROJECT DESCRIPTION

Areas Investigated and Affected CSI Projects

Four project areas for the Initial I/I Reduction project were selected in October 2006 by the Engineering and Planning (E&P) Subcommittee of the Metropolitan Water Pollution Abatement Advisory Committee (MWPAAC), which represents all the jurisdictions served by the King County regional wastewater system. The four project areas—Eastgate, Issaquah, Renton and Skyway—were chosen from a list of nine that were originally identified as potentially cost-effective in the November 2005 *Benefit/Cost Analysis Report*. Each project area consists of one or more "mini-basins," which were previously delineated by King County's Regional I/I Control Program. Figure ES-1 shows the locations of the four project areas.

The following CSI projects could be affected by I/I reduction in each project area:

- Eastgate Project Area (City of Bellevue)—The 2.33-million-gallon (MG) Eastgate Storage project

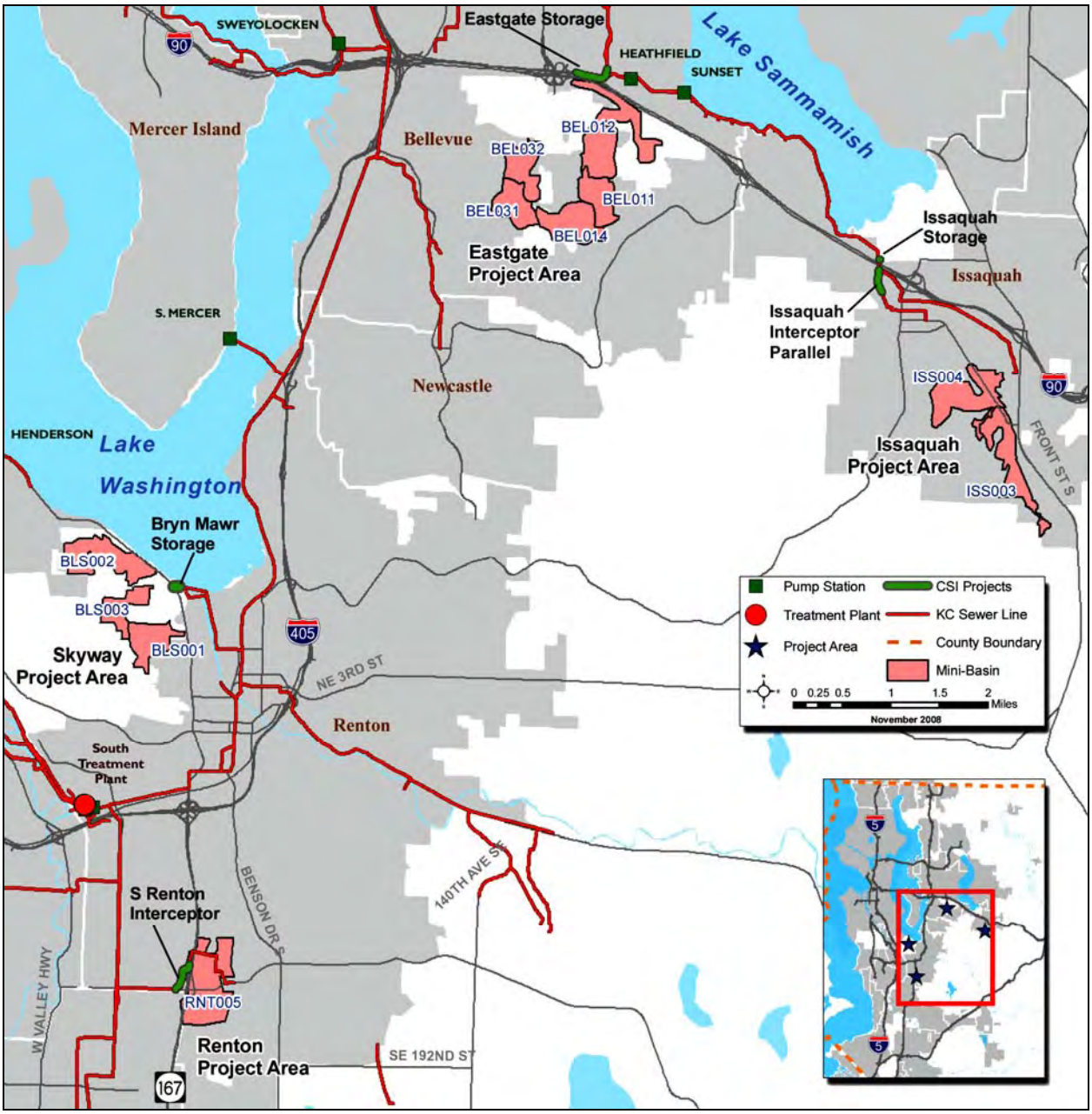

Figure ES-1. Project Areas and Mini-Basins Evaluated for Initial I/I Reduction Project

- Issaquah Project Area:
  - The 2.33-MG Eastgate Storage project
  - The 1.77-MG Issaquah Storage project
  - The 1.72-million-gallon-per-day (mgd) Issaquah Interceptor Parallel
- Renton Project Area—The South Renton Interceptor project
- Skyway Project Area—The 0.27-MG Bryn Mawr Storage project

Initial Evaluations Performed

For each mini-basin, the county has performed computer modeling to estimate the amount of I/I that would enter the sewer system within the mini-basin for a 20-year peak-flow event. These estimates are used as the baseline I/I flow for each mini-basin in this alternatives analysis. The evaluation of alternatives involved estimating how much each mini-basin's 20-year peak I/I flow could be reduced by implementing each alternative.

Investigations were conducted to assess the sewer system and surrounding environment for each project area. The sewer system evaluation survey (SSES) consisted of video inspections of sewers, smoke-testing, new flow monitoring, and limited dye testing and field visits to evaluate the condition of the existing sewer system and the level of flows attributable to I/I. The environmental assessment used field visits and review of previous studies to determine whether I/I reduction projects would have the potential for negative impacts on groundwater, surface water, geotechnical features or local drainage systems.

Alternatives Analysis Approach

Following the initial evaluations of the sewer system and surrounding environment, the analysis of alternatives for the initial I/I reduction project consisted of the following steps:

- Rehabilitation unit costs were developed based on field conditions in each mini-basin. Each property in the project areas was assigned a rehabilitation difficulty rating (easy, medium or difficult) and associated unit cost for rehabilitation.
- I/I quantities were uniformly apportioned across each mini-basin and were equated to an average I/I per property in the mini-basin.
- Rehabilitation alternatives were developed that consisted of rehabilitation in single or multiple mini-basins, including alternatives that combine rehabilitation in the Issaquah and Eastgate project areas where there are mutual benefits in the reduction of regional downstream conveyance needs. The alternatives considered a range of I/I reduction effectiveness from 60 to 75 percent.
- Alternatives were rated using criteria developed by the E&P Subcommittee. To be considered cost-effective under these criteria, an I/I reduction project must reduce, delay or eliminate a recommended downstream CSI project; and the associated cost savings must equal or exceed the cost of the I/I reduction project. Rehabilitation scenarios found to be cost-effective were evaluated in greater detail to identify preferred alternatives.

GENERAL FINDINGS

The following findings were made based on the analysis of project areas:

- The SSES revealed a moderate number of defects in mains, laterals and side sewers in each project area. I/I appears to be fairly uniformly allocated across each project area.
- The SSES generally confirmed the conventional wisdom that laterals and side sewers represent the major source of I/I in a system.
- New flow monitoring data collected in each project area during the 2007/2008 wet season was generally consistent with previous data; and both the new and old data suggest that a large percentage of I/I in the project areas originates from private property.
- The only significant difference between new and previous flow monitoring data was in the Renton project area, where the new data showed lower peak I/I levels. The SSES, including smoke tests and CCTV inspections, failed to identify the source of peak inflows in this

project area. However, several manholes in a wetland within the project area were identified as becoming submerged during heavy rainfall events; water entering the system through these manholes is a likely significant source of inflow.

- Although geotechnical, groundwater and environmental conditions were found to vary widely across the project areas, no conditions were found that pose significant issues for potential rehabilitation projects.
- It is likely that instances of drainage-related problems will result from I/I reduction improvements. In order to address drainage complaints that could be caused by any initial I/I reduction projects, it is recommended that a portion of the project construction cost be allocated to fixing any associated drainage problems that occur following rehabilitation.
- For some of the basins, rehabilitation unit costs, which were developed based on actual field conditions in each project area, are substantially higher than previously estimated in King County's 2005 benefit/cost analysis because of the degree of difficulty in accessing mains, laterals and side sewers. This was particularly true for portions of the Eastgate and Issaquah project areas. Table ES-1 summarizes the unit costs developed for this project.
- A general finding of the analysis was that basins with an I/I allocation of less than 3 gallons per minute (gpm) per property were not good candidates for cost-effective removal of I/I because achieving the total targeted I/I reduction in those basins would require rehabilitation of too many properties.

ALTERNATIVES ANALYSIS

Mini-Basin Scenarios

Mini-basin rehabilitation scenarios were developed consisting of varying combinations of rehabilitation of side sewers and laterals, and direct disconnections of roof drains and yard drains from the sewer system. The following are typical mini-basin rehabilitation scenarios:

- Rehabilitate laterals and side sewers on 50 percent of service parcels; rehabilitate only side sewers on 45 percent of service parcels; and implement direct disconnects on 4 percent of service parcels (this scenario, which does not distinguish between easy, medium and difficult parcels, was defined as "Technique 4" in the 2005 *Benefit/Cost Analysis Report* and was the recommended scenario in that report).
- Rehabilitate laterals and side sewers on all service parcels.
- Rehabilitate laterals and side sewers on 95 percent of service parcels.
- Rehabilitate laterals and side sewers on all easy and medium service parcels.

Variations of these scenarios were developed for each mini-basin. The goal was to establish and evaluate a reasonable range of I/I reduction approaches in order to find a suitable balance between construction cost and I/I reduction. Where smoke testing identified direct inflow sources, direct disconnects to eliminate the inflow sources are included in the rehabilitation scenarios. In all, 46 rehabilitation scenarios were developed and evaluated for nine mini-basins. Based on the evaluation, 20 scenarios in seven mini-basis were selected to create initial I/I reduction alternatives.

I/I Reduction Alternatives

Mini-basin rehabilitation scenarios selected for use in alternatives were evaluated individually or in combinations, based on the downstream CSI project that could be affected by their implementation. Twenty-seven alternatives were developed from the selected scenarios.

The alternatives and their estimated impacts on I/I were provided to King County's modeling group to assess the potential for reducing or eliminating downstream CSI projects due to the reduced I/I flows. Cost savings associated with CSI project reduction allowed by each initial I/I reduction alternative were estimated for comparison to the construction costs for the alternative. Alternatives with a benefit/cost ratio of 1.0 or greater may be recommended for implementation as initial I/I reduction projects.

RECOMMENDATIONS

The alternatives analysis indicated that cost-effective rehabilitation is feasible in only four mini-basins. Cost-effective rehabilitation in all other mini-basins is limited due to a low I/I allocation per property (requiring a greater number of properties to be rehabilitated) and high unit costs for rehabilitation because of difficult field conditions. Two I/I reduction alternatives, consisting of rehabilitation in three of the four feasible mini-basins, are recommended for implementation:

- **Eastgate/Issaquah Alternative BEL/ISS-B (see Figure ES-2)**—This alternative includes rehabilitation of laterals and side sewers in Eastgate Mini-Basin BEL031 and Issaquah Mini-Basin ISS003. Components include the following:
  - 82 easy and 25 medium lateral and side sewer replacements in Mini-Basin BEL031 (50 percent of 213 properties in the mini-basin).
  - 37 easy and 76 medium lateral and side sewer replacements in Mini-Basin ISS003 (85 percent of 133 properties in the mini-basin).
  - The combined estimated range of I/I reduction for the two mini-basins is 1.04 mgd (75-percent reduction effectiveness) to 0.85 mgd (60-percent reduction effectiveness).
  - Reduction in the Eastgate Storage requirement is between 320,000 gallons (75-percent reduction effectiveness) and 260,000 gallons (60-percent reduction effectiveness).

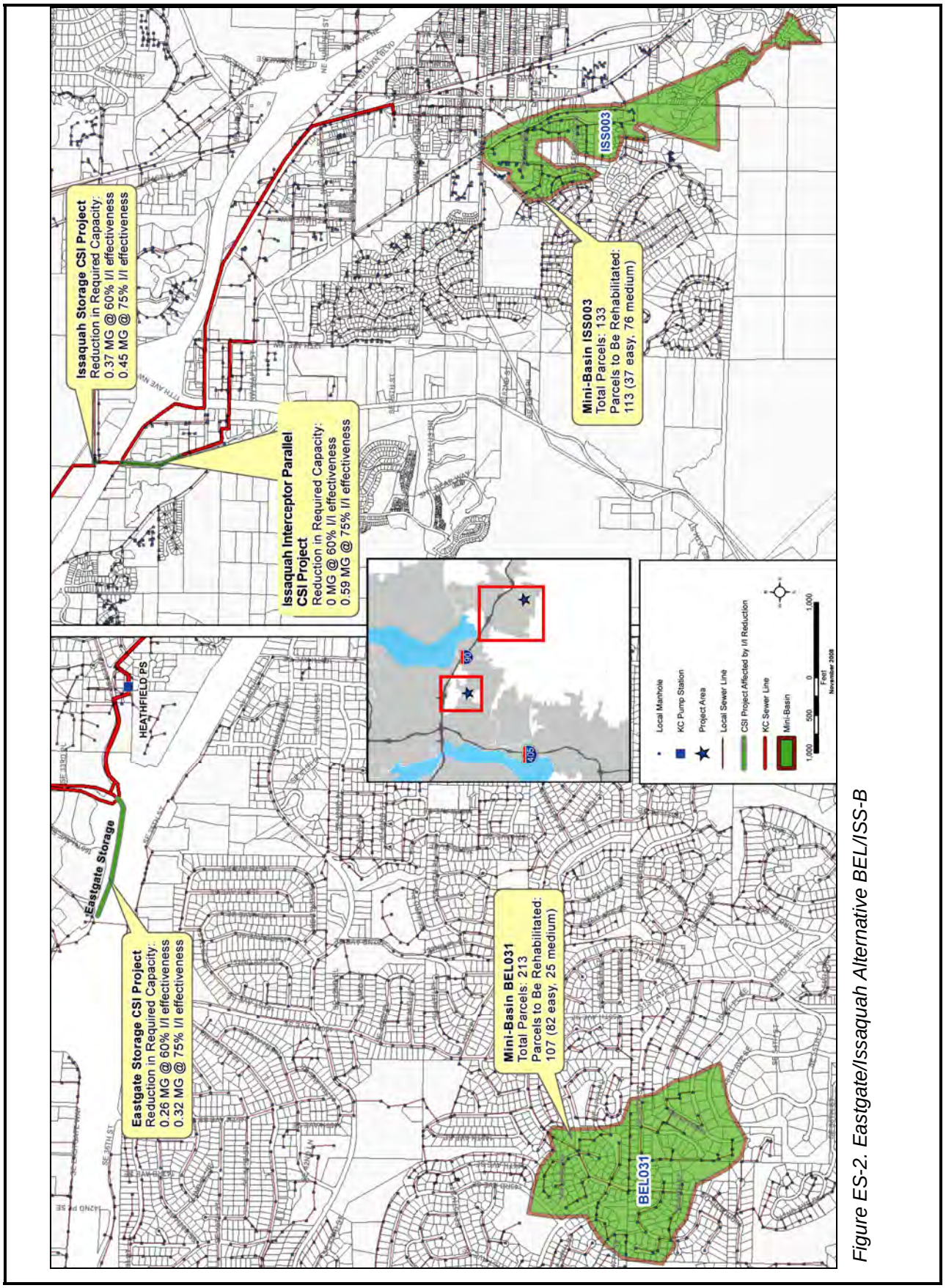

Figure ES-2. Eastgate/Issaquah Alternative BEL/ISS-B

  - Reduction in the Issaquah Storage requirement is between 450,000 gallons (75-percent reduction effectiveness) and 370,000 gallons (60-percent reduction effectiveness).
  - Reduction in the downstream CSI project costs is between $6.37 million (75-percent reduction effectiveness) and $5.12 million (60-percent reduction effectiveness).
  - The estimated project cost for the I/I rehabilitation is $5.23 million. Although this project is marginally below the cost-effectiveness threshold of 1.0 if only 60-percent I/I removal is achieved, past similar projects have shown I/I removal rates on average of 77 percent. The cost estimate for I/I reduction is also conservative, so the risk is minimized that the project would not achieve cost-effectiveness.

- **Skyway Alternative BLS-F (see Figure ES-3)**—This alternative includes rehabilitation of laterals and side sewers in Skyway Mini-Basin BLS002. Components include the following:
  - 292 easy and 51 medium lateral and side sewer replacements (89 percent of the 386 properties in the mini-basin).
  - The estimated range of I/I reduction is 2.29 mgd (75-percent reduction effectiveness) to 1.88 mgd (60-percent reduction effectiveness).
  - The rehabilitation eliminates the need for the 270,000-gallon Bryn Mawr Storage project, and the associated $5.37 million total project cost.
  - The estimated project cost for the I/I rehabilitation is $5.63 million, requiring cost-sharing of $260,000 by the Skyway Water and Sewer District to make the project cost-effective.
  - The Skyway Water and Sewer District wants to add rehabilitation of mains and manholes to this project. The District has agreed to pay for the additional construction cost to add these components.

Estimates and project details will be refined through the predesign process in 2009 and the final design in 2010. The predesign will identify exact parcels for rehabilitation and confirm the preferred construction method. During final design, contract documents will be prepared, rights of entry will be acquired, and the public participation program will be carried out. Construction of the projects will take place in 2011 and 2012. Post-project evaluation and the King County Executive's submittal of recommendations for future work to the King County Council will occur in 2013.

For the Renton project area, flow monitoring performed for this alternatives analysis did not indicate the level of I/I that had previously been measured or predicted by modeling. It is possible that Washington State Department of Transportation construction on the SR-167 on-ramp resulted in changes to the surface water drainage patterns, diverting surface water away from the sewer line in the wetland area. Given the current levels of measured I/I in the mini-basin, it does not appear that rehabilitation in the mini-basin will meet the cost-effectiveness criteria established for this project. At the April 16, 2008 E&P Subcommittee meeting, a decision was made to remove the Renton project area from further consideration of large-scale rehabilitation under the Initial I/I Reduction project.

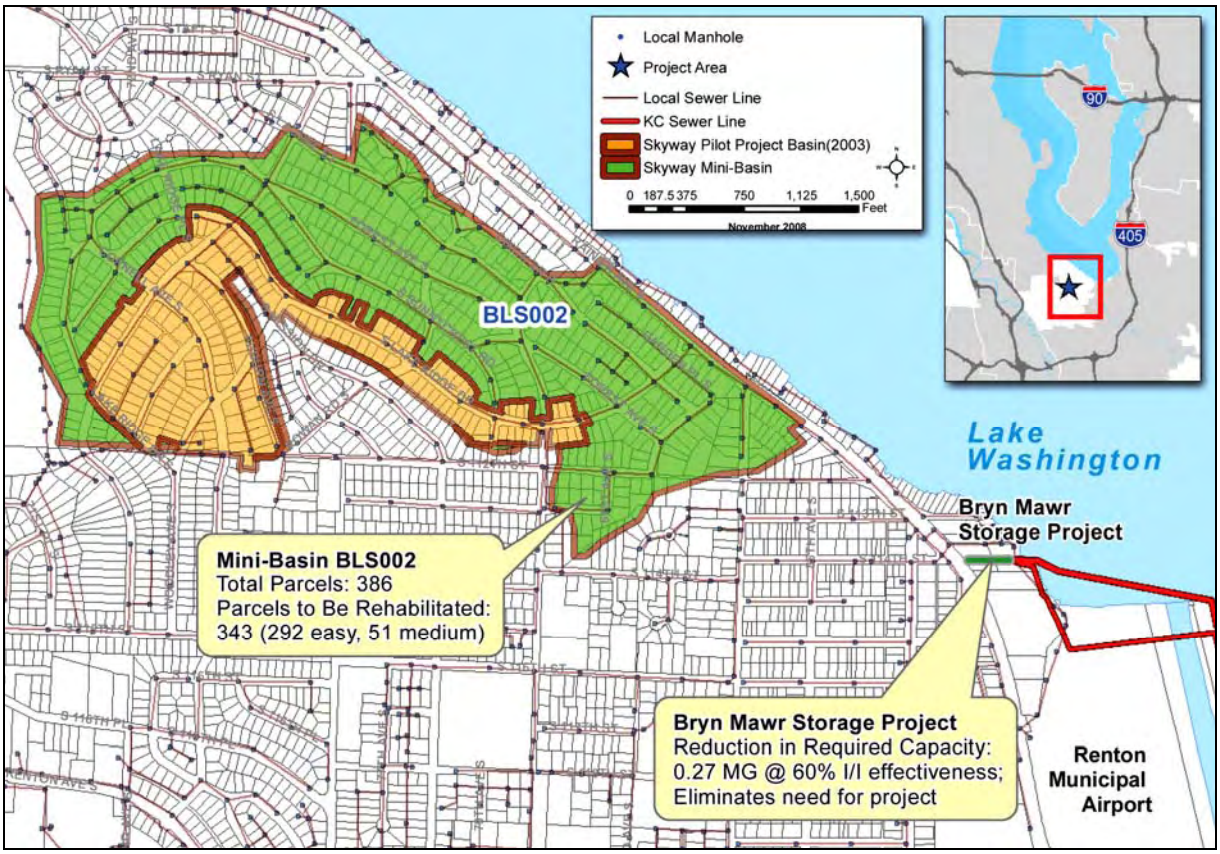

Figure ES-3. Skyway Alternative BLS-F

CHAPTER 1.
PROJECT BACKGROUND AND STUDY AREAS

This alternatives analysis report presents recommendations for projects to reduce infiltration and inflow (I/I) in portions of King County's regional wastewater conveyance system. It describes the analysis performed to identify and evaluate potential projects, provides estimates of project cost and benefit, and presents considerations that must be addressed in moving forward to design of the recommended projects.

1.1 PLANNING BACKGROUND

1.1.1 Regional I/I Control Program

The King County Wastewater Treatment Division (WTD) serves 34 local cities and sewer districts in the county's regional service area. WTD must provide adequate capacity in its system to convey and treat wastewater flows sent by the cities and districts through their collection systems. With the exception of portions of the City of Seattle that have combined sewers (designed to convey wastewater and stormwater in the same pipes), sewers in the regional wastewater system are designed to convey only wastewater. However, many of these "separated" sewers also convey clean groundwater and stormwater that enter through leaky pipes, improper storm drain connections, and other means.

This clean water consists of infiltration, which is groundwater that enters a wastewater conveyance system through cracks or other defects in the buried infrastructure, and inflow, which is rainwater runoff that enters the system through manholes, roof drains or other surface openings connecting to the system. The combined contribution of infiltration and inflow (I/I) takes up capacity that could otherwise be used for wastewater alone and generates the need to build added capacity in pipelines, treatment plants and other facilities. This need for added capacity results in higher capital and operating costs for the regional system that are borne by ratepayers in all local jurisdictions. Reducing I/I in the system has the potential to lower the risk of sanitary sewer overflows and decrease the costs of conveying and treating wastewater.

The King County Regional I/I Control Program was created in 1999 as part of the Regional Wastewater Services Plan (RWSP). The purpose of the program is to reduce I/I in the county's wastewater conveyance system when it is cost-effective to do so. The county worked with local agencies to conduct a six-year I/I control study beginning in 2000. The study included pilot testing and a benefit/cost analysis of potential I/I control approaches, and culminated with an Executive's recommendation for regional I/I control. The key thrusts of the Executive's recommendation are twofold (King County, 2005a):

- King County and the local agencies would select, implement, and evaluate two or three "initial" I/I reduction projects to test the cost-effectiveness and feasibility of I/I reduction on a larger scale than the pilot projects.
- After completion of the initial projects, recommendations would be made to the King County Council regarding long-term I/I reduction and control.

The Initial Infiltration and Inflow Reduction Project is the implementation of the Executive's recommendation. Figure 1-1 shows the milestones included in the project. The project's scope includes an analysis of alternatives for four candidate I/I project areas and final design and construction for up to three initial I/I reduction projects.

Figure 1-1. Projected I/I Program Milestones

The recommended projects will consist of replacing or rehabilitating sanitary sewer collection system facilities in local agency systems to remove groundwater and stormwater sources from the sewer system. Work on private property might consist of rehabilitation or replacement of side sewers (the private-property portion of a pipe connecting the property to the public sewer system). Work in the public right-of-way would generally include the rehabilitation or replacement of main lines, service connections to the main line, laterals (the public-property portion of a pipe connecting a private property to the public sewer system), and manholes. Construction techniques could include pipe bursting, pipe replacement, pipe lining, manhole rehabilitation, manhole replacement, cleanout installations, and disconnection or repair of direct-connection inflow sources.

1.1.2 Conveyance System Improvement Program

King County's Conveyance System Improvement (CSI) Program outlines needed capital improvements to the county-owned regional conveyance system to provide adequate capacity for 20-year peak wastewater flows through 2050. The process for identifying capacity needs consisted of four main steps:

- Estimating current 20-year peak flow demands on the regional conveyance system to establish a baseline that represents how the system currently performs under peak flow conditions.
- Projecting 20-year peak flows by decade through 2050 for the regional conveyance system using population and employment growth projections.
- Using a hydraulic model of the conveyance system to identify capacity constraints based on when the 20-year peak flows will exceed the capacity of existing regional conveyance facilities.
- Verifying and adjusting identified growth assumptions and capacity constraints using updated information from component agencies.

The most recent update to the CSI Program (King County, 2007a) presents 33 project recommendations assuming no broad I/I reduction across the service region. Successful I/I reduction projects may eliminate the need for an identified CSI project, reduce the required size of the project, or allow for delay in the implementation of the project. Any of these results can lead to cost savings in the CSI Program.

1.1.3 Benefit/Cost Analysis

King County's November 2005 *Benefit/Cost Analysis Report; Regional Infiltration and Inflow Control Program* compared the estimated costs of constructing conveyance system improvement projects with the estimated costs of I/I reduction projects. The report drew upon pilot test results and discussions with local agencies to establish assumptions for estimating rehabilitation costs for I/I rehabilitation projects and the expected amount of I/I reduction. Among these was the assumption that unit costs could be established

for components of I/I rehabilitation work that would be uniform across King County. These unit costs included the following:

- $3,900 for rehabilitation of a lateral on any one property
- $3,500 for rehabilitation of a side sewer on any one property
- $6,800 for rehabilitation of a lateral and side sewer on any one property
- $3,000 for disconnection of any direct source of inflow to the sewer system (these projects are called “direct disconnects”).

The benefit/cost report also presented assumptions for the amount of I/I in a sewer basin that could be removed by a given set of I/I rehabilitation projects. It defined four techniques for I/I reduction in a basin, and presented the following conservative I/I reduction estimates for each:

- Technique 1—Perform direct disconnects on 4 percent of basin parcels: 10-percent I/I reduction
- Technique 2—Rehabilitate 95 percent of sewer mains, manholes, laterals and side sewers; perform direct disconnects on 4 percent of basin parcels: 80-percent I/I reduction
- Technique 3—Rehabilitate 50 percent of sewer mains, manholes and laterals; perform direct disconnects on 4 percent of basin parcels: 40-percent I/I reduction
- Technique 4—Rehabilitate 50 percent of laterals and side sewers and 45 percent of side sewers only; perform direct disconnects on 4 percent of basin parcels: 60-percent I/I reduction

The report identified Technique 4 as its preferred approach for I/I reduction projects based on pilot project results, which suggested that it provides the most cost-effective I/I removal. The benefit/cost report assumptions were used as a starting point for this alternatives analysis, but were modified as appropriate based on new information collected as part of this project.

1.2 PROJECT GOALS

The overall objective of the initial I/I reduction projects is to remove enough I/I to downsize, delay or eliminate the need for downstream conveyance improvement projects, resulting in a net savings to the county. The benefit/cost report outlined specific I/I reduction targets for flows to nine proposed CSI projects. Four of those were selected for evaluation in the initial I/I reduction project. Table 1-1 summarizes the benefit/cost report’s estimates for the four projects. These results established a starting point for the analysis of alternatives for initial I/I reduction. The costs and I/I reduction targets were updated as part of the analysis to select initial projects. The results of the initial projects will be used to inform further recommendations to the King County Council regarding long-term I/I reduction, including applicable changes to policy or code.

Much is yet to be learned about the feasibility and cost-effectiveness of I/I reduction on a large scale, therefore the Executive’s recommendation called for implementation of two or three initial demonstration projects to gain more information prior to the county launching a full I/I reduction program. If I/I reduction on a large scale proves to be cost-effective and feasible, a recommendation would be made that it be considered as a project alternative during planning and pre-design for any conveyance improvement project. For future work, wherever I/I reduction is less expensive than the otherwise needed conveyance project, WTD would fund the I/I project, including work in local agency systems and on private property.

TABLE 1-1.
ORIGINAL TARGETS AND ESTIMATED BENEFITS AND COSTS
FOR INITIAL I/I REDUCTION PROJECT

Affected CSI Project	Intended Benefit	I/I Reduction Target to Achieve Intended Benefit	I/I Reduction Project Cost	CSI Project Cost Savings	Benefit / Cost Ratio
Eastgate Storage & Trunk	Eliminate the need for Eastgate Tube Storage	3.55 million gallons/day (mgd)	$14.46 million	$16.63 million	1.2
Issaquah 2 Trunk	Eliminate the need for Issaquah 2 Trunk upgrades; reduce required size for Issaquah Tube Storage	1.05 mgd	$3.96 million	$5.77 million	1.5
South Renton Interceptor	Eliminate the need for South Renton Interceptor upgrade	0.81 mgd	$2.22 million	$7.27 million	3.3
Bryn Mawr Storage	Reduce the size of the Bryn Mawr Storage	2.04 mgd	$6.02 million	$8.51 million	1.4

Source: King County, 2005b.

Once completed, the initial I/I reduction projects are to be evaluated to determine whether they were able to reduce I/I levels enough to delay, downsize or eliminate the need for downstream CSI projects, and whether I/I reduction on this scale is cost-effective.

The following are the goals of the Initial I/I Reduction Project:

- Conduct an I/I reduction alternatives analysis for four project areas: Eastgate, Issaquah, Renton and Skyway.
- Select and implement up to three initial I/I reduction projects in 2010-12 to test the cost-effectiveness of I/I reduction on a scale large enough to potentially reduce the need for downstream conveyance or storage facility capacity. The total construction cost budget for all projects combined will not exceed $8.5 million.
- Analyze the results of these initial projects and make recommendations to the King County Council regarding long-term I/I reduction and control, including applicable changes to policy or code.

1.3 DESCRIPTION OF PROJECT AREAS

Four candidate project areas for the Initial I/I Reduction project were selected in October 2006 by the Engineering and Planning (E&P) Subcommittee of the Metropolitan Water Pollution Abatement Advisory Committee (MWPAAC), which represents all the jurisdictions served by the King County regional system. The four project areas—Eastgate, Issaquah, Renton and Skyway—were chosen from a list of nine that were originally identified as potentially cost-effective in the November 2005 *Benefit/Cost Analysis Report*. The selection was based on a comparative evaluation using criteria established by the MWPAAC. Figure 1-2 shows the locations of the four project areas.

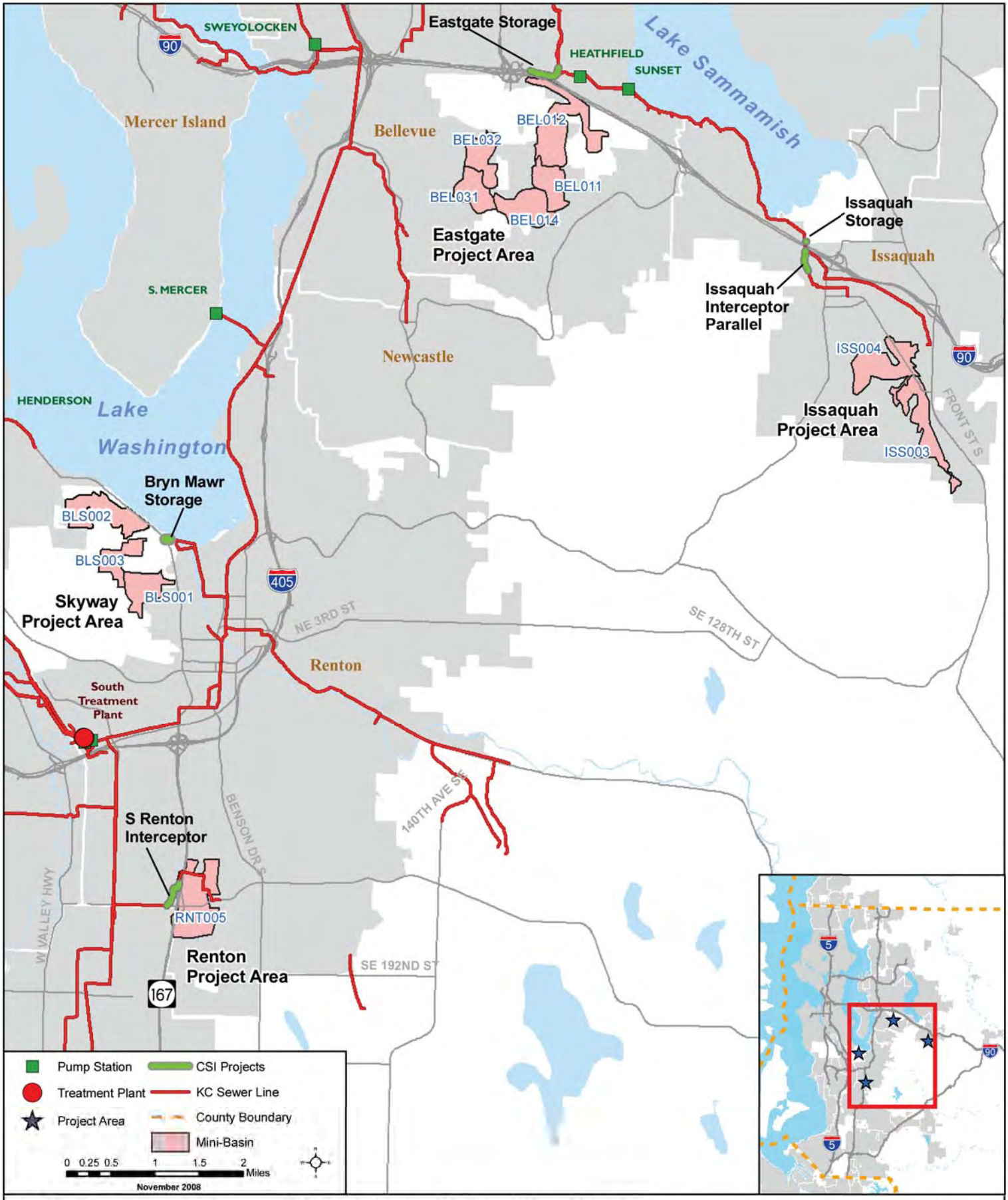

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Figure 1 - 2

Project Area Locations

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

Each project area consists of one or more "mini-basins," which were previously delineated by King County's Regional I/I Control Program. For each mini-basin, the county has performed computer modeling to estimate the amount of I/I that would enter the sewer system within the mini-basin for a 20-year peak-flow event. These estimates are used as the baseline I/I flow for each mini-basin in this alternatives analysis. The evaluation of alternatives involved estimating how much each mini-basin's 20-year peak I/I flow could be reduced by implementing each alternative.

The following sections provide additional information about each project area and its component mini-basins.

1.3.1 Eastgate

Physical Area

The Eastgate project area is in the City of Bellevue, south of the I-90 corridor and following 148th/150th Avenue SE through the Eastgate and Hilltop neighborhoods (see Figure 1-3). The project area consists of five mini-basins:

- Mini-Basin BEL011—259 Parcels, 97 acres
- Mini-Basin BEL012—441 Parcels, 221 acres
- Mini-Basin BEL014—225 Parcels, 131 acres
- Mini-Basin BEL031—213 Parcels, 93 acres
- Mini-Basin BEL032—223 Parcels, 94 acres

The mini-basins in this project area vary in size but share similar physical attributes: steep topography, winding rights of way, and numerous areas of heavy forest separating adjacent rights of way.

Sewer System

The Eastgate project area is served entirely by gravity sewers, consisting primarily of cement concrete pipe, with isolated pockets of polyvinyl chloride (PVC) side sewers. Based on the results of King County modeling, the 20-year peak I/I flow contribution to Eastgate mini-basins is as follows:

- Mini-Basin BEL011—0.78 million gallons per day (mgd)
- Mini-Basin BEL012—1.35 mgd
- Mini-Basin BEL014—0.56 mgd
- Mini-Basin BEL031—1.31 mgd
- Mini-Basin BEL032—0.72 mgd

Flow monitoring before and during the efforts included in this report did not reveal any need for modifications to the modeling results, so these values are used in calculating potential downstream impacts of I/I reduction in the Eastgate project area.

Affected CSI Projects

The CSI Program capital project downstream of this project area that is expected to be affected by I/I reduction in the project area is the 2.33-million-gallon (MG) Eastgate Storage project. Flows would have to be reduced by 5 mgd to allow for elimination of the facility.

1.3.2 Issaquah

Physical Area

The Issaquah project area is in the west-central portion of the City of Issaquah (see Figure 1-4). The project area consists of two mini-basins:

- Mini-Basin ISS003—133 Parcels, 81 acres
- Mini-Basin ISS004—293 Parcels, 136 acres

Mini-Basin ISS003 extends east from the eastern side of Squak Mountain to about Issaquah Creek. Mini-Basin ISS004 extends east from the eastern side of Squak Mountain to about Newport Way SE.

The project area consists of single-family residences and multi-family apartments and condos. There is no commercial development. Most properties within the project area are on hillside developments. Storm drainage infrastructure is present.

Sewer System

The Issaquah project area is served entirely by gravity sewers. Wastewater flows are conveyed generally east and north. Older neighborhoods in the project area are served by concrete sewers, and newer neighborhoods are served by PVC sewers. Based on the results of King County modeling, the 20-year peak I/I flow contribution is as follows:

- Mini-Basin ISS003—0.65 mgd
- Mini-Basin ISS004—0.81 mgd

Flow monitoring before and during the efforts included in this report did not reveal any need for modifications to the modeling results, so these values are used in calculating potential downstream impacts of I/I reduction in the Eastgate project area.

Affected CSI Projects

The following CSI Program capital projects downstream of this project area have the potential to be impacted by the amount of I/I in the system:

- The 2.33-MG Eastgate Storage
- The 1.77-MG Issaquah Storage
- The 26.6-mgd Sunset/Heathfield Pump Station Replacement
- The 1.72-mgd Issaquah Interceptor Parallel

The Sunset and Heathfield pump stations will be sized to accommodate the peak flows that can reach the facilities. I/I reduction upstream of these pump stations will affect the sizing requirements for the Issaquah Storage and the Issaquah Interceptor Parallel, but will not significantly reduce the required pump station capacity requirements. Therefore, any slight capacity reduction in the Sunset/Heathfield Pump Station Replacement determined by this analysis will not be considered in the analysis of potential I/I projects in this area.

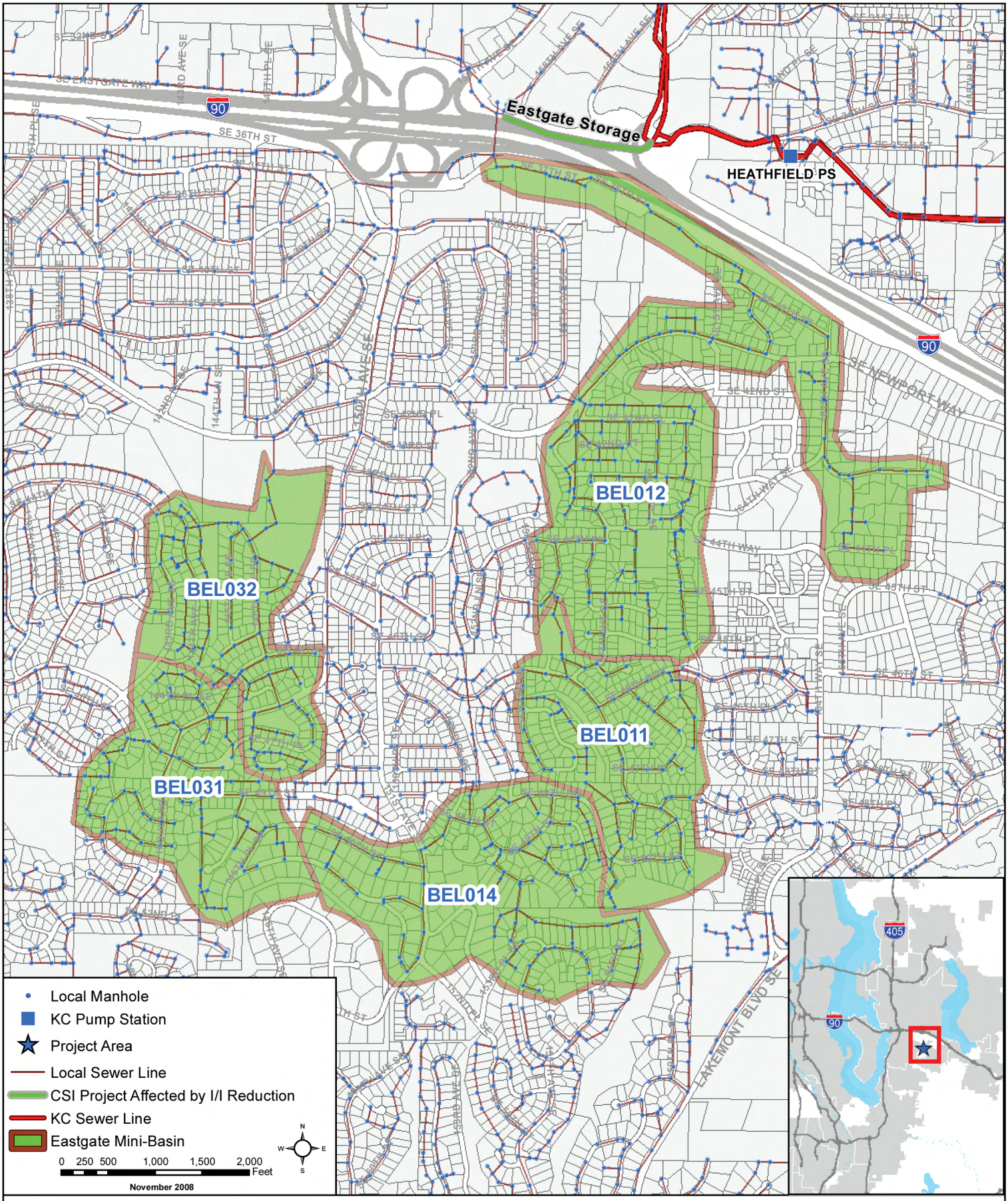

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Figure 1 - 3

Eastgate Project Area

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

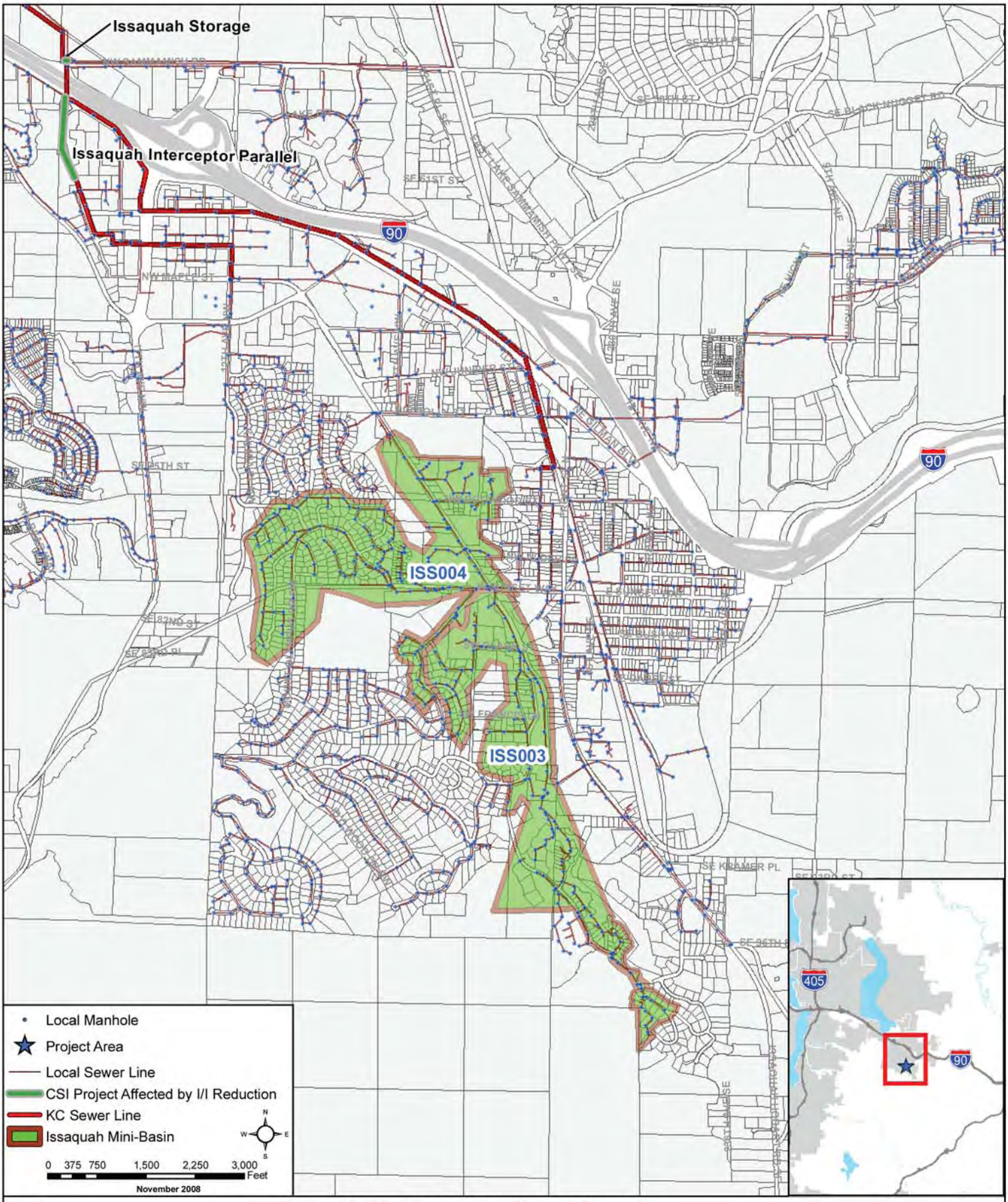

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Figure 1 - 4

Issaquah Project Area

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

1.3.3 Renton

Physical Area

The Renton project area lies at the foot of the east slopes of the Green River valley (see Figure 1-5). The project area consists of one mini-basin, RNT005, which is east of SR-167, roughly between about South 36th Street and South 47th Street. The 2005 *Benefit/Cost Analysis Report* identified a second mini-basin in this project area as potentially cost-effective for I/I reduction—Mini-Basin SOO021; however, this mini-basin was excluded from the analysis because it was determined that only slight I/I reduction in the mini-basin is feasible and because it includes many commercial properties, which would not easily be rehabilitated. Evaluation for this project focused on the western portion of the Renton project area, where a north-south sewer line crosses a wetland between SR-167 and Valley Medical Center.

Mini-Basin RNT005 includes about 185 property parcels, including multi-family development, undeveloped land, single-family housing, the Valley Medical Center and its appurtenant clinics, and small businesses. Approximately 20 percent of the 111-acre mini-basin is single-family housing and 50 percent is multi-family housing. The hospital is currently undergoing an expansion.

Sewer System

The Renton project area is served entirely by gravity sewers; there are no wastewater pump stations. Wastewater flows generally southeast to northwest. According to modeling performed for the I/I Control Program, the 20-year peak I/I contribution to sewers in this project area is 7 mgd.

Affected CSI Projects

The CSI Program capital project downstream of this project area that is expected to be affected by I/I reduction in the project area is the South Renton Interceptor project, which will be a parallel pipeline constructed to increase capacity in the regional sewer system

1.3.4 Skyway

Physical Area

The Skyway project area is immediately west of the southern end of Lake Washington above Rainier Avenue South (see Figure 1-6). The project area consists of three mini-basins:

- Mini-Basin BLS001—391 Parcels, 93 acres
- Mini-Basin BLS002—386 Parcels, 157 acres
- Mini-Basin BLS003—232 Parcels, 63 acres

The 2005 *Benefit/Cost Analysis Report* did not identify Mini-Basin BLS002 as a potential candidate for I/I reduction. This mini-basin was part of the I/I pilot project performed in 2003, which replaced sewer mains and manholes and rehabilitated approximately 175 laterals and side sewers. Comprehensive flow monitoring of the mini-basin was not performed following the pilot project, so the amount of I/I remaining in the mini-basin following rehabilitation was undefined. The mini-basin was added for this analysis after flow monitoring performed as part of this project revealed high levels of I/I remaining in the portions of the mini-basin that were not rehabilitated during the pilot project.

Development within each of the three mini-basins is predominantly single-family residential, constructed in the late 1950s and early 1960s. Mini-Basin BLS002 includes additional properties not included in this analysis because they were rehabilitated as part of the pilot project.

Sewer System

The Skyway project area is served entirely by gravity sewers. Wastewater generally flows from south to north in Mini-Basins BLS001 and BLS003 and from east to west in Mini-Basin BLS002. The sewer collection system in the three mini-basins conveys flow to Rainer Avenue South, where the system discharges to King County's regional sewer system. Sewer mains, laterals and side sewers are constructed primarily of concrete pipe, which was installed in the 1950s by the Bryn Mawr Sewer District, which provided sewer service to the area at the time.

According to the Skyway Water and Sewer District, several portions of the collection system have experienced capacity problems during significant rain events. Overflows and sewer backups have occurred in several locations; including the northeast portion of Mini-Basin BLS003 and the downstream portion of Mini-Basin BLS002 near Rainer Avenue South.

Based on King County modeling, the 20-year peak I/I contributions in this project area are as follows:

- Mini-Basin BLS001—0.97 mgd
- Mini-Basin BLS002—3.00 mgd (this is the quantity attributed to the portion of the mini-basin not rehabilitated in the pilot project; based on post-pilot-project monitoring, the remaining I/I within the rehabilitated area is estimated to be an additional 0.39 mgd)
- Mini-Basin BLS003—1.68 mgd

Flow monitoring before and during the efforts included in this report did not reveal any need for modifications to the modeling results, so this value is used in calculating potential downstream impacts of I/I reduction in the Skyway project area.

Affected CSI Projects

The CSI Program capital project downstream of this project area that is expected to be affected by I/I reduction in the project area is the Bryn Mawr Storage Facility, a 0.27-MG underground off-line storage facility to be located northwest of the Renton Airport. The project consists of a 12-foot diameter storage pipe with a small pump station to discharge stored flows after a peak flow event. Waterfront property acquisition costs have been included in the project cost estimate for siting the facility. The storage facility would limit downstream flow to the existing capacity of the Bryn Mawr Trunk. Flow reduction at the Bryn Mawr Storage Facility would also help to maintain available capacity in King County's Eastside Interceptor Section 1.

1.4 ALTERNATIVES ANALYSIS APPROACH

The analysis of alternatives for the initial I/I reduction project consisted of the following steps:

- The results of smoke testing and closed-circuit television (CCTV) inspection of sewer mains, laterals and side sewers were reviewed. Smoke testing and CCTV inspection help to identify specific locations where infiltration or inflow may be entering the sewer system.
- Flow monitors were installed in each project area during the 2007/2008 wet season. The data collected is to be used as follows:
  - The results were compared to previous flow monitoring data to identify where I/I conditions have changed since previous monitoring was performed, affecting the scope of potential I/I reduction measures.

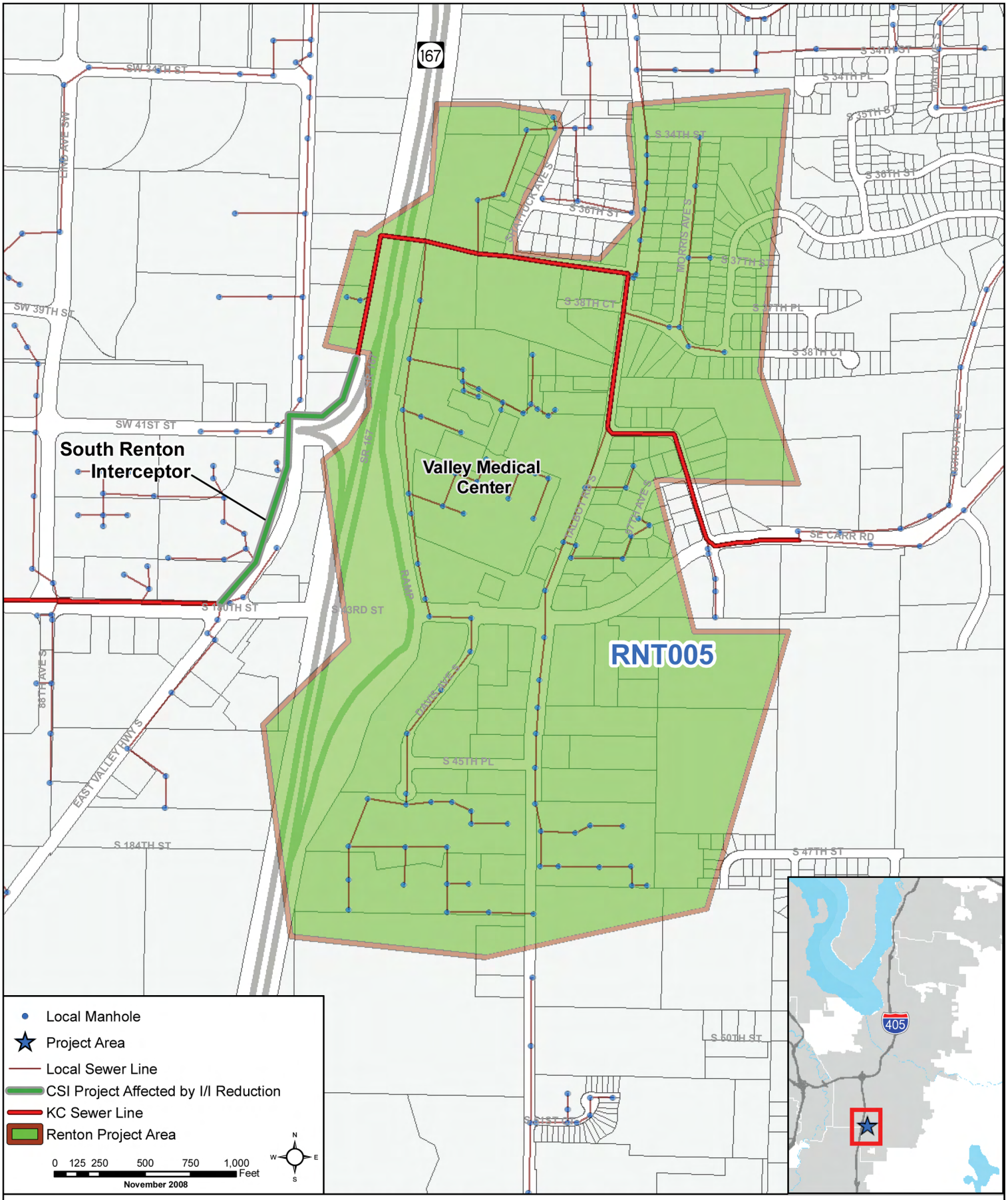

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Figure 1 - 5

Renton Project Area

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

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Figure 1 - 6

Skyway Project Area

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

  - The results allow assessment of whether I/I appears to be coming from shallow side sewers and laterals or from deeper sewer main lines, based on how quickly flows increase in response to rainfall.
  - The results provide "before-project" data that can be used to help assess the effectiveness of any implemented I/I reduction measures.
- Field visits and reviews of previous reports were performed for the following reasons:
  - Geotechnical, groundwater, environmental and storm drainage conditions were evaluated in the field and by review of existing documents to identify any locations where I/I reduction measures could have negative impacts on these conditions.
  - A field visit to a wetland in the Renton project area was conducted to identify manholes that may become submerged during heavy storm events, representing significant sources of inflow.
  - Limited field investigations were performed to assess conditions of individual parcels in the project areas that could affect constructability of I/I reduction measures.
- Rehabilitation unit costs were developed for each project area. The unit costs are for rehabilitation of sewer system components and are based on actual field conditions in each mini-basin. Each property in the project areas was assigned a rehabilitation difficulty rating (easy, medium or difficult) and associated unit cost for rehabilitation. The unit costs were used in developing overall project cost estimates for identified I/I reduction alternatives.
- I/I quantities were uniformly apportioned across each mini-basin and were equated to an average I/I per property in the mini-basin. The I/I allocation per property provided a benchmark for areas that would be most cost-effective to rehabilitate.
- Rehabilitation alternatives were developed that consisted of rehabilitation in single or multiple mini-basins, including alternatives that combine rehabilitation in the Issaquah and Eastgate project areas where there are mutual benefits in the reduction of regional downstream conveyance needs. The alternatives considered a range of I/I reduction effectiveness from 60 to 75 percent.

The alternatives analysis used criteria developed by the E&P Subcommittee. To be considered cost-effective under these criteria, an I/I reduction project must reduce, delay or eliminate a recommended downstream CSI project; and the associated cost savings must equal or exceed the cost of the I/I reduction project. A project was designated as "cost-effective" if its benefit/cost ratio, calculated as follows, is 1.0 or greater:

$$\text{Benefit/Cost Ratio} = \frac{\text{(CSI Project Cost Savings After I/I Reduction)}}{\text{(Cost of Proposed I/I Reduction Project)}}$$

In order to measure I/I reduction rates achieved and confirm the appropriateness of reducing or eliminating a downstream CSI project, the I/I Control Program will conduct flow monitoring within each project mini-basin after I/I reduction work has been completed. The results of the post-project evaluations will be presented to the E&P Subcommittee, and a recommendation regarding whether to proceed with additional I/I reduction projects will be presented to the King County Council.

CHAPTER 2.
SEWER SYSTEM EVALUATION SURVEY

The analysis of I/I reduction alternatives required a detailed assessment of the current physical condition of the sewer system in each project area as well as the best available estimates of current sewer flows and peak I/I levels. These characteristics were assessed through a sewer system evaluation survey (SSES) using updated flow monitoring, extensive CCTV inspection and smoke testing, and, in the Renton project area, limited dye testing. This chapter describes procedures and results for each element of the SSES.

2.1 ACCESS PROCEDURES

Prior to performing smoke testing and CCTV inspection, King County provided mailers to all residents in the project areas describing the methods of evaluation that would be performed and the general timing of the investigations. The mailers included a county contact person and phone number to address any questions or concerns that residents had about the investigations. All questions, concerns and requirements raised by the public were logged into a database for tracking the communications.

Smoke testing required physical access to each property to assess whether I/I sources were present. In the Eastgate, Issaquah and Renton project areas, city ordinances allowed access to properties for inspection purposes, and these rights were passed on to the county through interlocal agreements established with the agencies. Skyway Water and Sewer District does not have such ordinances, so a right-of-entry agreement from each property owner was required in order to perform the investigations. The county gathered all rights-of-entry required for the smoke testing in the Skyway project area.

2.2 FLOW MONITORING

2.2.1 Techniques and Requirements for Evaluation

New flow monitoring was performed to acquire current data on I/I flows in the project mini-basins, at selected downstream CSI project locations, and at selected control mini-basins where no I/I reduction is being considered. The flow monitoring results are to be used as follows:

- Current flow estimates for each mini-basin can be used to quantify and confirm the I/I reduction that could be achieved by projects in each mini-basin.
- Evaluation of how quickly flows increase after the start of rainfall events helps to identify whether I/I is entering the sewer system primarily through shallow side sewers and laterals or through deeper main sewers.
- Current flow estimates for each mini-basin serve as a “before-project” baseline value for comparison to “post-project” monitoring, in order to assess the effectiveness of implemented projects.
- Flow monitoring of the control mini-basins allows an assessment of the change in I/I over time for mini-basins where no I/I reduction project was implemented.

Monitoring was conducted from September 2007 through June 2008 using 23 flow meters throughout the four project areas. Meters were placed at the downstream outlet of mini-basins to measure mini-basin outflows, and, where necessary, at upstream locations to measure flows into the mini-basin. Proposed monitoring locations were physically inspected prior to the installation of the flow meters to assess ease of access, safety, availability of a telemetry connection, and physical and hydraulic suitability. Accessible

sites with suitable flow characteristics that would produce high-quality flow data were selected. County field crews installed and field-verified each flow monitor.

The monitors measured sewer flow depth and velocity and calculated flow rate from the measured parameters. Details on the monitor installation and data collection and analysis methods are provided in *Initial I/I Projects Flow Monitoring Report* (King County, August 2008). Results of the monitoring were used by King County's modeling group to produce the estimates of I/I for each mini-basin used in this project.

2.2.2 Eastgate Flow Monitoring Results

Seven monitoring locations were established to evaluate flows for the five Eastgate mini-basins, one control mini-basin, and the location of the downstream Eastgate Storage CSI project. The Eastgate flow monitoring locations are shown in Figure 2-1 and described in Table 2-1.

TABLE 2-1.
EASTGATE PROJECT AREA FLOW MONITORING LOCATIONS

Monitor ID	Monitoring Location	Flows Monitored	Reporting Period
BEL011	Middle of SE 44th Court	Mini-Basin BEL011 outflows; Mini-Basin BEL012 inflows	9/1/2007 – 6/13/2008
BEL012	North side of 37th Road, along chain link fence facing I-90 in field	Mini-Basin BEL012 outflows	9/1/2007 – 6/13/2008
BEL014	4800 SE 152nd Place	Mini-Basin BEL014 outflows	9/1/2007 – 6/10/2008
BEL016	In the middle of intersection of 150th Avenue SE and SE 43rd Street	Control Mini-Basin BEL016 outflows	9/1/2007 – 6/13/2008
BEL031	In street SE 46th, opposite 14503	Mini-Basin BEL031 outflows; Mini-Basin BEL032 inflows	9/1/2007 – 6/13/2008
BEL032	In entrance driveway of East Gate Park	Mini-Basin BEL032 outflows	9/1/2007 – 6/13/2008
BEL081	In parking lot behind 15220 37th SE (76 gas station) by fence closest to I-90	Eastgate Storage CSI project inflows	9/1/2007 – 6/13/2008

The monitoring results were integrated into the existing county hydraulic models to provide a comparison between the latest monitoring results and previous model predictions. The results compared favorably in all five Eastgate mini-basins. An example of this, for Mini-Basin BEL011, is shown in Figure 2-2, which compares the measured flow in the mini-basin to the flow rate predicted by the model for the same measured rainfall event. The two lines track very close to one another, indicating that previous assumptions for I/I levels in the mini-basin are valid.

The flow monitoring results for all five mini-basins continue to exhibit a rapid response to rainfall, indicating that side sewers, sewer laterals and inflow sources are the most likely contributors to I/I.

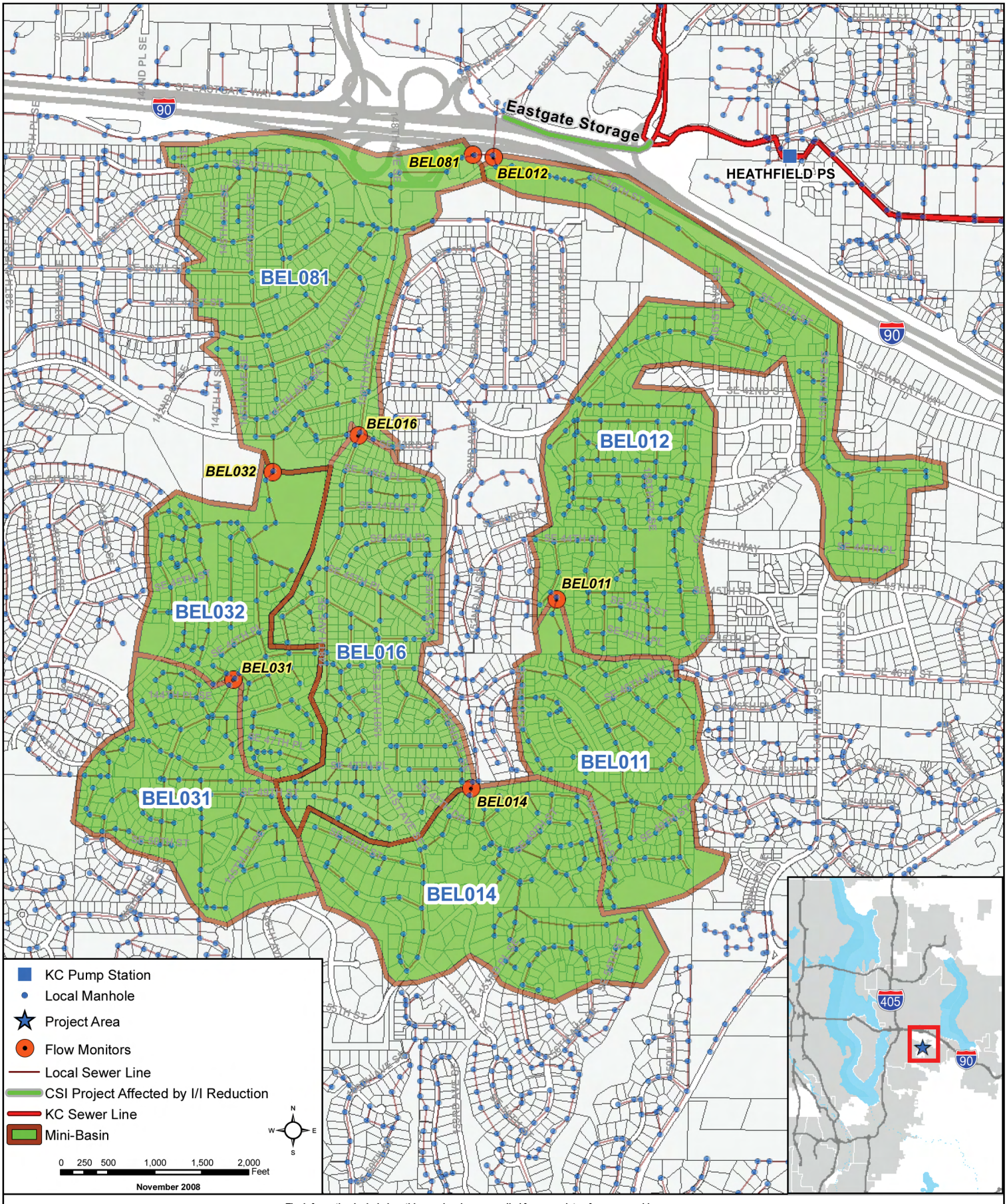

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Figure 2 - 1
Eastgate Project Area
Flow Monitor Locations
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

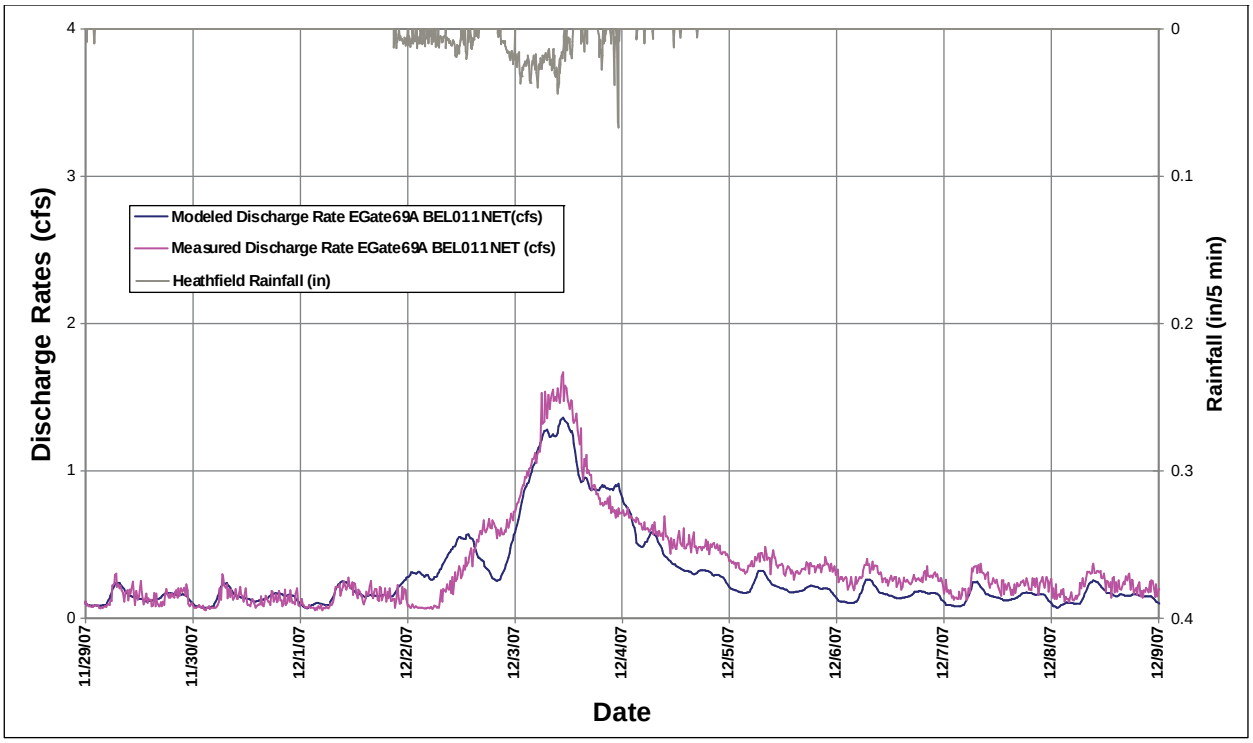


Figure 2-2. Modeled and Measured Flow Comparison for Mini-Basin BEL011

2.2.3 Issaquah Flow Monitoring Results

Six monitoring locations were established to evaluate flows for the two Issaquah mini-basins, one control mini-basin, and the location of the downstream Issaquah Storage CSI project. The Issaquah flow monitoring locations are shown in Figure 2-3 and described in Table 2-2.

TABLE 2-2.
ISSAQUAH PROJECT AREA FLOW MONITORING LOCATIONS

Monitor ID	Monitoring Location	Flows Monitored	Reporting Period
ISS002	Intersection of Sunrise Place SW and Wildwood Blvd	Mini-Basin ISS003 inflows	9/1/2007 – 6/13/2008
ISS003	Across from 40 Newport Way close to Newport Way and Sunset Way intersection	Mini-Basin ISS003 outflows; Mini-Basin ISS004 inflows	9/1/2007 – 6/13/2008
ISS004	595 Newport Way NW (Morgan Manor)	Mini-Basin ISS004 outflows	9/1/2007 – 6/13/2008
ISS014	Intersection of Mountain Park and Mt Everest Lane SW	Mini-Basin ISS004 inflows	9/1/2007 – 6/13/2008
ISSAQ038	1500 19th Avenue NW in front of Bldg #10	Control Mini-Basin ISSAQ038 outflows	9/1/2007 – 6/13/2008
ISSCK39A	1875 NW Poplar Way	Issaquah Storage CSI Project inflows	9/1/2007 – 6/13/2008

The flow monitoring results compared favorably with previous model data for Mini-Basin ISS003, as shown in Figure 2-4. The results for Mini-Basin ISS004 are less conclusive because the flow monitor was not functioning properly during the peak of the storm event. Figure 2-5 compares the flow monitoring results and predicted model flows for Mini-Basin ISS004. The flow monitoring results for Mini-Basin ISS003 continue to exhibit a rapid response to rainfall, indicating potential defects in side sewers, sewer laterals and inflow sources.

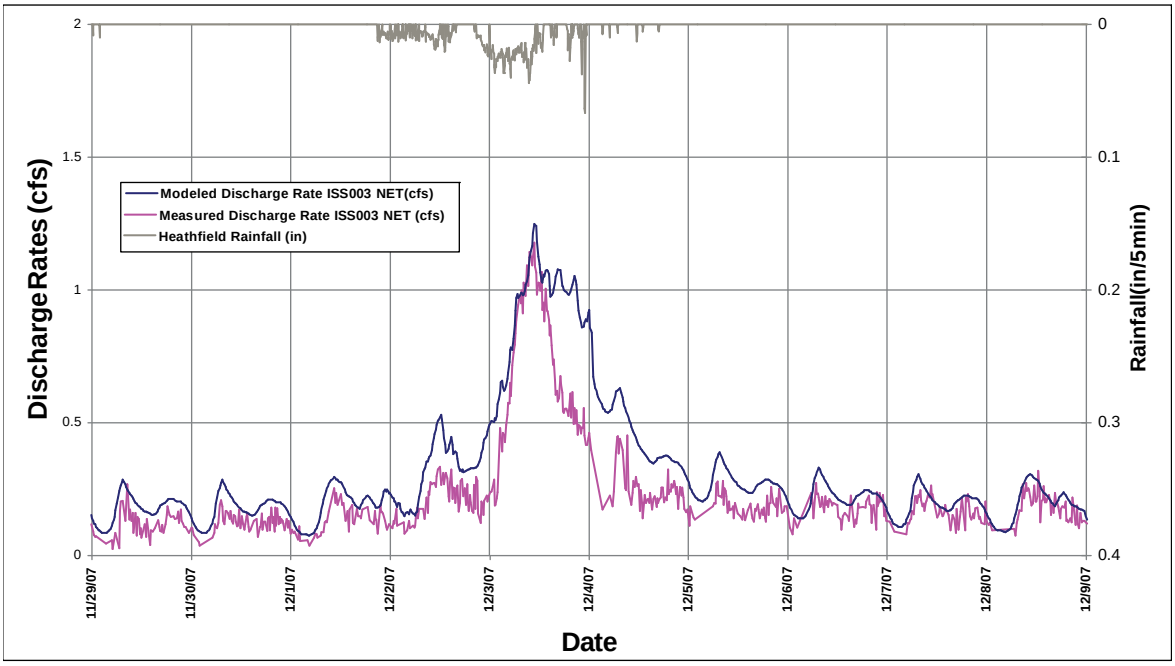


Figure 2-4. Modeled and Measured Flow Comparison for Mini-Basin ISS003

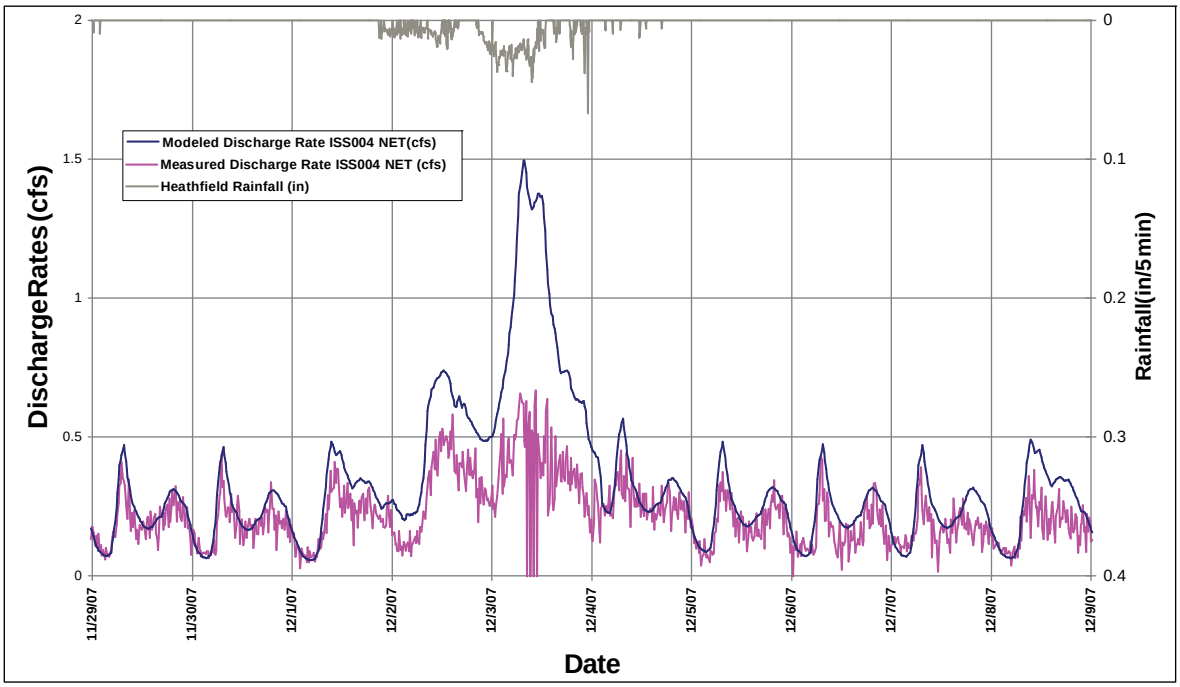
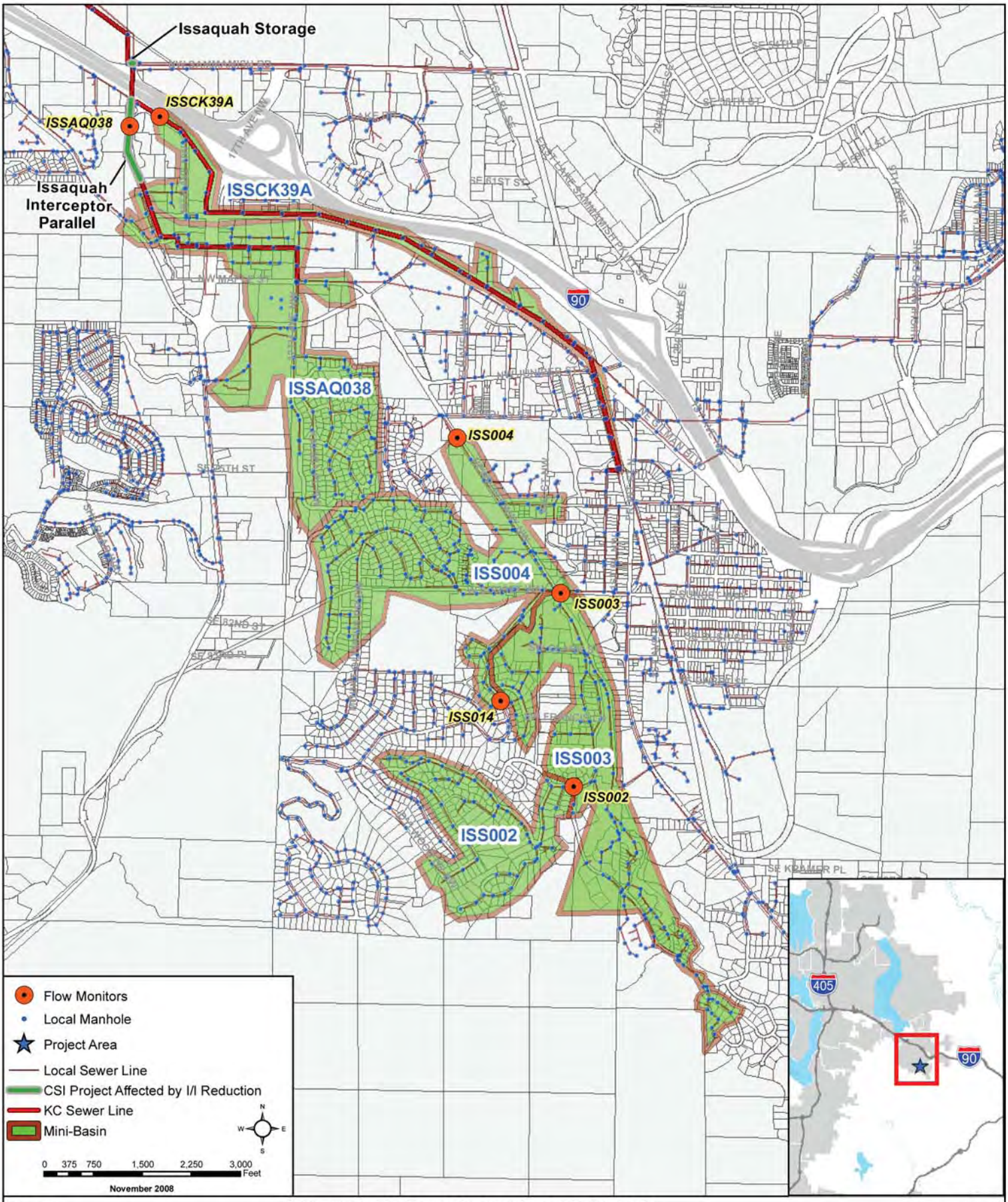


Figure 2-5. Modeled and Measured Flow Comparison for Mini-Basin ISS004



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Data Source: King County

Figure 2 - 3
Issaquah Project Area
Flow Monitor Locations
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

2.2.4 Renton Flow Monitoring Results

Four monitoring locations were established to evaluate flows for the one Renton mini-basin and the location of the downstream South Renton Interceptor CSI project. The Renton flow monitoring locations are shown in Figure 2-6 and described in Table 2-3.

The results of the flow monitoring do not show the same levels of peak flow and I/I predicted by previous modeling. Figure 2-7 shows a relatively modest peak flow during the peak of the December 3, 2007 storm event. The model predicted much higher peak flows for the event. One possible explanation for the discrepancy is that a previous inflow source in the mini-basin is no longer present. This possibility is discussed in Section 2.6.6.

TABLE 2-3.
RENTON PROJECT AREA FLOW MONITORING LOCATIONS

Monitor ID	Monitoring Location	Flows Monitored	Reporting Period
RNT005	In the back of car lot of Yonker Nissan 5 feet from fence next to light post	Mini-Basin RNT005 outflows; South Renton Interceptor CSI Project inflows	9/1/2007 – 6/13/2008
RNT006	3431 Shattuck Avenue South	Mini-Basin RNT005 inflows	9/1/2007 – 6/13/2008
SOO021	Intersection of 98 Ave S and S 178th Street	Mini-Basin RNT005 inflows	9/1/2007 – 6/13/2008
SRENT21	404 South 37th Street across street on edge of field	Mini-Basin RNT005 inflows (installed to verify SOO021)	1/10/2008 – 6/13/2008

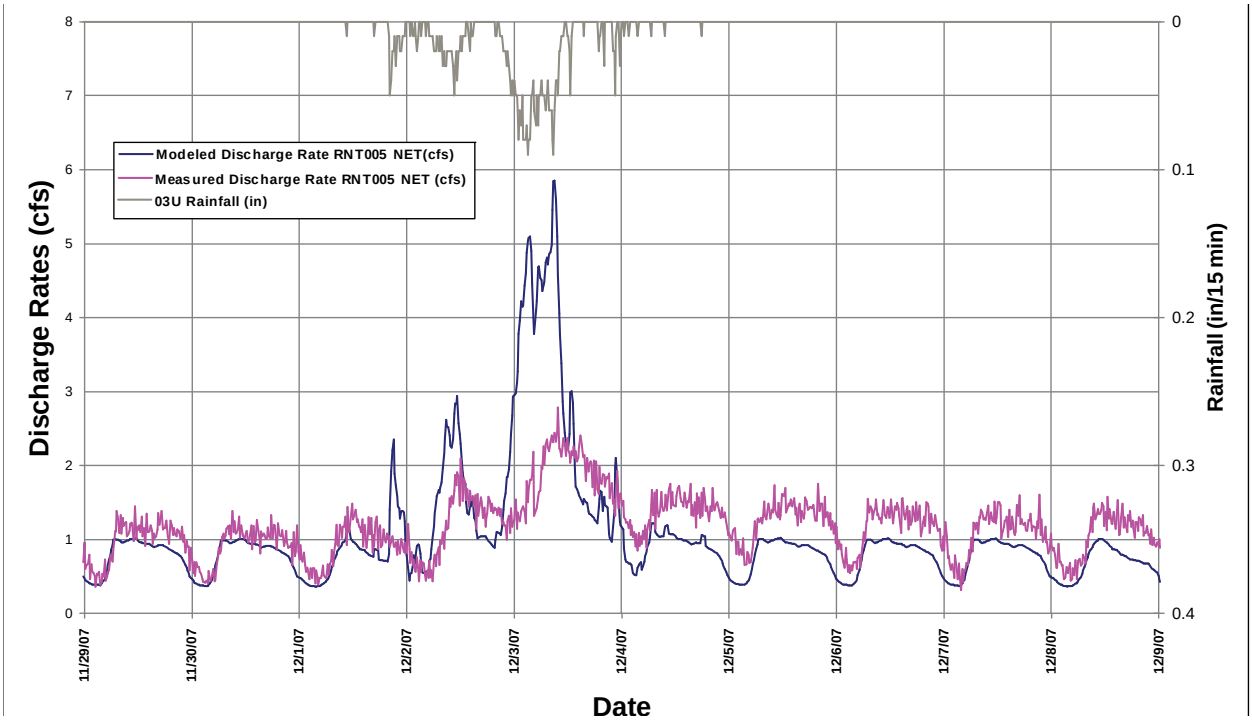


Figure 2-7. Modeled and Measured Flow Comparison for Mini-Basin RNT005

2.2.5 Skyway Flow Monitoring Results

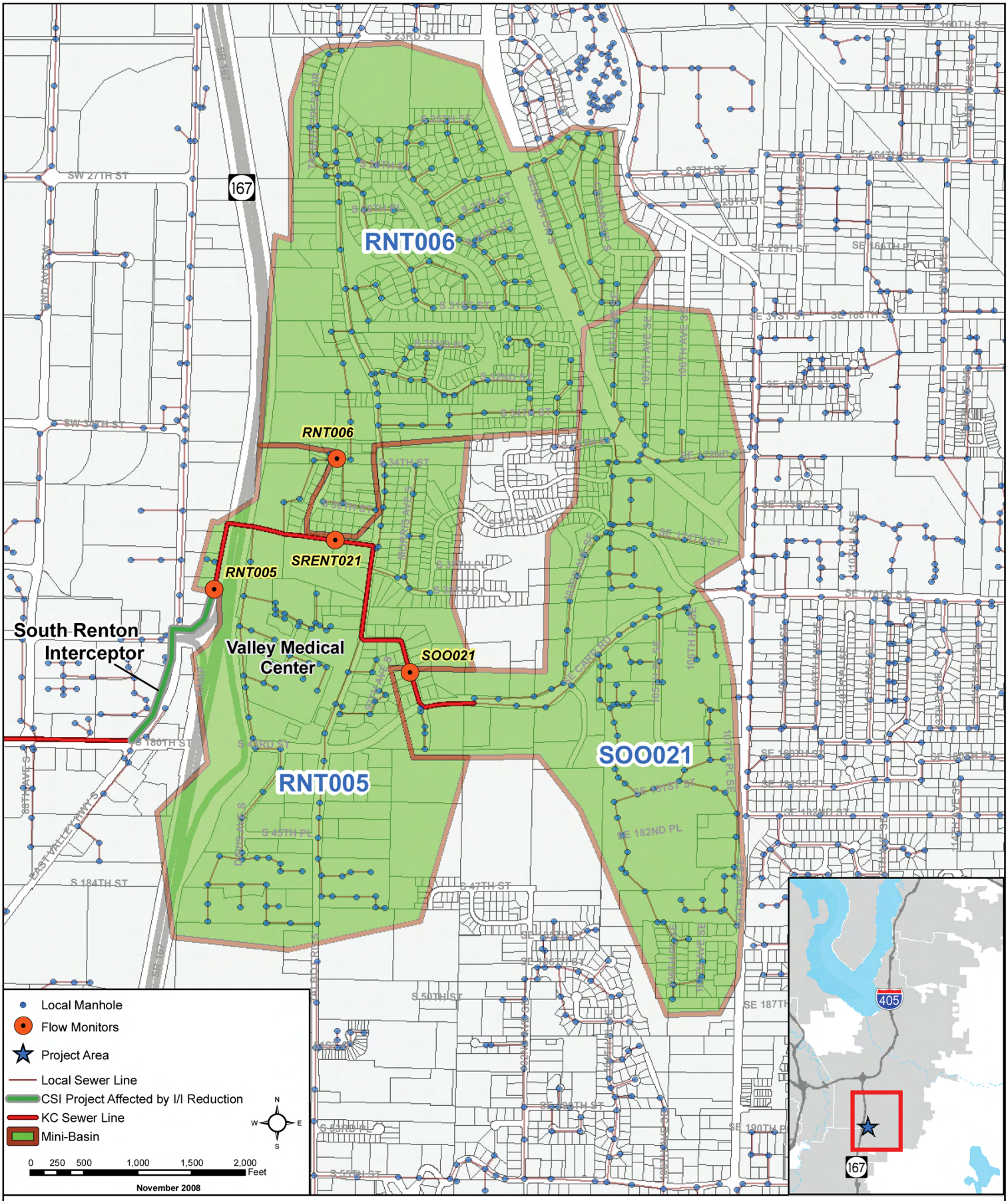
Six monitoring locations were established to evaluate flows for the three Skyway mini-basins, one control mini-basin, and the location of the downstream Bryn Mawr Storage CSI project. The Skyway flow monitoring locations are shown in Figure 2-8 and described in Table 2-4.

Flow monitoring results compared favorably with predicted model results for Mini-Basins BLS001 and BLS003, as shown in Figures 2-9 and 2-10. Monitoring in Mini-Basin BLS002 shows high levels of I/I remain in the mini-basin. The monitoring results do not appear to compare favorably with the predicted model results in this mini-basin; this is because the model did not include the I/I reductions that were achieved following the pilot project construction. When the approximately 3.9 cubic feet per second (cfs) peak I/I reduction attained in the mini-basin is factored into the predicted model results, the comparative results are more favorable. Figure 2-11 compares flow monitoring results and predicted model flows for Mini-Basin BLS002.

The flow monitoring results for all three mini-basins exhibit a rapid response to rainfall, indicating potential defects in side sewers, sewer laterals and inflow sources.

TABLE 2-4.
SKYWAY PROJECT AREA FLOW MONITORING LOCATIONS

Monitor ID	Monitoring Location	Flows Monitored	Reporting Period
BLS001	11900 87th Ave. South	Mini-Basin BLS001 outflows	9/1/2007 – 6/13/2008
BLS002	11015 Rainer Ave. S. In side walk in front of house	Mini-Basin BLS002 outflows	11/10/2007 – 6/5/2008
BLS003	8421 S. 114th St.	Mini-Basin BLS003 outflows	9/1/2007 – 6/13/2008
BLS003A	8225 S. 116th St. in East bound lane	Mini-Basin BLS003 inflows (installed to avoid adding an upstream subtraction meter)	9/6/2007 – 6/13/2008
BLS006	8050 S. 114th St.	Control Mini-Basin BLS006 outflows; Mini-Basin BLS003 inflows	9/17/2007 – 6/13/2008
BLS43B	11416 Rainer Ave. S., upstream of flow meter vault (west of siphon inlet structure)	Bryn Mawr Storage CSI Project inflows	9/1/2007 – 6/13/2008



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Data Source: King County

Figure 2 - 6
Renton Project Area
Flow Monitor Locations
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

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Data Source: King County

Figure 2 - 8
Skyway Project Area
Flow Monitor Locations
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

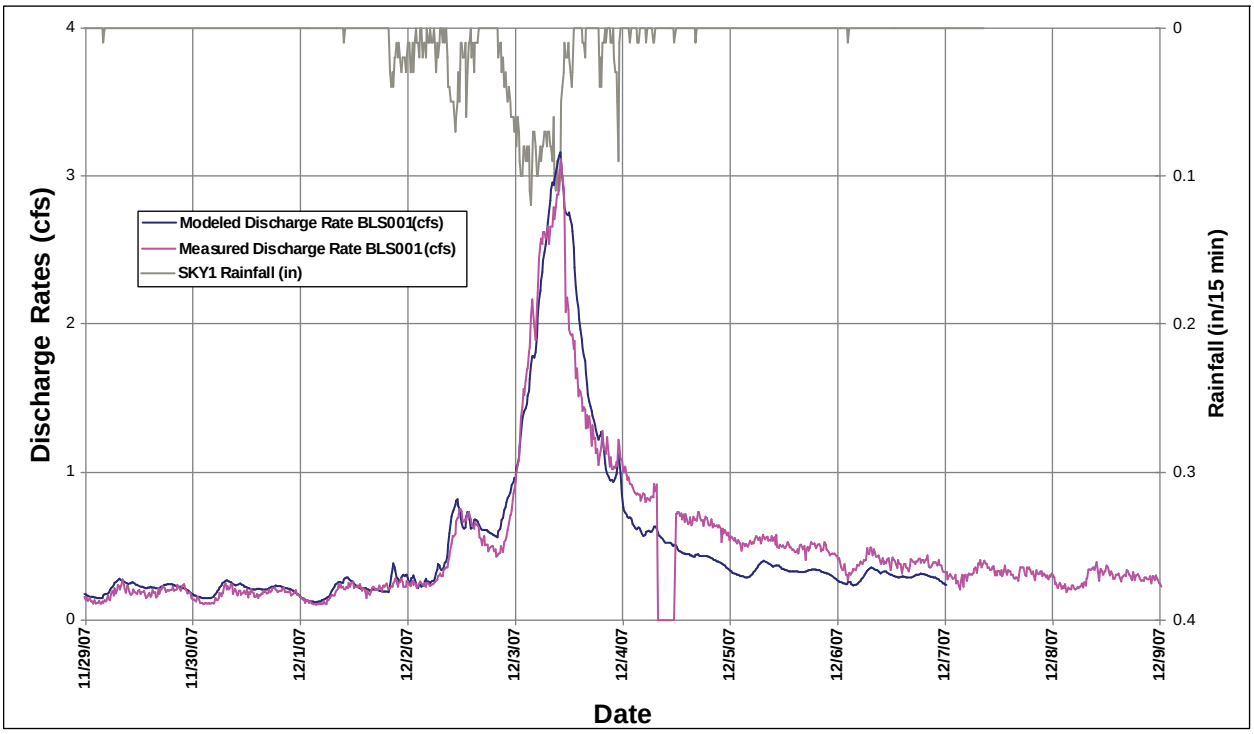

Figure 2-9. Modeled and Measured Flow Comparison for Mini-Basin BLS001

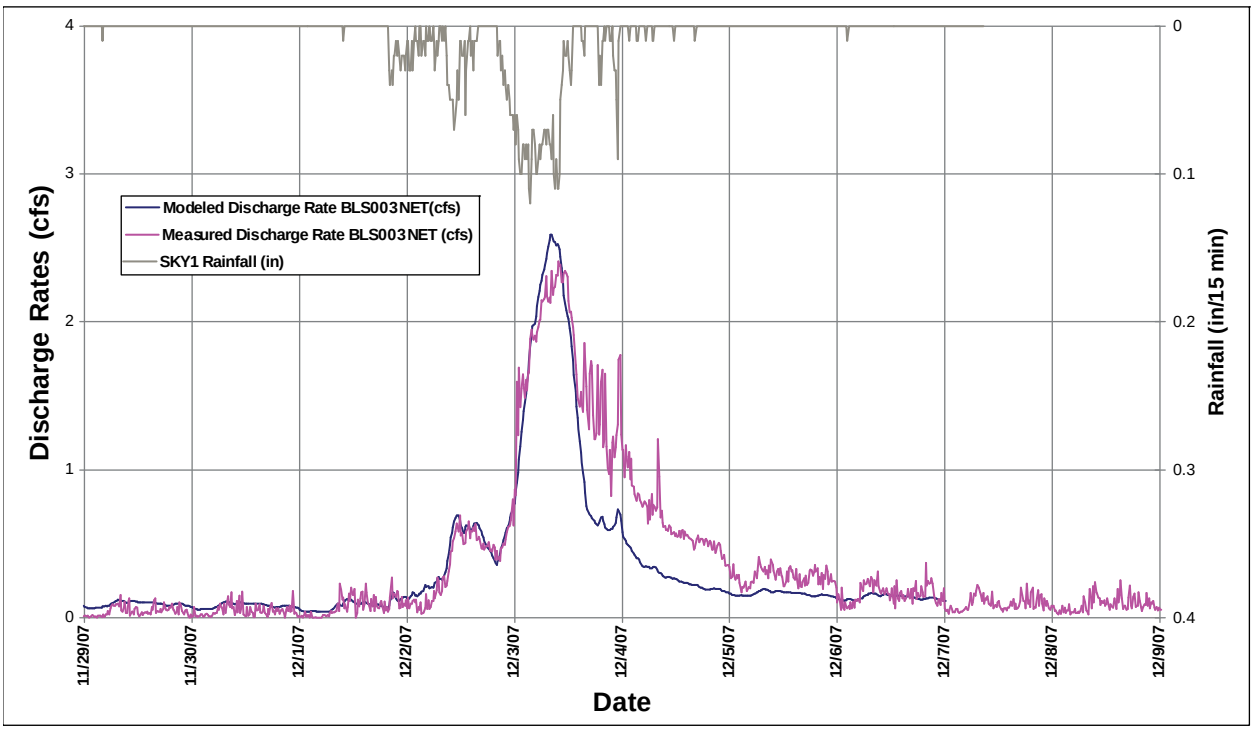

Figure 2-10. Modeled and Measured Flow Comparison for Mini-Basin BLS003

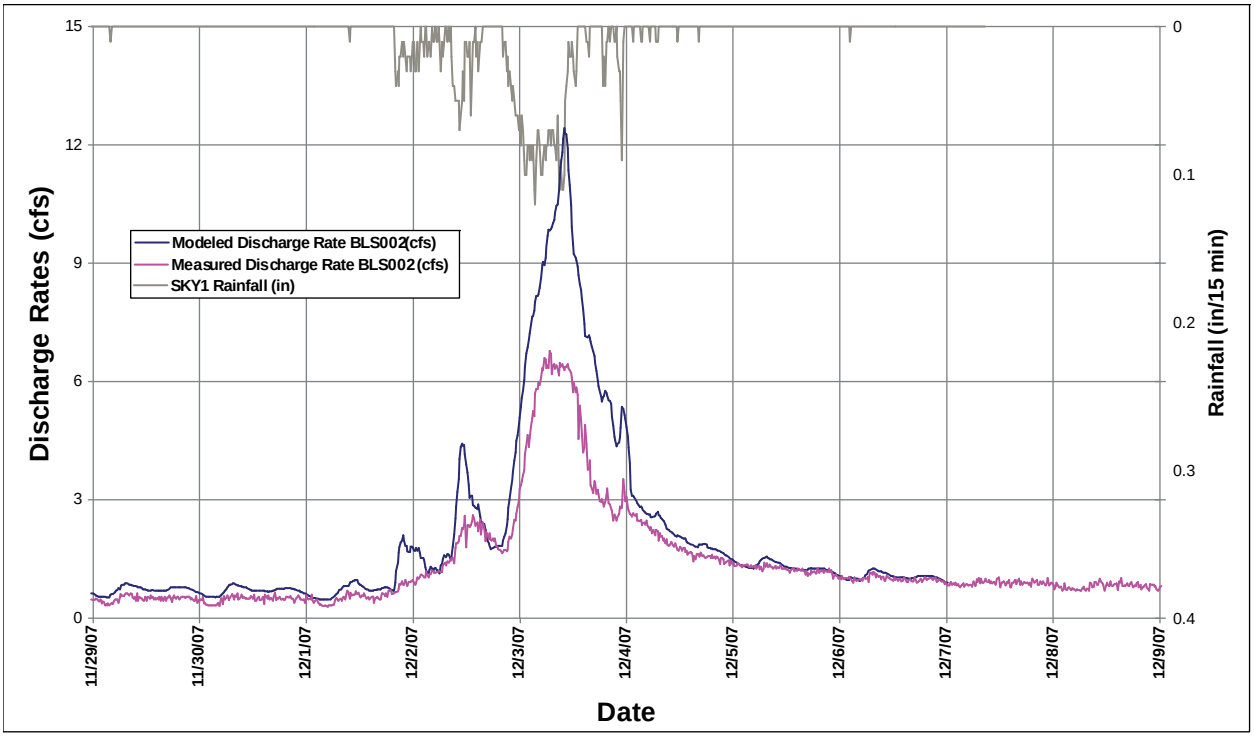

Figure 2-11. Modeled and Measured Flow Comparison for Mini-Basin BLS002

2.3 CCTV INSPECTION

2.3.1 Techniques and Requirements for Evaluation

Closed circuit television (CCTV) inspections use remotely operated video cameras to assess the condition of an existing main sewer, side sewer or lateral, and to identify potential sources of I/I. CCTV inspection provides a means to identify illegal connections, bad connections and joints, and structural and operational defects in the sewer.

CCTV inspection for this project consisted of running a remotely operated camera through sewer mains and recording the results on DVDs for review by design engineers. The cameras also had the ability to launch a second cable mounted camera out of the sewer main and into a sewer lateral and side sewer. Field work required to facilitate the inspection, such as hydraulic cleaning, root removal and debris removal, was performed before the inspection began.

CCTV work is best performed during a rainfall event after groundwater levels have begun to rise, allowing visual confirmation of specific I/I entry points. A small amount of the CCTV work for this project was completed during periods of high precipitation, but much of it took place during dry weather, so it was difficult to pinpoint specific locations where I/I is entering the system.

2.3.2 Eastgate CCTV Analysis

Scope of Investigation

The extent of the CCTV analysis in the Eastgate project area was as follows:

- Mini-Basin BEL011—Approximately 12,000 feet of 8-inch-diameter sewer mains and 4,500 feet of 6-inch-diameter laterals and side sewers were inspected. A total of 119 individual laterals and side sewers were inspected in the mini-basin.
- Mini-Basin BEL012—Approximately 26,000 feet of 8-, 12- and 15-inch-diameter sewer mains and 8,500 feet of 6-inch-diameter laterals and side sewers were inspected. A total of 223 individual laterals and side sewers were inspected in the mini-basin.
- Mini-Basin BEL014—Approximately 27,500 feet of 8-inch-diameter sewer mains and 7,200 feet 6-inch-diameter laterals and side sewers were inspected. A total of 192 individual laterals and side sewers were inspected in the mini-basin.
- Mini-Basin BEL031—Approximately 14,500 feet of 8-inch-diameter sewer mains and 6,000 feet of 6-inch-diameter laterals and side sewers were inspected. A total of 154 individual laterals and side sewers were inspected in the mini-basin.
- Mini-Basin BEL032—Approximately 16,000 feet of 8-inch-diameter sewer mains and 5,500 feet of 4-, 6-inch-diameter laterals and side sewers were inspected. A total of 181 individual laterals and side sewers were inspected in the mini-basin.

General System Age and Materials

Most of the sewer system serving the Eastgate project area was constructed in the 1970s; the system was built in 1970 in Mini-Basin BEL031, in 1976 in Mini-Basins BEL031 and BEL011, and in 1979 in Mini-Basin BEL012. The only exception is Mini-Basin BEL014, where the system was built in 1980.

Sewer mains in the Eastgate project area consist primarily of cement concrete pipe. The vast majority of side sewer and lateral pipe materials also are of cement concrete pipe, although PVC side sewers are used in isolated pockets. PVC laterals and side sewers are installed on less than 10 percent of the total number of properties in most of the project area. The exception is Mini-Basin BEL014, which has more extensive areas of both PVC mains and PVC side sewers and laterals.

Deficiencies and Observed I/I Sources

Deficiencies identified through CCTV inspection did not include many structural problems. A few offset or separated joints in the mains were observed, but these were infrequent and indicated no larger patterns for the overall system.

A generally consistent deficiency was observed with regards to the joint conditions in the laterals and side sewers. These sewers were largely constructed of cement concrete pipe with ungasketed joints, which was typical for the era of construction and the size of these lines. This type of joint construction is extremely susceptible to infiltration as well as root intrusion and loss of bedding and support material at the joint. Few structural defects were noted, but there were many instances of root intrusion and separated joints.

2.3.3 Issaquah CCTV Analysis

Scope of Investigation

The extent of the CCTV analysis in the Issaquah project area was as follows:

- Mini-Basin ISS003— Approximately 16,000 feet of 8-inch-diameter sewer mains and 1,200 feet of 6-inch-diameter laterals and side sewers were inspected. A total of 51 individual laterals and side sewers were inspected in the mini-basin.

- Mini-Basin ISS004— Approximately 27,000 feet of 8-, 12- and 15-inch-diameter sewer mains and 2,000 feet of 6-inch-diameter laterals and side sewers were inspected. A total of 177 individual laterals and side sewers were inspected in the mini-basin.

General System Age and Materials

The sewer system in the Issaquah project area consists of a wide variety of pipe material, such as concrete segments unbolted (CSU), PVC, ductile iron (DI), asbestos cement (AC), polyethylene (PE) and some other unidentified pipe materials. Most of the single-family neighborhoods in the project area were built in early 1960s and 1970s with concrete pipe mains, laterals and side sewers. Newer construction of both single-family and multi-family areas generally used PVC pipe for mains, laterals and side sewers.

Of the inspected sewer mains in Mini-Basin ISS003, 52 percent of pipes were CSU pipes, 41 percent were PVC pipes, 4 percent were DI pipe, and the remainder were unidentified materials. Of the lateral sewers inspected, 20 percent were PVC and 80 percent were concrete.

Of the inspected sewer mains in Mini-Basin ISS004, 43 percent of pipes were CSU pipes, 50 percent were PVC pipes, and the remainder were varying materials. Of the lateral sewers inspected, 70 percent were PVC and the rest were concrete or AC pipe.

Deficiencies and Observed I/I sources

Most of the main lines in Mini-Basin ISS003 have moderate to few defects, with the CSU pipes having the majority of the defects. For most of the laterals, the inspection was not completed due to frequent changes in pipe size and/or orientation. Still, about 50 percent of the concrete laterals and 50 percent of the PVC laterals were found to have structural defects in this mini-basin.

The CSU pipes in Mini-Basin ISS004 have more defects than the pipes made of PVC and other materials. About 60 percent of the concrete laterals and 45 percent of the PVC laterals were found to have structural defects in this mini-basin.

CCTV videos indicated that few of the main lines and laterals in the Issaquah project area had evidence of infiltration (deposits and encrustation on the walls of the pipe, and fine to medium root intrusions in the pipe). This indicates that this project area is a low to medium source of slow-response infiltration.

2.3.4 Renton CCTV Analysis

Scope of Investigation

CCTV inspection of the Renton project area included mains on the west side of SR-167, a sewer main under SR-167, mains west of the Valley Medical Center and north of South 43rd Street, the three mains serving the hospital, and one main in the South 37th Street alignment. The focus of the inspection was to identify pipe defects and I/I in the wetland area northwest of the hospital. Roughly 5,000 feet of 8-through, 24-inch-diameter sewer mains were inspected in Mini-Basin RNT005. No laterals or side sewers were inspected in this basin.

General System Age and Materials

Most of the single-family development in the Renton project area is served by concrete pipe installed in the 1960s and 1970s. Most of the commercial and multi-family development is served by concrete pipe installed in the 1980s and 1990s, with some PVC pipe in areas of newer construction.

Deficiencies and Observed I/I sources

Overall, the inspected pipes are in generally good condition. There were some signs of infiltration at pipe joints, indicated by light root intrusion and encrustation. Small amounts of infiltration were observed in a few locations. Some minor corrosion problems were noted, but none that indicated structural problems. Indicators of potential future problems were the large number of sags in the mains and a few misaligned joints. One pipe has already been repaired.

The pipeline in the wetland was in the worst condition of those inspected. These pipes are shallow (5 to 6 feet deep) and have large cottonwood trees growing near and on top of them; a few of the trees have fallen over. Several of the manholes in this area are buried, likely because of the heavy growth of grass and shrubs, which trap soils being transported by moving water and contribute material through their own death and decay that can help bury the manholes.

2.3.5 Skyway CCTV Analysis

Scope of Investigation

The extent of the CCTV analysis in the Skyway project area was as follows:

- Mini-Basin BLS001—Approximately 12,000 feet of 6-, 8- and 12-inch-diameter sewer mains and 3,100 feet of 6-inch-diameter laterals and side sewers were inspected. A total of 88 individual laterals and side sewers were inspected in the mini-basin.
- Mini-Basin BLS002—This mini-basin was added to the project area after the study had begun, so CCTV inspection was conducted on a limited portion of the basin. Approximately 2,200 feet of 8-inch-diameter sewer mains and 400 feet of 6-inch-diameter laterals and side sewers were inspected. A total of 12 individual laterals and side sewers were inspected in this mini-basin.
- Mini-Basin BLS003— Approximately 8,500 feet of 8-inch-diameter sewer mains and 1,800 feet of 4-, and 6-,inch-diameter laterals and side sewers were inspected. A total of 41 individual laterals and side sewers were inspected in the mini-basin..

General System Age and Materials

Most of the sewer system in the Skyway project area was built during the late 1950s and early 1960s. The sewer system consists of a wide variety of pipe material, such as CSU, PVC, clay tile (CT) pipe and some other unidentified pipe materials. The materials observed in the CCTV analysis were as follows:

- Mini-Basin BLS001—Of the inspected sewer mains, 79 percent were CSU pipe, 19 percent were PVC (both 8-inch and 12-inch), and 2 percent were CT pipe. Of the lateral sewers inspected, 67 percent were concrete pipe and the remainder were PVC.
- Mini-Basin BLS002—All the main lines and laterals inspected were CSU pipe.
- Mini-Basin BLS003—Of the inspected sewer mains, 94 percent were CSU pipe and the remainder were PVC. Of the lateral sewers inspected, 88 percent were CSU pipe and the remainder were PVC.

Deficiencies and Observed I/I sources

A major portion of the CSU mains and CT mains in Mini-Basin BLS001 have substantial defects. The inspection videos showed structural defects to the main lines such as exposed aggregate and encrustation. The PVC mains inspected showed no visible infiltration. Approximately 61 percent of the CSU laterals

and 22 percent of the PVC laterals inspected had defects. Based on the CCTV inspection results, the main lines and laterals in this mini-basin are moderately to severely defective.

CCTV inspection videos in Mini-Basin BLS002 indicated defects including broken pipes, cracks, exposed aggregates, sags in the pipe and encrustation around the joints of the pipe. Based on the number of general visual observations, pipe defect observations and infiltration observations, the main lines in this mini-basin are moderately to severely defective and require rehabilitation. About 75 percent of laterals inspected were found defective in this mini-basin. Most of the main lines and laterals in this mini-basin have a high number of defects and require rehabilitation.

The CSU mains in Mini-Basin BLS003 have more defects than the PVC main lines. CCTV videos indicated that the defects include rough pipe surface, stains on the pipe wall, exposed aggregates and encrustation around the pipe joints. The PVC mains inspected showed no visible infiltration. Approximately 40 percent of the CSU laterals and 25 percent of the PVC laterals inspected were found defective in this mini-basin.

2.4 SMOKE TESTING

2.4.1 Techniques and Requirements for Evaluation

Smoke testing is done by blowing low-pressure, non-toxic, non-staining vapor or smoke into a section of sewer line through manholes, allowing the smoke to flow through the system and escape at any exposed surface connection to the system. Smoke testing is used to identify two types of I/I:

- Direct inflow connections—Direct connections for surface water to enter the sanitary sewer system typically include pipes from roof drains, cross connections from storm sewer systems, open cleanouts, and holes in a sewer pipe that are exposed to the ground surface. These are identified by smoke rising from an identifiable source during the test, such as a roof downspout or a cleanout.
- Sewer system defects (infiltration)—Smoke leaks rising from the ground rather than from an observable structure generally indicate defects in sewer mains, laterals, side sewers and manholes. These smoke sources may indicate the need for rehabilitation if the observed leaks are in locations where surface water runoff flows over or near the manholes. Smoke testing only indicates these types of problems above the flow line in the pipe; the smoke does not indicate holes and cracks below the flow line and it cannot indicate problems for broken pipes that are buried too deep in the ground.

In the evaluation of I/I reduction measures, it is assumed that direct inflow connections can be disconnected relatively easily and inexpensively to reduce I/I. In order to estimate the reduction benefit of these direct disconnects, the quantity of flow entering the sewer system at sources where smoke tests indicated direct inflow connections was estimated based on the following equation:

$$Q = C * i * A * (448.83/43{,}560)$$

Where

Q = Peak flow in gallons per minute (gpm).

C = Runoff coefficient; a runoff coefficient of 0.9 was used for runoff from highly impervious areas such as roofs and pavement, and a runoff coefficient of 0.35 was used for less impervious areas such as lawns.

i = Peak-hour rainfall intensity in inches per hour; a peak-hour rainfall intensity of 0.7 inches per hour was assumed.

A = Tributary area in square feet; tributary areas were approximated from the smoke testing videos.

(448.83/43,560) = Is a factor to convert area from acres to square feet and flow from cubic feet per second to gallons per minute.

2.4.2 Smoke Test Results

Smoke testing showed a significant number of I/I sources in the Eastgate and Skyway project areas, but few in the Issaquah and Renton project areas:

- In the Eastgate mini-basins, 33 instances of smoke leakage were observed, of which 15 indicated direct inflow connections.
- In the Skyway mini-basins, 127 instances of smoke leakage were observed, of which 53 indicated direct inflow connections. A comparison between the CCTV inspection videos and the smoke testing videos for Mini-Basins BLS001 and BLS003 indicated broken laterals at the point where smoke was generated on the ground, suggesting that these mini-basins have sources of infiltration. No correlation was obtained between the smoke testing data and the CCTV inspections for Mini-Basin BLS002 as CCTV was performed on few laterals in this mini-basin.
- Only three leaks were observed in Issaquah, all of which indicated direct inflow.
- Smoke testing was not performed in the Renton project area near Valley Medical Center due to concerns of smoke getting into the hospital buildings. Smoke testing in other portions of the Renton project area yielded seven hits—four at sewer line cleanouts, two around the lids of manholes, and one in a side sewer that was temporarily cut during construction at the hospital. None were in areas where inflow would be considered a problem, and no inflow quantity estimates were made.

Figures 2-12 and 2-13 show the distribution of observed smoke leaks in the Eastgate and Skyway project areas, respectively. Table 2-5 summarizes the smoke test results for all four project areas.

2.5 ADDITIONAL RENTON PROJECT AREA INVESTIGATIONS

2.5.1 Dye Testing

Dye testing was performed in lieu of smoke testing to evaluate the system around Valley Medical Center in the Renton project area. The dye test consisted of placing a fluorescent dye into the storm drainage system around the hospital. The dye was flushed down catch basins, drains and downspouts around the building and parking garages. If the dye showed up in the sanitary sewer, this would indicate a connection between the storm drainage system and the sanitary sewer. The dye testing did not indicate any such connections.

2.5.2 Field Visit

A field visit to the Renton project area the day after the heavy December 3, 2007 storm investigated inflow problems in the wetland west of Valley Medical Center (see Figure 2-14). Ten manholes were investigated. Several had lids at ground level, and some were underwater the day of the field visit or showed evidence of having been underwater within the previous day. It was assumed that large amounts of inflow had entered the sewer system through the pick-holes on submerged manhole lids. One manhole was buried about 18 inches below the ground surface; another is almost within the channel of a drainage ditch.

TABLE 2-5.
SMOKE TEST RESULTS

Mini-Basin	Total Observed Smoke Leaks[a]	Leaks Indicating Direct Inflow Connection	Estimated Inflow from Direct Connections (mgd)
Eastgate Project Area			
BEL011	4	4	0.049
BEL012	9	3	0.030
BEL014	7	5	0.043
BEL031	6	2	0.063
BEL032	7	1	0.019
Issaquah Project Area			
ISS003	3	3	0.013
ISS004	0	0	0
Renton Project Area			
RNT005	7	7	n/a[b]
Skyway Project Area			
BLS001	34	13	0.0745
BLS002	72	32	0.2537
BLS003	21	8	0.0608

a. Total observed smoke leaks include direct inflow connections and sewer system defects, as defined in Section 2.4.1.
b. Inflow volume not calculated for Mini-Basin RNT005 because none of the observed smoke leaks were in areas where inflow would be considered a problem.

2.6 SSES RESULTS AND CONCLUSIONS

The findings of the SSES, together with the results of King County's 2003 I/I pilot project, established some basic understandings to be used in developing and evaluating initial I/I reduction alternatives. Some of the findings relate to all project areas investigated; others are specific to individual project areas or mini-basins. The following sections describe the essential results and conclusions of the SSES.

2.6.1 Spreadsheet Summary of Findings

A "pipe summary" spreadsheet was created to summarize all the data on sewer mains, laterals and side sewers obtained during the SSES work. Each row of the spreadsheet presents the data for a single mainline run investigated in the SSES work, including data on the laterals and side sewers discharging to that section of sewer main. This spreadsheet provides a single location for the key information obtained during the SSES and helps to indicate patterns in the collected data. For example, it contains a column that indicates the number of laterals with defects along each sewer main, and a review of this column for Eastgate Mini-Basin BEL011 shows a fairly uniform distribution across the mini-basin, indicating that there is no localized area of deficiency in the system.

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Data Source: King County

Figure 2 -12
Eastgate Project Area
Smoke Test Results
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

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Wastewater Treatment Division

File Name: dnrp1:\\wtd\projects\II_Initial_Projec\project \TechReport\Skyway_ProjectArea_SmokeTest.mxd - peter keum
Data Source: King County

Figure 2 - 13
Skyway Project Area
Smoking Test Results
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: dnrp1:\\wtd\projects\II_Initial_Projec\project \TechReport\Renton_wetlandSites.mxd - peter keum
Data Source: King County

Figure 2 - 14
Wetland Site of Renton Project Area Field Visit
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

2.6.2 Focus on Laterals and Side Sewers

The pilot projects, the SSES and the flow monitoring results generally confirmed the conventional wisdom that laterals and side sewers represent the major source of I/I in a system. In instances where sewer mains are a considerable source of I/I, CCTV work often revealed clear evidence of this in the form of extensive and obvious structural and joint problems. Although CCTV inspections generally cannot directly identify I/I sources in side sewers and laterals, due to the camera's limited access to these sewers and to the physical characteristics of the side piping, CCTV inspection can identify side sewers and laterals that are made of concrete and clay piping, which are typically susceptible to cracks and leaks that lead to I/I. The SSES and the pilot projects both found the same general conditions present in much of evaluated area: structurally sound, well jointed sewer mains with concrete and clay tile laterals and side sewers; except in Skyway, where mains are in poor condition and contribute significantly to I/I.

Another indication that laterals and side sewers are the primary I/I sources in the project areas is the fast I/I response to rainfall observed in the flow monitoring conducted for this project. Because laterals and side sewers are buried at shallow depths, I/I that enters them tends to appear quickly after a storm event begins, and subside quickly after the rainfall stops. This fast response was observed in the flow monitoring results. When I/I enters through sewer mains, which are buried deeper, it is generally attributable to the rise in groundwater, which lags behind the beginning of the storm event. The flow monitoring results did not indicate this type of slow, groundwater-based response.

These conditions suggest that most of the I/I comes from laterals and side sewers, so rehabilitation of laterals and side sewers, rather than sewer mains, is the focus of alternatives developed for the initial I/I reduction projects.

2.6.3 Distribution of I/I Within Mini-Basins

The SSES analyses did not show any great variety within individual mini-basins in the distribution of sewer defects that are the likely sources of I/I. Therefore, it is likely that I/I enters the system in a generally uniform way across each mini-basin. Inflow sources identified by smoke testing are exceptions to this uniform allocation because they are specific entry points for stormwater flows. Thus, I/I quantities can be evenly distributed across the parcels in each mini-basin as follows:

- Estimated flow rates for all inflow sources in the mini-basin are subtracted from the total estimated I/I quantity.
- The I/I remaining after removal of inflow is divided by the number of parcels actually served by the sewer system, providing an anticipated amount of I/I that can be attributed to each parcel served. Parcels that are open space or are not served by the sewer system are not included in the allocation.

2.6.4 Appropriate Rehabilitation Technologies

During the pilot projects, it was found that pipe lining of lateral and side sewers can be effectively accomplished only in a narrow range of field conditions: single service side sewers (no branching lines), limited bends, and relatively short runs. When all of these conditions are not met, lining is difficult and often infeasible. The SSES found that the side sewers in the project areas usually fail to conform to at least one of these conditions. In Eastgate and Issaquah, most side sewers failed to meet even one of these conditions.

Successful lining of side sewers can be done, and there are many small contractors who perform the service. However, it is typically done one side sewer at a time and takes a highly experienced crew an

entire day to complete. Doing such work on the scale of a project area or mini-basin would likely be difficult to contract and execute in the local market.

Pipe bursting was also performed extensively in the pilot projects. While it does not have the same challenges as pipe lining, it has added costs, typically in the form of restoration and access costs. Pipe bursting involves more excavation, so there is also typically greater disruption to the homeowner. However, it can be used successfully in the most challenging of the project areas, and it has been performed successfully on many large-scale projects in the Northwest.

Based on consideration of these factors, it was determined that cost estimating for initial I/I reduction alternatives would be developed assuming pipe bursting as the rehabilitation technique.

2.6.5 Eastgate Mini-Basin BEL014

While all of the Eastgate mini-basins have some PVC laterals and side sewers, the City of Bellevue has indicated that Mini-Basin BEL014 is the only one with high percentages of PVC mains, laterals and side sewers. Only two likely sources of direct inflow were observed in Mini-Basin BEL014, and both of these are related to catch basins located in or directly adjacent to rights of way. These conditions led to reassessment of the need to include Mini-Basin BEL014 in further analysis and consideration. Mini-Basin BEL014 has the lowest potential I/I contribution of the five Eastgate mini-basins, at 0.56 mgd. If this I/I were equally distributed among the 225 properties in the mini-basin, the potential reduction associated with each property would be low. In addition, early field reviews indicated challenging site conditions in Mini-Basin BEL014, with very steep topography and long main runs located in easements and forested areas.

Due to these considerations, it was decided that Mini-Basin BEL014 would not likely prove to be cost-effective as a potential reduction project, and it was dropped from further consideration after the smoke testing work was completed.

2.6.6 Renton Project Area

Renton project area flow monitoring performed for this alternatives analysis did not indicate the level of I/I that had previously been measured or predicted by modeling for this project area. The reason for this change is not clear, but the Washington State Department of Transportation recently completed work on the SR-167 on-ramp adjacent to the wetland area where a field visit indicated inflow through submerged manhole covers. It is possible that construction resulted in changes to the surface water drainage patterns. The work may have resulted in a diversion of surface water away from the sewer line in the wetland area, which could have changed or reduced the tendency for inflow into the sewer system.

Given the current levels of measured I/I in the mini-basin, it does not appear that rehabilitation in the mini-basin will meet the cost-effectiveness criteria established for this project. At the April 16, 2008 E&P Subcommittee meeting, a decision was made to remove the Renton project area from further consideration of large-scale rehabilitation under the Initial I/I Reduction project.

2.6.7 System Map Development and Review

Maps of the existing sewer system in the project areas were developed from sewer system information provided by each local agency and property information from King County databases. The sewer system information available varied from agency to agency, but in general consisted of side sewer record drawings, geographical information system data, and CAD system inventory drawings. King County property information consisted of property lines, rights of ways, and aerial photography. These data

sources were reviewed and combined to produce system maps indicating main and side sewer locations, property lines and aerial imagery.

Once the system maps were developed, a review was conducted of the mapping information and the CCTV data. This review was intended to provide a general sense of the accuracy of the system mapping data and to identify areas where mapping may have recorded incorrect information or where there are gaps in the CCTV data. The CCTV reports and video provided accurate locations of all side sewer connections on the mains, and these were compared to approximate locations indicated on the mapping information.

In several cases, it was discovered that the number of side sewer connections recorded in the CCTV analysis did not correspond with the information on the mapping data. Typically these discrepancies consisted of the CCTV work indicating fewer taps than shown on the system maps, which generally indicates shared laterals. In these locations, CCTV side sewer records were then reviewed to attempt to confirm if a shared side sewer existed. In many cases, it was difficult to make this final determination, as side sewer lengths prevented the side launch camera from reaching individual side sewer branches. However, these long lengths, combined with sewer main data documenting fewer service taps than the number of properties served by the main, were interpreted to indicate shared side sewers.

CHAPTER 3.
GEOTECHNICAL, GROUNDWATER AND ENVIRONMENTAL EVALUATIONS

Based on the SSES findings, the Renton project area was removed from further detailed analysis for I/I reduction. The Eastgate, Issaquah and Skyway project areas were further evaluated for general conditions pertinent to consideration of I/I reduction projects in *King County Inflow & Infiltration Project Study Environmental Technical Memorandum* (Shannon & Wilson, 2007), which is included in Appendix A of this alternatives analysis report. The findings of these further evaluations are summarized in this chapter.

3.1 LANDSLIDES AND EROSION

3.1.1 Geological Conditions

Eastgate

Most of the Eastgate project area lies on the north-facing slope of Bellevue's Newcastle Hills near the southwestern corner of Lake Sammamish. This north-facing slope consists of several ridges separated by three prominent, steep-sided, north-oriented drainages. In general, slopes on the ridges range from 15 to 50 percent while the slopes within the ravines range from 45 percent to steeper than 110 percent.

The project area is underlain by Pleistocene glacial soils and Tertiary bedrock. The primary surface deposit is Vashon Till, a very dense, gray, gravelly silty sand that is commonly referred to as "hardpan." Vashon glacial recessional deposits, consisting of normally consolidated, stratified sand and gravel with variable amounts of interbedded fine-grained silt and clay, exist along the lower portions of the project area. The Vashon recessional deposits range in density from loose to dense and from very soft to stiff. Many of the steep slopes in the project area have been modified by residential housing construction, street grading, and park development.

Issaquah

Nearly the entire Issaquah project area is on the lower portions of the east-facing slope of Squak Mountain west of the Issaquah city center. Relatively flat topography of the Issaquah Creek alluvial plain characterizes the eastern portion of the project area. Several east-oriented tributary drainages to Issaquah Creek, separated by several prominent, steep-sided ridges, characterize the project area topography. In general, slope inclinations on the ridges range from 15 to 60 percent, while the slopes within the ravines range from 65 to steeper than 100 percent.

The project area is underlain by Pleistocene glacial soils and Tertiary bedrock. Glacially consolidated soils consisting of Vashon till and Vashon advance outwash mantle most of the slope in the northern portion of the project area. Older, pre Vashon, fine-grained deposits of silt and clay underlie the advance outwash sand and gravel near the toe of the east-facing slope at the northern and southern portions of the project area. Soils within the relatively flat floodplain of Issaquah Creek in the eastern portion of mini-basin ISS004 include fill soils overlying alluvium, with groundwater depths as shallow as 4 feet below ground surface.

Intensive underground coal mining in the late 19th and early 20th centuries occurred in the southern portion of the project area, in the vicinity of Wildwood Boulevard SW. Coal mine related subsidence features have been documented in several reports and newspaper articles. Elsewhere in the project area,

many of the steep slopes have been modified by residential housing construction, street grading, and park development.

Skyway

The Skyway project area is located on an upland plateau that overlooks Lake Washington. The ground surface is gently sloping, from 0 to 20 percent. Steep slopes (greater than 40 percent) exist in and adjacent to the western and eastern portions of Mini-Basin BLS001, within the creek ravines at the north and south margins of Mini-Basin BLS002, and within the Bryn Mawr Park area of Mini-Basin BLS003.

Vashon till underlies most of the Skyway project area. Glacial recessional, normally consolidated soils are mapped on top of the till in several locations. Older, pre-Vashon glacial and interglacial deposits underlying the Vashon till are exposed along the steep valley walls of Taylor Creek.

Bedrock of the Tukwila Formation underlies the glacial soils in the project area. Bedrock exposures were observed during field reconnaissance on the steep, east-facing slopes of the Bryn Mawr Park area in BLS003 and along the western margin of BLS001.

3.1.2 Potential Slope Stability Issues

Eastgate

King County and City of Bellevue critical-area maps identify landslide hazard areas in the Eastgate project area at the following locations:

- Between SE Newport Way and SE 44th Place (Mini-Basin BEL012)
- Between SE 43rd Place and SE 44th Place (Mini-Basin BEL012)
- East of 158th Place SE (Mini-Basin BEL012)
- West of 158th Avenue SE (Mini-Basin BEL011)
- South of SE 50th Street (Mini-Basin BEL011)
- East of the SE 46th Way and 159th Avenue SE intersection (Mini-Basin BEL011)

Erosion hazard areas are generally confined to the Vasa Creek ravine and the northeast-trending ravine to the east in Mini-Basin BEL012. Portions of the area underlain by Vashon recessional soils in the Eastgate Park area in Mini-Basin BEL032 are also classified as an erosion hazard area.

The mapped erosion and landslide hazard areas are generally consistent with field observations performed for the alternatives analysis. However, steep slope hazard areas consisting of slopes of 40 percent or greater are not mapped and are ubiquitous throughout the project area.

No coal mine or seismic hazard areas are indicated on King County or City of Bellevue maps of the project area.

The potential for inducing landslides or erosion in most of the Eastgate project area is low to negligible. However, improvements to reduce I/I could cause groundwater levels to rise, thereby increasing the risk of landslides. The ground surface around maintenance holes located in steep, undeveloped rights-of-way could be disturbed during construction, which could cause erosion if construction best management practices are not followed.

Issaquah

The entire Issaquah project area is situated within Issaquah city limits, and the City of Issaquah does not currently have citywide critical areas maps. Erosion hazard areas regulated by the City of Issaquah consist of areas mapped by the Natural Resource Conservation Service (NRCS) as having a "severe" or "very severe" erosion hazard. Based on the NRCS soils map of the project area, erosion hazards exist along portions of Sunrise Place SE, Mount Quay Drive SW, the steep east-facing slope west of Newport Way NW, and in the vicinity of Mount Defiance Circle SW.

Steep slope hazard areas, as defined by slopes of 40 percent or greater, are present throughout the Issaquah project area.

The entire Issaquah project area south of Mountain Park Boulevard SW is classified as a coal mine hazard area. No seismic hazard areas are indicated on the King County Sensitive Areas maps within the Issaquah project area. However, portions of the project area situated within the Issaquah Creek alluvial plain could be considered seismically hazardous.

The potential for inducing landsliding or erosion in most of the Issaquah project area is low to negligible. However, in some areas the potential could be moderate to high if I/I is currently being directed into sewer lines in the following areas:

- The bowl area northeast of West Sunset Way, in the vicinity of Sunset Court NW (Mini-Basin ISS004)
- The bowl area between the Almak Court NW and Dorado Drive NW dead ends (Mini-Basin ISS004)
- The Mount Quay Drive NW area of historical instability (Mini-Basin ISS004)
- The bowl area between Mount Defiance Circle NW and SW Mount Baker Drive (Mini-Basins ISS003 and ISS004)
- The area east of Wildwood Boulevard SW between SW Clark Street and Sunrise Place SW (Mini-Basin ISS003)

Improvements to reduce I/I could cause groundwater levels to rise, thereby increasing the risk of landslides. The ground surface around maintenance holes located in steep, undeveloped rights-of-way could be disturbed during construction, which could cause erosion if construction best management practices are not followed.

Skyway

King County and City of Renton critical-area maps identify landslide hazard areas in the Skyway project area at the following locations:

- Adjacent to Taylor Creek, west of Rustic Road South (BLS002)
- Upslope and downslope of Raymond Place NW (BLS001)
- East of 87th Avenue South along the slope adjacent to Rainier Avenue South (BLS001).

Mapped erosion hazard areas are generally adjacent to and/or coincident with the landslide hazard areas in Mini-Basin BLS001. Areas of observed instability that are not currently mapped by local jurisdictions within geologically hazardous are as follows:

- The steep slope between South 123rd and South 124th Streets east of 81st Place South (BLS001)

- The steep slope between South 120th and South 122nd Streets west of 82nd Avenue South (BLS001)
- The ravine slopes along Stream 1 (BLS002)
- The east-facing slope below Garden Place South along Rainier Avenue South (BLS002)
- The east-facing slopes located east of 80th Avenue South, between South 120th and South 123rd Streets (BLS003)

The potential for inducing landsliding or erosion in most of the Skyway project area is low to negligible. However, in some areas the potential could be moderate to high if I/I is currently being directed into sewer lines in the following areas:

- The slope above Rainier Avenue South east of South 121st and NW 7th Streets (easternmost portion of BLS001)
- The slope east of 84th Avenue South in the vicinity of Raymond Place NW (BLS001)
- The slope between South 123rd and South 124th Streets east of 81st Place South (eastern portion of BLS001)
- The slopes located between South 120th and South 122nd Streets west of 82nd Avenue South (eastern portion of BLS001)
- The east-facing slopes located east of 80th Avenue South, between South 120th and South 123rd Streets (BLS003)
- The slopes north of South Sunnycrest Road, between Cornell Avenue South and Crestwood Drive South (BLS002)
- The west-facing slope adjacent to the houses along Rustic Road South and Crestwood Drive South, between house nos. 10619 Rustic Road South and 11033 Crestwood Drive South (BLS002)
- In the vicinity of the steep-sided depression, approximately 200 feet south and 200 feet north of house no. 10800 Forest Avenue South (BLS002)
- The slope between Garden Place South and Rainier Avenue South, from South Lakeridge Drive, north to the Garden Place South cul-de-sac (BLS002)
- The Stream 1 ravine slopes between 81st and 82nd Avenues South, and between Lotus Place South and 84th Avenue South (BLS002).

Improvements to reduce I/I could cause groundwater levels to rise, thereby increasing the risk of landslides. The ground surface around maintenance holes located in steep, undeveloped rights-of-way could be disturbed during construction, which could cause erosion if construction best management practices are not followed.

3.2 GROUNDWATER

3.2.1 Groundwater Conditions

Eastgate

Many residences in the Eastgate project area have drains from their property through the sidewalk that discharge into the street. Some of these drains direct up to 1 gallon per minute of groundwater off the subject properties into storm drains. These drains are an indication of shallow groundwater, as well as groundwater inflow into the sewer system. However, the project area does not have a significant shallow

groundwater table within the glacial till areas in the upland sections. Most seeps in the project area come from areas of colluvium at steep slopes, with the water likely perching on less permeable bedrock or glacial till. Pockets of coarse-grained soils in the glacial till could contribute to small amounts of groundwater. In general, shallow groundwater follows the surface topography, flowing to the north toward Lake Sammamish and Lake Washington.

No specific water-level fluctuation data were identified but based on experience in similar locations, groundwater in recessional outwash in the project area could fluctuate seasonally in relation to surface water features and rainfall. Also, groundwater may perch on top of the glacial till. The amount of perched water likely would fluctuate seasonally, with less water present during the summer and fall and more water present during the winter and spring.

Issaquah

Issaquah is located in the Issaquah Creek Valley groundwater management area (KCDNR, 1998). East of Newport Way NW, the Issaquah project area is located in a wellhead protection area. Areas in Mini-Basin ISS004, around Big Bear Place NW and Mount Fury Circle SW, are mapped as having a medium susceptibility to groundwater contamination (King County, 2007b).

Stormwater ditches with standing water were found in Mini-Basin ISS003 on Mt. Defiance Circle SW, SW Mt. Baker Drive, and Hillside Drive SE, indicating a potential impact on shallow groundwater through water infiltration. Groundwater seeps, indicating perched or shallow groundwater, were found in abundance in the northwestern end of Mini-Basin ISS004 and off Mount Park Boulevard SW and Mount Defiance Circle SW in Mini-Basin ISS003. Minor seeps in the southern end of Mini-Basin ISS003 were found emerging from the slope along Hillside Drive SE.

In general, groundwater flows with topography to the northwest, toward Lake Sammamish. No specific water-level fluctuation data were identified, but groundwater perching on low-permeability soil would likely fluctuate seasonally, with less water present during the summer and fall and more water present during the winter and spring. Groundwater in the alluvium deposits would likely fluctuate seasonally in direct relationship to the elevation of Issaquah Creek.

Skyway

The southeastern end of Mini-Basin BLS002 is in a wellhead protection area, near the Oakwood Ave South and South Lakeridge Drive intersection. Mini-Basins BLS001 and BLS003 are in a wellhead protection area, centered around the community water source wells at 78th Ave South and South 116th Street.

All three Skyway mini-basins have scattered, open stormwater ditches with standing water, indicating that the area has a high groundwater table. In general, where glacial till is present, relatively low volumes of groundwater would likely occur because of the low permeability of the till. At the western edge of Mini-Basin BLS002, more groundwater might be encountered, depending on the extent of the recessional outwash sand deposits into the project area.

In general, shallow groundwater that perches on top of the glacial till likely follows the surface topography, flowing downhill to the north, toward Lake Washington. In Mini-Basin BLS001, water may flow eastward as well, toward the Cedar River. No specific water-level fluctuation data were identified, but groundwater perching on low-permeability soil would likely fluctuate seasonally, with less water present during the summer and fall and more water present during the winter and spring.

3.2.2 Potential Groundwater Issues

Eastgate

Significant volumes of groundwater may be found in Mini-Basin BEL012 in the vicinity of sewer lines and manholes along the northern part of the Eastgate project area in the recessional outwash deposits. Excavation in these sand and gravel areas may require dewatering to control groundwater inflow. Pipe-bursting activity could cause groundwater pressures to rise around the bursting head, making the saturated soils more fluid. In this area, construction methods used in pipe bursting should control soil brought by groundwater inflow between the burst and replacement pipes, to prevent locking of the pipes during installation.

Lesser accumulations of groundwater could perch atop glacial till or exist within coarse-grained lenses in the till. Groundwater in glacial till areas could contribute to sewer infiltration but likely does not pose significant problems during excavation activities.

Basins BEL031, BEL032 and BEL012 have potential stormwater infiltration or retention areas. Through infiltration, there is a potential for increased groundwater in these areas, which could result in a need for limited construction dewatering. Open ditches with standing water in Mini-Basins BEL031 and BEL012 indicate that these areas have a high groundwater table, which could result in a need for limited construction dewatering.

The presence of a wellhead protection area between Mini-Basins BEL031 and BEL011 may require coordination with regulatory agencies for the proposed project. The King County Department of Health is responsible for the wellhead protection area. Notification prior to work in the area is recommended and the use of BMPs may be required to protect groundwater resources.

Issaquah

Significant amounts of groundwater could be encountered near Issaquah Creek in both Issaquah mini-basins, and excavation activities in the area could require construction dewatering to control groundwater inflow. Pipe-bursting activity could cause groundwater pressures to rise around the bursting head, making the saturated soils more fluid. In this area, construction methods used in pipe bursting should control soil brought by groundwater inflow between the burst and replacement pipes, to prevent locking of the pipes during installation.

Groundwater could be present in significant amounts in glacial advanced outwash deposits in the northwestern part of Mini-Basin ISS004. Groundwater in the deposits might need to be controlled with dewatering activity around pits associated with pipe-bursting activities. Construction methods should also control soil and groundwater inflow between pipes during construction.

In the mine-altered ground found in Mini-Basin ISS003, excavation activities could require limited to significant dewatering activities because of the variable nature of the backfill.

With both Issaquah project area mini-basins being located in a groundwater management area, and with the presence of a wellhead protection area east of Newport Way NW in Mini-Basin ISS004, coordination with local regulatory agencies could be necessary. King County and the City of Issaquah regulate the groundwater management area, and the King County Department of Health is responsible for the wetland protection area. In both cases, notification is required for work in both areas and the use of BMPs may be required to protect groundwater resources.

Skyway

Small accumulations of groundwater could perch atop glacial till or exist within coarse-grained lenses in till in the Skyway project area. Groundwater in these areas may seasonally contribute to sewer infiltration, but likely would not pose significant problems during excavation. Only limited construction dewatering may be necessary in the vicinity of pits for pipe-bursting activity. Groundwater seeps could be captured or diverted to reduce construction impacts.

Greater amounts of groundwater may be encountered in the western part of Mini-Basin BLS002, near the occurrence of sandy, advanced outwash soils. Excavation activities for pipe-bursting pits in these sand areas may require construction dewatering to control groundwater inflow into pipe-bursting pits. Pipe-bursting activity could cause groundwater pressures to rise around the bursting head, making the saturated soils more fluid. In this area, construction methods used in pipe bursting should control soil brought by groundwater inflow between the burst and replacement pipes, to prevent locking of the pipes during installation.

The presence of a wellhead protection area in the project area may require coordination with regulatory agencies. The King County Department of Health is responsible for the wetland protection area. Notification prior to work in the area is recommended and the use of BMPs may be required to protect groundwater resources.

3.3 IDENTIFICATION OF WETLANDS, STREAMS AND WILDLIFE

Wetlands, streams and wildlife were identified through a document review and site reconnaissance for each project area. The complete report of the identification study (Shannon & Wilson, 2007) is included in Appendix A of this alternatives analysis report and summarized below.

3.3.1 Eastgate

A document review identified the following resources in the Eastgate project area:

- **Washington Department of Fish and Wildlife (WDFW) Priority Habitat and Species Map**—Two priority habitats associated with Eastgate Park in Mini-Basin BEL032 are designated as urban natural open space. One priority habitat, containing two steep, wooded, riparian ravines that extend south from Eastgate Park in Mini-Basin BEL032, is designated as a riparian zone. No priority species are mapped in the project area.
- **Washington Department of Natural Resources (WDNR) Natural Heritage Information System Database**—No records for rare plant or high quality ecosystems are identified in the project area.
- **WDNR Forest Practices Application Review System**—Sunset Creek in Mini-Basin BEL032 and Vasa Creek in Mini-Basin BEL012 (also known as Squibbs Creek) are mapped as type F (fish-bearing) waters. A tributary to Vasa Creek in Mini-Basins BEL011 and BEL012 and an unnamed stream in the eastern project portion of Mini-Basin BEL012 are mapped as type N (non-fish-bearing) waters.
- **King County Critical Areas Map**—Vasa Creek and an unnamed stream that crosses SE 43rd Street southeast of 164th Way SE in Mini-Basin BEL012 are tributaries to Lake Sammamish. Sunset Creek flows north to Richards Creek. North of the project area and downstream of I-90, Vasa Creek and Sunset Creek are mapped as Class 2 Salmonid streams. No wetlands are mapped in the project area. No portion of the King County Wildlife Network is mapped in the project area.

A site reconnaissance on March 3 and 4, 2008 identified six wetlands in the project area:

- Wetlands A, B and D in Mini-Basin BEL012
- Wetland C in Mini-Basin BEL011
- Wetland E in Mini-Basin BEL031
- Wetland F in Mini-Basins BEL031 and BEL032.

Wetlands A, B, and C are forested/scrub/shrub riparian systems associated with site streams. Wetlands D, E, and F are palustrine forested/scrub/shrub systems. Wetland F is likely a stormwater detention pond and may not be subject to wetland regulations.

The City of Bellevue has jurisdiction over Wetlands A, B, C, and D. The Bellevue Municipal Code requires wetland buffer widths ranging from 40 to 225 feet, or as established through a previously approved and recorded Native Growth Protection Area (NGPA) or Native Growth Protection Easement (NGPE). Wetlands E and F are located in unincorporated King County and are subject to King County's buffer requirements. Under King County code, Wetlands E and F would be subject to buffer widths ranging from 50 to 225 feet.

No areas were observed that would be regulated as habitats associated with species of local importance (under LUC 20.25H.150) or as a Wildlife Habitat Conservation area (under King County Code 21A.24.382).

Within the project area, Vasa Creek, the east tributary to Vasa Creek, and Sunset Creek fall under the City of Bellevue's jurisdiction. For Type N waters, the City of Bellevue code requires a 50-foot buffer on undeveloped sites (i.e., sites that do not contain a primary structure). For developed sites (i.e., sites with an existing primary structure), the City of Bellevue code requires a 25-foot buffer or a buffer width as established with the existing NGPA or NGPE, whichever is greater.

The unnamed stream that crosses SE 43rd Street is located in unincorporated King County and is subject to King County's buffer requirements. King County's buffer requirements will need to be met for all site streams within King County. King County requires a 65-foot buffer for Type N waters. The classifications and buffer widths for the site streams are summarized in Table 5 of Appendix A.

3.3.2 Issaquah

A document review identified the following resources in the Issaquah project area:

- **Washington Department of Fish and Wildlife (WDFW) Priority Habitat and Species Map**—The PHS maps show wetlands associated with Issaquah Creek south of Newport Way SW in Mini-Basin ISS003 and three wetlands associated with fish hatchery ponds northeast of Newport Way SW and between West Sunset Way and Front Street South in Mini-Basin ISS004. Priority anadromous and resident fish include fall Chinook salmon, coho salmon, sockeye salmon, winter steelhead, coastal cutthroat trout, and kokanee salmon in Issaquah Creek, and coho salmon and resident coastal cutthroat trout in an unnamed stream.
- **Washington Department of Natural Resources (WDNR) Natural Heritage Information System Database**—No records for rare plant or high quality ecosystems are identified in the project area.
- **WDNR Forest Practices Application Review System**—Issaquah Creek, which parallels the east sides of Mini-Basins ISS003 and ISS004, is mapped as a Type S water. Eight tributaries to Issaquah Creek are classified as Type F or Type N waters.

- **King County Critical Areas Map**—Issaquah Creek is mapped as a Class 2 Salmonid stream and four unclassified tributaries to Issaquah Creek are mapped in the project area. No wetlands are mapped in the project area. No portion of the King County Wildlife Network is mapped in the project area.
- **City of Issaquah Stream Inventory and Habitat Evaluation Report**—Issaquah Creek is rated as a Class 1 stream and seven smaller streams in the project area are mapped as Class 2, Class 2 with Salmonids, or Class 3 streams. Four wetlands associated with Issaquah Creek are mapped in the project area. Fall Chinook salmon, coho salmon, sockeye salmon, winter steelhead, coastal cutthroat trout, and kokanee salmon are reported in Issaquah Creek. Cutthroat trout presence is reported in two other streams in the project area

A site reconnaissance on March 4, 2008 identified several wetlands in Mini-Basin ISS003, including forested riparian wetlands associated with Issaquah Creek, riparian scrub/shrub wetlands associated with three tributary streams, and a forested/scrub/shrub wetland near the convergence of Issaquah Creek and its east fork.

Issaquah's municipal code requires that wetland buffer widths range from 40 to 225 feet. Issaquah does not have specific regulations regarding wildlife habitat conservation areas. Issaquah's buffer width requirements are 100 feet for Class 1 and Class 2S streams, 75 feet for Class 2 streams, 50 feet for Class 3 streams, and 25 feet for Class 4 streams.

3.3.3 Skyway

A document review identified the following resources in the Skyway project area:

- **Washington Department of Fish and Wildlife (WDFW) Priority Habitat and Species Map**—Two priority habitats, designated as "Urban Natural Open Space," are mapped in Mini-Basin BLS002. Two bald eagle nest sites, identified in 2006, are mapped in or near the project area. Northern portions of Mini-Basin BLS002 fall within the mapped bald eagle 800-foot and shoreline nest buffer.
- **Washington Department of Natural Resources (WDNR) Natural Heritage Information System Database**—No records for rare plant or high quality ecosystems are identified in the project area.
- **WDNR Forest Practices Application Review System**—An unnamed stream in Mini-Basin BLS002, identified as Stream 1, is mapped as a Type N stream (for the upper 400 feet) and as a Type F stream. Taylor Creek, to the west of Mini-Basin BLS002, is mapped as a Type F stream. No wetlands were mapped in the project area.
- **King County Critical Areas Map**—Three unclassified streams are mapped: Taylor Creek, Stream 1, and a tributary to Stream 1 in Mini-Basin BLS003. No wetlands are mapped in the project area. No portion of the King County Wildlife Network is mapped in the project area.
- **King County Shoreline Management Program Map**—A narrow portion of Mini-Basin BLS002 along Rainier Avenue South is designated as urban shoreline environment.
- **City of Seattle Department of Planning and Development GIS**— A riparian corridor and wetland along a stream are shown along Taylor Creek at the western boundary of Mini-Basin BLS002. Wildlife areas are mapped along western and southwestern boundaries of Mini-Basin BLS002.

A site reconnaissance on March 3 and June 30, 2008 identified three wetlands: a scrub/shrub system within the ravine east of 76th Avenue South and south of South 116th Street in Mini-Basin BLS003; a

small scrub/shrub system associated with Stream 2 in Mini-Basin BLS001; and a small forested/scrub/shrub system on a vacated segment of the South 123rd Street right-of-way west of 85th Avenue South in Mini-Basin BLS001.

I/I reduction projects likely would qualify as exempt from shoreline substantial development permit requirements as they are normal maintenance or repair of existing structures or developments. Shoreline exemptions can be approved by King County.

King County code requires wetland buffer widths ranging from 50 to 225 feet. King County also requires 25-foot buffers for Type O streams, 65-foot buffers for Type N streams and 115-foot buffers for Type F streams. Taylor Creek is approximately 60 feet west of the project area boundary, but its associated buffer would likely overlap the project area.

County, state and federal regulations establish restrictions on activities within define distances from active bald eagle nests.

3.4 HAZARDOUS MATERIALS EVALUATION

An evaluation was conducted to determine if hazardous materials are likely to be encountered during the I/I reduction projects. The complete report of the evaluation (Shannon & Wilson, 2007) is included in Appendix A of this alternatives analysis report and summarized below.

Properties were ranked "low," "moderate," or "high" based on the likelihood of contaminants to be present in the soil in the vicinity of the sewer line and manholes. Properties with known groundwater or soil contamination located near or adjacent to the sewer are rated "high." Properties where spills have been reported or where there are no known releases but where businesses using hazardous materials are or previously were present (e.g. older gas stations, older automobile repair shops, dry cleaners, print shops) are rated "moderate." Other businesses—including gas stations and automobile repair shops developed since 1988 and construction companies with no known underground storage tanks—and residences with heating oil tanks are considered to have a low potential for contamination.

The potential for impact on the sewer line from contaminated sites was evaluated based on the type of business, the proximity of the parcel to the sewer line, and the known or suspected presence of contaminants. In areas where the water table is at or above the sewer pipe elevation, the potential exists that the sewer trench backfill could be serving as a hydraulic conduit for contaminated groundwater migration. In such cases, groundwater could carry contamination for considerable distances along the sewer line corridor. Excavation and dewatering practices used during sewer line repair activities could create or modify contaminant migration pathways and/or distribution.

The toxicity and cost of remediating contaminated soil that could be encountered during sewer line improvements varies depending on the type of contaminant. For example, dry cleaning solvents are highly toxic at low concentrations, and remediation costs are typically very high. Other solvent contaminants resulting from businesses such as photo processing or printing shops may be less toxic than dry cleaning solvents, but they can also result in high remediation costs. Soils contaminated with gasoline-range petroleum hydrocarbons generally have a lower toxicity and a lower disposal cost than soils contaminated with solvents. Older gasoline tends to be less toxic and somewhat less expensive to remediate. Diesel- and oil-range petroleum hydrocarbons are the least toxic and least mobile petroleum contaminants and typically have the lowest cleanup costs. Metal contaminants could result in high remediation costs, but they have a relatively low health risk unless they are ingested.

Construction monitoring should be performed where excavation is planned in areas of low potential for impact from contaminated sites (such as where spills have occurred and where underground storage tanks are suspected to be present). If contamination is identified, it would then be necessary to provide appropriate health and safety measures to protect site workers and to analyze the soil for proper disposal. Hazardous household materials such as cleaners, paints, and solvents are often disposed of in the sanitary sewer system from residences and businesses such as paint shops, printers, and photo developers. These materials can leak into the soil through sewer line joints. Sediments should be removed from manholes prior to work within them to reduce the risk of exposure to hazardous materials for site workers.

Based on the potential health risks associated with contaminated soil and groundwater, earthwork should be avoided in the vicinity of moderate and high risk sites. If earthwork cannot be avoided, a Phase II Environmental Site Assessment should be performed to determine whether contamination is present and to analyze the soil and groundwater for health and safety measures and proper disposal. The Phase II explorations should be confined to soil and/or groundwater sampling in the sewer line easement adjacent to each site.

Tables 3-1 through 3-3 summarize specific parcel ratings for hazardous materials in the Eastgate, Issaquah and Skyway project areas, respectively.

3.5 GEOTECHNICAL, GROUNDWATER AND ENVIRONMENTAL CONCLUSIONS

Although geotechnical, groundwater and environmental conditions were found to vary widely across the project areas, no conditions were found that pose significant issues for potential rehabilitation projects.

Potential groundwater, geotechnical and slope stability issues are generally limited to undeveloped portions of the project areas. Due to the highly variable nature of subsurface conditions, impacts of a potential rehabilitation project can only be estimated and judged in a broad qualitative fashion unless extensive studies are performed. While the potential for increased sloughing and erosion is always present if additional water is conveyed through the soil, areas susceptible to these mechanisms are limited within the project mini-basins.

Areas of recorded hazardous material concern are almost uniformly found to have minimal potential for influence by any potential rehabilitation project. The main potential for project impacts associated with hazardous materials is the possibility of construction cost impacts related to the discovery of residential heating oil tanks and associated soils.

TABLE 3-1.
EASTGATE PROPERTIES OF CONCERN FOR HAZARDOUS MATERIALS

Property	Location (Mini-Basin)	Contaminants of Concern
Low Risk		
Residences with heating oil	Various	Petroleum products
SPU Eastside Reservoir	4404 146th Avenue SE (BEL032)	Unknown
Hotel	15805 SE 37th Street (BEL012)	Petroleum products
Washington Environmental Pro T	4017 162nd Avenue SE (BEL012)	Unknown
Comcast Cable Communications Bellevue	3622 156th Avenue SE (BEL012)	Unknown
Arrow Lumber	16343 SE 40th Street (BEL012)	Petroleum products
5101 145th Place SE	5101 145th Place SE (BEL031)	Petroleum products
Theil Collins Residence	5215 146th Avenue SE (BEL 031)	Petroleum products
76 Gas Station/ Tosco Corp. Site 2564273	15220 SE 37th Street (BEL012)	Petroleum products
Schuck's Auto Supply	15303 SE 37th Street (BEL012)	Petroleum products
South Bellevue Community Center	14509 SE Newport Way (BEL032)	Petroleum products
Moderate Risk		
Eastgate Plaza Custom Cleaner	15220 SE 38th Place (BEL012)	Solvents
Hewlett-Packard Company	15815 SE 37th Street (BEL012	Petroleum products, metals

TABLE 3-2.
ISSAQUAH PROPERTIES OF CONCERN FOR HAZARDOUS MATERIALS

Property	Location (Mini-Basin)	Contaminants of Concern
Low Risk		
Residences with Heating Oil	Various	Petroleum products
660 Wildwood Boulevard	660 Wildwood Boulevard SW (ISS003)	Unknown
18 Mt. Pilchuck Avenue NW	18 Mount Pilchuck Avenue NW (ISS004)	Sewage sludge
Fish Hatchery Maintenance Garage	120 Newport Way SW (ISS003)	Petroleum products
Moderate Risk		
Puget Sound Energy Substation	NW of the Newport Way SW/ West Sunset Way intersection (ISS004)	Polychlorinated biphenyls
King County Fire District 10 Station	175 Newport Way NW (ISS004)	Petroleum products
Gilman Meadows Apartments	360 NW Dogwood Street (ISS004)	Unknown spilled material: screen for petroleum products, volatiles, pesticides
High Risk		
Former Gasoline Station	South of the Newport Way SW/ West Sunset Way intersection (ISS003)	Petroleum products

TABLE 3-3.
SKYWAY PROPERTIES OF CONCERN FOR HAZARDOUS MATERIALS

Property	Location (Mini-Basin)	Contaminants of Concern
Low Risk		
Residences with heating oil	Various	Petroleum products
8528 South 121st Street	8528 South 121st Street (BLS001)	Unknown
Renton Facilities and Operation Center/Site SE 11 Renton	12607 82nd Avenue South (BLS001)	Unknown
King County Fire District 20	11619 84th Avenue South (BLS003)	Petroleum products
Perovich & Son	12433 84th Avenue South (BLS001)	Petroleum products
S. 120th St. and 79th Ave. S.	S. 120th Street and 79th Avenue S. (BLS003)	Unknown
Bryn Mawr Lakeridge Water & Sewer District	7843 South 116th Street (BLS003)	Unknown
Moderate Risk		
11440 82nd Place South	11440 82nd Place South (BLS003)	Petroleum products
Former Lake Washington Greenhouses, Inc.	12167 87th Avenue South (BLS003)	Petroleum products, lead, pesticides, herbicides

CHAPTER 4.
DRAINAGE EVALUATIONS

I/I reduction activities have the potential to aggravate drainage problems that are caused by groundwater or by drainage systems with insufficient capacity. As improvements are made to prevent surface drainage or groundwater from entering the sewer system, flows that previously contributed to I/I can increase groundwater flows that cause drainage problems or lead to further exceeding the capacity of drainage infrastructure. In order that the potential for such problems be recognized in the development of I/I reduction projects, each project area was evaluated for records of existing drainage problems and complaints. This information will be used in project development so that steps can be taken to avoid any worsening of drainage problems resulting from the I/I reduction. This chapter describes the drainage problems that were identified in the evaluation.

4.1 EASTGATE

4.1.1 Existing Storm Drainage Infrastructure

In general, storm drainage in the Eastgate project area follows the topography, and systems drain from the south end toward the north. Three major ravines run north-south through the project area; depending on the topography, conveyance lines either discharge to these ravines within the limits of a mini-basin, or extend beyond the mini-basin limits and discharge to the ravine systems downstream. The westernmost ravine ultimately becomes Sunset Creek as it heads north. The easternmost ravine becomes Vasa Creek. Existing drainage infrastructure in the project area consists of a combination of public and private facilities.

Private elements of the system consist of roof downspout collection and conveyance lines, yard drains, wall and foundation drains, and driveway drains. There is little documentation of private drainage systems; the City of Bellevue does not maintain drawings of these elements.

Public storm drain collection and conveyance structures are primarily located within street rights of way, although portions are located in easements across private property. Based on City of Bellevue system inventory drawings, the following are the key elements of the existing public systems serving the Eastgate project area, beginning with the downstream end of each system:

- Two drainage systems serve Mini-Basin BEL032. The system that serves the northern half leaves the mini-basin and discharges to a ravine to the north. The system that serves the southern half conveys the flows for the majority of the mini-basin. Both systems consist of corrugated metal pipe and concrete pipe, 12 inches to 30 inches in diameter.
- Mini-Basin BEL012 is served by several small systems that discharge to a ravine along the west side of the mini-basin. These systems consist of corrugated metal pipe (CMP), PVC and concrete pipe, 8 inches to 18 inches in diameter.
- Mini-Basin BEL011 is served primarily by one system, which discharges to a ravine at the north end of the mini-basin. This system consists of CMP, PVC and concrete pipe, 8 inches to 30 inches in diameter.

4.1.2 Summary of Drainage Complaints

Drainage complaints for the Eastgate Project Area were obtained from City of Bellevue Maintenance and Operations staff. Table 4-1 identifies the complaints within the Eastgate mini-basins.

TABLE 4-1.
DRAINAGE COMPLAINTS AFFECTING I/I REDUCTION IMPROVEMENTS IN THE EASTGATE PROJECT AREA

	Number of Complaints				
	Broken / Inadequate Drainage System	Problem Due to Groundwater	Adjacent Property/ development	Road	Other complaints
Mini-Basin BEL011	1	4	0	10	0
Mini-Basin BEL012	5	3	6	8	5
Mini-Basin BEL014	3	3	1	3	2
Mini-Basin BEL031	3	4	3	2	3
Mini-Basin BEL032	3	1	4	3	1

4.2 ISSAQUAH

4.2.1 Existing Storm Drainage Infrastructure

Based on information provided by the City of Issaquah, Mini-Basins ISS003 and ISS004 both contain a fully developed drainage infrastructure consisting of a hard-piped conveyance system, with pipes made of a variety of pipe materials ranging and from 4 to 24 inches in diameters. The majority of the drainage system routes stormwater flows to the east, following the predominant slope of the area. Virtually all of the stormwater is eventually discharged to Issaquah Creek at locations along the eastern edge of the area.

4.2.2 Summary of Drainage Complaints

According to City of Issaquah staff, drainage complaints are rare and concern simple problems that are normally handled in the City's routine system maintenance program, such as catch basins occasionally blocked with leaves or debris.

4.3 SKYWAY

4.3.1 Existing Storm Drainage Infrastructure

The Skyway project area is in unincorporated King County, and the county owns and maintains the storm drainage infrastructure in the three study mini-basins. Stormwater collection and conveyance primarily consists of catch basins and storm drainage pipelines; however approximately 10 percent of the area includes open ditches and culverts.

The King County Roads Department has indicated that the storm drainage infrastructure in the Skyway project area has limited capacity, with capacity to convey flows up to a 10-year storm event.

4.3.2 Summary of Drainage Complaints

King County Interactive Mapping System

Drainage complaint maps by property were generated for the Skyway project area from data included in King County's Interactive Mapping System (IMAP), which provides such data for Skyway and other unincorporated areas of the county. Each complaint listing includes a complaint number, the date it was reported and closed, the address of the property, and comments relating to the complaint. In the IMAP data for Skyway, some properties have more than one drainage-related complaint. The complaints are categorized as follows, based on the source of the problem:

- Broken/Inadequate Drainage System—Complaints related to natural drainage blockage or broken or inadequate drainage systems
- Groundwater—Complaints related to groundwater impact on private property, such as subsurface flow creating ponding or wet backyards
- Adjacent Property/Development—Complaints related to runoff from adjacent properties, such as sheet flows from adjacent property or property impact from adjacent single family residential development
- Road—Complaints related to road runoff, such as sheet flow from roads and alleyways, offsite flows, road runoff bypassing a catch basin, or road runoff flowing into driveways
- Downspout—Complaints related to discharge of downspouts or footing drains over sidewalks
- Other Complaints—All other general complaints reported by the property owners.

Figure 4-1 shows the properties identified on IMAP as having reported drainage complaints over the past 30 years in the Skyway project area. Tables listing each complaint from 1977 to 2006 are included in Appendix B; this includes 65 properties in Mini-Basin BLS001, 58 properties in Mini-Basin BLS002, and 33 properties in Mini-Basin BLS003. Table 4-2 summarizes the number of complaints related to inadequate drainage systems and groundwater problems, which are the type of complaints that would be most likely to increase as a result of I/I rehabilitation.

TABLE 4-2.
DRAINAGE COMPLAINTS AFFECTING I/I REDUCTION IMPROVEMENTS IN THE SKYWAY PROJECT AREA

	Number of Complaints	
	Broken / Inadequate Drainage System	Problem Due to Groundwater
Mini-Basin BLS001	3	6
Mini-Basin BLS002	2	4
Mini-Basin BLS003	3	2

Skyway Water and Sewer District

Additional information on potential drainage problems in the Skyway project area was obtained from discussions with Skyway Water and Sewer District officials. Following the pilot project improvements of approximately 175 properties in Skyway, there were reports of drainage problems from four property owners. The property owners reported groundwater problems that resulted in wet backyards and surface ponding. The District investigated the reports and determined that the problems were the responsibility of

the property owners to fix. No project funds were used to remedy the drainage complaints. Surface ponding around a manhole also occurred following sewer main rehabilitation. The District remedied the problem by installing a subsurface drain to collect groundwater and convey it to a storm drainage pipeline. The work was added to the construction contract by change order.

4.4 DRAINAGE CONCLUSIONS

It is likely that instances of drainage-related problems will result from I/I reduction improvements. Based on previous history and anecdotal information provided by local agencies, the Skyway project area has the highest probability of experiencing such problems. Drainage problems resulting from increased groundwater volumes such as wet backyards and surface ponding have a moderate potential to occur. Storm drainage infrastructure capacity problems resulting from increased surface water runoff due to I/I reduction improvements are less likely, given the relatively low volume reductions that result from I/I rehabilitation.

It is not possible to predict specific locations where problems will occur; therefore drainage complaints should be monitored after the I/I removal improvements are performed to better identify any potential negative drainage impacts.

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: dnrp1:\\wtd\projects\II_Initial_Projec\project \TechReport\Skyway_ProjectArea_DrainageComplaints.mxd - peter keum
Data Source: King County

Figure 4 - 1

Drainage Complaints Identified by IMAP in Skyway Project Area

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

CHAPTER 5.
FIELD RECONNAISSANCE AND PARCEL DIFFICULTY RATINGS

The I/I reduction approach developed in King County's 2004 benefit/cost report was used as a starting point for this alternatives analysis. However, a key assumption of that approach—that unit costs for I/I rehabilitation work could be applied uniformly across all properties in all mini-basins—was brought into question early in this effort. Field visits to the project areas suggested that the range of natural and developed conditions within each mini-basin would result in a range of costs for performing rehabilitation work. In order to account for this variation, a detailed field reconnaissance was performed, and "difficulty ratings" were established for every parcel in the four project areas. The field reconnaissance and difficulty ratings are described in the following sections.

5.1 FIELD RECONNAISSANCE

Initial field reconnaissance consisting of windshield and walking surveys was performed in portions of each project area. Access to private property was not feasible, so field observations were limited to those that could be made from the right of way or from easements traversing open space. The purpose of the initial field reconnaissance was to assess the general topographic and physical characteristics of the parcels in each mini-basin, in order to allow for quick assessment of individual parcels. These assessments could be used to assign appropriate unit costs for the rehabilitation of each parcel.

Following the initial field reconnaissance, a full field review of all the parcels in each project area was performed to assess key parameters. The following parameters were assessed during the full field review:

- Topography of the parcel—Topography of the parcels ranged form relatively flat to slopes over 40 percent, and often varied dramatically between adjacent parcels.
- Access to the sewer main serving the parcel—The location of the main serving the parcel was typically consistent among parcels on the same street, but this was not always the case. Main location was either in front of the parcel or behind the parcel, but the access to the main was observed to be either from a paved street right of way, across an unimproved easement within a greenbelt or forest, or from an easement running through developed parcels. In many cases, where a main was located in a greenbelt or forest, it was evident that the main would have to be accessed through the parcel it served, as access along the easement would require forest clearing and grading of an access route.
- Access to the side sewer point of connection to the building waste line—Access to the side sewer point of connection was related in large part to the topography. In cases where the building served has a level below-grade, access to the side sewer point of connection would require deep excavation. In locations were the topography was steep, accessing the point of connection with construction equipment would be more difficult. In many cases, the building had only one floor, and access could be gained across a level driveway or lawn area.
- Level of improvement of the parcel—Assessment of the level of improvement took into consideration the presence of walls, structures, decorative pavements, and the degree of landscaping on the parcel. The level of improvement appeared to be largely related to topography. In most cases where a parcel was in an area of greater relief, parcels were developed with rockeries, retaining walls and larger shrubs and landscaping occupying the majority of the site. In areas of more moderate or flatter relief, parcels tended to have pockets

of large landscape plantings and decorative pavements, but large areas of the parcels were low groundcovers and lawns.

5.2 PARCEL DIFFICULTY RATING

The field review of individual parcels in the project areas led to the development of three levels of difficulty for performing rehabilitation on each parcel: easy, medium, and difficult. Table 5-1 lists the characteristics of each parameter for the individual levels of difficulty. These ratings are used to associate a level of difficulty and cost with each parcel where it is feasible to perform rehabilitation of laterals and side sewers for I/I reduction.

TABLE 5-1.
CRITERIA FOR ESTABLISHING LEVEL OF DIFFICULTY BY PARCEL

	Easy	Medium	Difficult
Layout	Individual side sewer and lateral	Shared side sewer or individual side sewer and lateral	Shared side sewer or individual side sewer and lateral
Topography	Low to moderate relief	High relief	High relief
Main Access	Main located in improved right of way	Main located in improved right of way	Main located in easement within developed property or within forested greenbelt with difficult access
Point of Connection Access	Ground floor or basement access	Access at basement level	Access in rear yard
Level of Improvement	Low to moderate level of improvement	Moderate to high level of improvement	Moderate to high level of improvement

The pipe summary spreadsheet created to summarize SSES data includes the distribution of the three difficulty levels for each mini-basin. For each main line run, a number has been entered representing the number of parcels served by that main that have been rated easy, medium and difficult. Table 5-2 summarizes the difficulty ratings for each mini-basin.

TABLE 5-2.
DIFFICULTY RATINGS BY MINI-BASIN

Mini-Basin	Total Number of Parcels	Easy Parcels		Medium Parcels		Difficult Parcels	
		Number	% of Total	Number	% of Total	Number	% of Total
BEL011	259	92	36	105	41	62	24
BEL012	441	84	19	202	46	155	35
BEL031	213	97	46	28	13	88	41
BEL032	223	85	38	20	9	118	53
Eastgate Total	**1,136**	**358**	**32**	**355**	**31**	**423**	**37**
ISS003[a]	133	39	29	80	60	12	9
ISS004[a]	293	91	31	76	26	27	9
Issaquah Total[a]	**426**	**130**	**30**	**156**	**37**	**39**	**9**
BLS001	391	176	45	138	35	77	20
BLS002	386	308	80	56	15	22	6
BLS003	232	131	56	60	26	41	18
Skyway Total	**1,009**	**615**	**61**	**253**	**25**	**141**	**14**

a. Percentages do not add to 100% for the Issaquah mini-basins because each of these basins included multi-family parcels where rehabilitation is not practical and single-family parcels where the difficulty was sufficient to make rehabilitation infeasible; difficulty ratings were not assigned for these parcels. Mini-Basin ISS003 has two such parcels and Mini-Basin ISS004 has 99.

CHAPTER 6.
PROJECT SCENARIOS AND ALTERNATIVES

Selection of recommended alternatives for the initial I/I reduction projects started with an evaluation of multiple rehabilitation scenarios for each mini-basin. Based on that initial evaluation, alternatives were developed consisting of selected scenarios for one or multiple mini-basins. The alternatives were evaluated for estimated cost, potential I/I reduction, and cost savings associated with potential elimination or reduction of downstream CSI projects.

6.1 ASSUMPTIONS

6.1.1 Rehabilitation Approach

Conclusions reached based on the SSES and 2003 pilot project findings established the following assumptions about the rehabilitation approach to be used in developing and evaluating initial I/I reduction alternatives:

- The alternatives focus on rehabilitation of side sewers and laterals rather than sewer mains, as these have been found to be the greater source of I/I.
- Cost estimates for the alternatives assume that pipe bursting will be used as the rehabilitation technique (predesign and final design may reveal additional information that would improve the feasibility of pipe lining for portions of the subject systems, and if so, that technique may be used to address the rehabilitation needs in those portions).
- I/I is assumed to be uniformly distributed across 90 percent of each mini-basin, with the exception of specific identified inflow sources. The 90-percent assumption accounts for the few parcels in each mini-basin where side sewers and laterals have recently been replaced and do not exhibit structural defects; these newer side sewers and laterals would not have the same level of I/I as older sections of pipe. Total mini-basin I/I, minus the contribution of inflow sources, was divided by 90 percent of the number of parcels in the mini-basin served by the sewer system to establish a per parcel reduction potential.
- The effectiveness of I/I reduction is assumed to range between 60 and 75 percent. For each alternative, total I/I reduction and associated CSI project cost savings were calculated for the high (75 percent) and low (60 percent) limits of this range.

6.1.2 Cost Assumptions

Unit construction costs per parcel for rehabilitation using pipe bursting were estimated for each of the three level-of-difficulty categories developed from the field reconnaissance. Unit construction costs for the Skyway project area were developed separately from those for Eastgate and Issaquah, in order to account for factors that are not uniform across the project areas, such as jurisdiction-specific overlay requirements and physical site conditions. Site restoration unit prices, for example, are higher for the Eastgate project area than for the Skyway project area, as a result of the typically higher level of landscape development and terrain challenges in the Eastgate area. Table 6-1 summarizes the unit construction costs developed based on project area and parcel level of difficulty.

TABLE 6-1.
UNIT CONSTRUCTION COST FOR I/I REHABILITATION

	Estimated Rehabilitation Cost per Parcel		
	Easy Parcels	Medium Parcels	Difficult Parcels
Eastgate and Issaquah Project Areas			
Side Sewer Pipe Bursting	$8,052	$9,047	$16,445
Lateral and Side Sewer Pipe Bursting	$9,995	$11,995	$16,995
Skyway Project Area			
Side Sewer Pipe Bursting	$3,310	$5,380	$6,600
Lateral and Side Sewer Pipe Bursting	$7,295	$8,515	$11,220

The unit construction costs estimated for this analysis are higher than those assumed in the previous benefit/cost analysis ($3,500 for all side sewer rehabilitations and $6,800 for all lateral and side sewer rehabilitations). This is because the field reconnaissance found that conditions in some of the project areas are considerably more difficult than previously assumed. Construction cost numbers derived from the pilot projects generally were not representative of conditions observed in the field reconnaissance. Construction cost escalation in the years since the pilot projects also had to be accounted for.

For all parcels and project areas, a unit construction cost of $3,000 was assumed for direct disconnects to remove inflow sources identified by the smoke testing.

Total project costs were estimated from construction costs assuming 9 percent for sales tax, 53 percent for allied costs, and 30 percent for contingency.

6.2 MINI-BASIN REHABILITATION SCENARIOS

6.2.1 Development of Scenarios

The mini-basin rehabilitation scenarios consist of varying combinations of improvements to manholes, side sewers and laterals and direct disconnections of roof drains and yard drains from the sewer system. The following are typical mini-basin rehabilitation scenarios:

- Rehabilitate laterals and side sewers on 50 percent of service parcels; rehabilitate only side sewers on 45 percent of service parcels; and implement direct disconnects on 4 percent of service parcels (this scenario, which does not distinguish between easy, medium and difficult parcels, was defined as "Technique 4" in the 2005 *Benefit/Cost Analysis Report* and was the recommended scenario in that report).
- Rehabilitate laterals and side sewers on 95 percent of service parcels.
- Rehabilitate laterals and side sewers on all easy and medium service parcels.
- Rehabilitate laterals and side sewers on 95 percent of easy and medium service parcels.

Variations of these scenarios were developed as appropriate for each mini-basin. The goal was to establish and evaluate a reasonable range of I/I reduction approaches in order to find a suitable balance between construction cost and I/I reduction. Where smoke testing identified direct inflow sources, direct disconnects to eliminate the inflow sources are included in the rehabilitation scenarios. In all, 46 rehabilitation scenarios were developed and evaluated for nine mini-basins.

6.2.2 Evaluation of Scenarios

Figure 6-1 shows a description of how each scenario was evaluated, using one scenario from the Eastgate project area (BEL031-E) as an example; detailed spreadsheets for this scenario are included in Appendix C.

- I/I removal was estimated as follows:
  - Determine remaining I/I after direct disconnects as the estimated mini-basin I/I minus the estimated inflow from direct connections. For Mini-Basin BEL031, the estimated I/I is 1.31 mgd and the estimated inflow through direct connections is 0.063 mgd:
    Remaining I/I = 1.25 mgd.
  - Calculate I/I allocation per parcel by dividing the remaining I/I by 90 percent of the number of parcels in the mini-basin. In Mini-Basin BEL031, there are 213 parcels, so the unit I/I per parcel is 1.25 mgd divided by 192 (90 percent of 213):
    I/I per parcel = 0.0065 mgd, or 4.52 gallons per minute (gpm).
  - Determine the number of parcels rehabilitated, based on the scenario. Scenario BEL031-E is defined as rehabilitation of 95 percent of parcels rated easy (97) or medium (28), less 10 percent to account for PVC connections not needing rehabilitation:
    Rehabilitated parcels = 107 (82 easy, 25 medium).
  - Calculate I/I to be removed through rehabilitation as the unit I/I per parcel times the number of rehabilitated parcels times the assumed rehabilitation effectiveness (60 percent or 75 percent). For Scenario BEL031-E, this is 4.52 gpm per parcel times 107 parcels time the percent effectiveness:
    Rehabilitation I/I removal (60% effectiveness) = 290 gpm, or 0.42 mgd
    Rehabilitation I/I removal (75% effectiveness) = 363 gpm, or 0.52 mgd
  - Calculate total I/I removal as the sum of removal from direct disconnects and removal from rehabilitation. For Scenario BEL031-E, direct disconnects would remove 0.063 mgd and rehabilitation would remove 0.42 mgd (60 percent effectiveness) or 0.52 mgd (75 percent effectiveness):
    Total I/I removal (60% effectiveness) = 0.48 mgd
    Total I/I removal (75% effectiveness) = 0.58 mgd
- Project cost for each scenario was estimated as follows:
  - Construction cost for rehabilitation was calculated based on the work included in the scenario and the unit costs presented in Table 6-1. Scenario BEL031-E includes side sewer and lateral rehabilitation on 82 easy parcels at $9,995 each and 25 medium parcels at $11,995 each:
    Rehabilitation construction cost = $1,119,000
  - Total construction cost is the sum of rehabilitation construction cost and construction cost for direct disconnects. Scenario BEL031-E includes two direct disconnects at $3,000 each:
    Direct disconnect construction cost = $6,000
    Total construction cost (rehabilitation + direct disconnects) = $1,125,000
  - Project cost is the construction cost plus sales tax, allied cost and contingency. For Scenario BEL031-E these values are as follows:
    Sales tax (9% of construction cost) = $101,000
    Allied costs (53% of the sum of construction cost and sales tax) = $650,000
    Contingency (30% of the sum of construction cost, sales tax and allied cost) = $563,000
    Total project cost = $2,440,000 (rounded)

Figure 6-1. Example Evaluation of I/I Scenario, Using Eastgate Scenario BEL031-E

In evaluating the rehabilitation scenarios, it became evident that the per-parcel distribution of I/I can be used to quickly determine whether a scenario has the potential to be cost-effective. It was found that in areas where there is less than 3 gpm of I/I per parcel, it typically will not be cost-effective to remove it through rehabilitation. In these cases it requires rehabilitation of too many individual properties, making implementation of the downstream conveyance improvement needs more cost-effective. Based on the evaluation, 20 scenarios in seven mini-basis were selected to create initial I/I reduction alternatives. Table 6-2 summarizes the scenarios developed and carried forward, by mini-basin.

TABLE 6-2.
MINI-BASIN REHABILITATION SCENARIOS

Mini-Basin	Number of Scenarios Evaluated	Scenarios Carried Forward for Use in Alternatives
BEL011	4	BEL011-D, BEL011-E
BEL012	4	BEL012-D, BEL012-E
BEL014	None (removed from evaluation based on SSES)	None
BEL031	5	BEL031-D, BEL031-E
BEL032	5	BEL032-D, BEL032-E
ISS003	8	ISS003C(2), ISS003D(2), ISS003E(2)
ISS004	6	None
RNT005	None (removed from evaluation based on SSES)	None
BLS001	2	None
BLS002	7	BLS002B, BLS002B1, BLS002B2, BLS002C, BLS002E, BLS002F
BLS003	5	BLS003B, BLS003C, BLS003E

6.3 I/I REDUCTION ALTERNATIVES

Mini-basin rehabilitation scenarios selected for use in alternatives were evaluated individually or in combinations, based on the downstream CSI project that could be affected by their implementation. Twenty-seven alternatives were developed from the selected scenarios:

- 16 alternatives were created from one or two Eastgate mini-basins.
- 3 alternatives were created from individual Issaquah mini-basins.
- 1 alternative was created from one Eastgate mini-basin and one Issaquah mini-basin.
- 7 alternatives were created from one or two Skyway mini-basins.

Table 6-3 summarizes the alternatives, along with their estimated total I/I removal and project cost, determined as described for the evaluation of scenarios.

The alternatives and their estimated impacts on I/I were provided to King County's modeling group to assess the potential for reducing or eliminating downstream CSI projects due to the reduced I/I flows. Cost savings associated with CSI project reduction allowed by each initial I/I reduction alternative were

estimated for comparison to the construction costs for the alternative. Alternatives with a benefit/cost ratio of 1.0 or greater may be recommended for implementation as initial I/I reduction projects. Table 6-4 summarizes the results of the benefit/cost analysis.

TABLE 6-3.
INITIAL I/I REDUCTION ALTERNATIVES SUMMARY

Alternative	Rehabilitation Scenarios Included	Properties Rehabilitated	Total I/I Project Cost ($million)	Total I/I Removal (mgd) 60% Effective	Total I/I Removal (mgd) 75% Effective
BEL-F	BEL031-D BEL032-E	82 easy, 25 medium, 75 difficult 69 easy, 17 medium, 0 difficult	$7.15	0.97	1.19
BEL-G	BEL031-E BEL032-D	82 easy, 25 medium, 0 difficult 69 easy, 17 medium, 105 difficult	$8.25	0.90	1.10
BEL-H	BEL031-D BEL032-D	82 easy, 25 medium, 75 difficult 69 easy, 17 medium, 105 difficult	$11.02	1.19	1.47
BEL-I	BEL031-E BEL032-E	82 easy, 25 medium, 0 difficult 69 easy, 17 medium, 0 difficult	$4.38	0.68	0.82
BEL-J	BEL031-D	82 easy, 25 medium, 75 difficult	$5.20	0.77	0.95
BEL-K	BEL031-E	82 easy, 25 medium, 0 difficult	$2.44	0.48	0.58
BEL-L	BEL032-D	69 easy, 17 medium, 105 difficult	$5.81	0.42	0.52
BEL-M	BEL032-E	69 easy, 17 medium, 0 difficult	$1.94	0.20	0.24
BEL-R	BEL011-D BEL012-E	78 easy, 89 medium, 53 difficult 71 easy, 172 medium, 0 difficult	$12.07	0.97	1.21
BEL-S	BEL011-E BEL012-D	78 easy, 89 medium, 0 difficult 71 easy, 172 medium, 132 difficult	$14.98	1.14	1.41
BEL-T	BEL011-D BEL012-D	78 easy, 89 medium, 53 difficult 71 easy, 172 medium, 132 difficult	$16.93	1.24	1.54
BEL-U	BEL011-E BEL012-E	78 easy, 89 medium, 0 difficult 71 easy, 172 medium, 0 difficult	$10.11	0.87	1.08
BEL-V	BEL011-D	78 easy, 89 medium, 53 difficult	$5.99	0.46	0.57
BEL-W	BEL011-E	78 easy, 89 medium, 0 difficult	$4.04	0.36	0.44
BEL-X	BEL012-D	71 easy, 172 medium, 132 difficult	$10.94	0.78	0.97
BEL-Y	BEL012-E	71 easy, 172 medium, 0 difficult	$6.08	0.51	0.64
ISS-E	ISS003C(2)	31 easy, 76 medium, 11 difficult	$3.19	0.40	0.51
ISS-F	ISS 003D(2)	37 easy, 76 medium, 0 difficult	$2.79	0.37	0.46
ISS-G	ISS003E(2)	37 easy, 0 medium, 0 difficult	$0.81	0.12	0.15
BEL/ISS-B[a]	BEL031-E ISS003D(2)	82 easy, 25 medium, 0 difficult 37 easy, 76 medium, 0 difficult	$5.23	0.85	1.04
BLS-B	BLS002B	190 easy, 0 medium, 0 difficult	$3.07	1.15	1.38
BLS-B1	BLS002B1	210 easy, 0 medium, 0 difficult	$3.39	1.25	1.50
BLS-B2	BLS002B2	185 easy, 0 medium, 0 difficult	$2.99	1.26	1.51
BLS-B3	BLS003B	124 easy, 56 medium, 28 difficult	$3.73	1.03	1.27
BLS002 /003-C	BLS002C BLS003C	120 easy, 0 medium, 0 difficult 69 easy, 50 medium, 13 difficult	$3.09	1.18	1.40
BLS-F[a]	BLS002F	292 easy, 51 medium, 0 difficult	$5.63	1.82	2.25
BLS-E[a]	BLS002E BLS003E	270 easy, 0 medium, 0 difficult 50 easy, 13 medium, 2 difficult	$5.47	1.82	2.24

a. Indicates alternatives selected for further evaluation, as described in Chapter 7.

TABLE 6-4.
BENEFIT/COST ANALYSIS FOR INITIAL I/I REDUCTION ALTERNATIVES

Alternative	CSI Projects Affected	CSI Project Size Reduction (MG)		Total CSI Project Cost Savings ($ million)		Benefit/Cost Ratio	
		60% Effective	75% Effective	60% Effective	75% Effective	60% Effective	75% Effective
BEL-F	• Eastgate Storage • Issaquah Storage	0.30 0.43	0.37 0.52	$6.00	$7.33	0.84	1.03
BEL-G	• Eastgate Storage • Issaquah Storage	0.28 0.40	0.34 0.49	$5.60	$6.79	0.68	0.82
BEL-H	• Eastgate Storage • Issaquah Storage	0.37 0.52	0.46 0.64	$7.33	$9.01	0.67	0.82
BEL-I	• Eastgate Storage • Issaquah Storage	0.21 0.31	0.26 0.37	$4.27	$5.12	0.97	1.17
BEL-J	• Eastgate Storage • Issaquah Storage	0.24 0.35	0.30 0.42	$4.82	$5.89	0.93	1.13
BEL-K	• Eastgate Storage • Issaquah Storage	0.15 0.22	0.18 0.26	$3.03	$3.66	1.24	1.50
BEL-L	• Eastgate Storage • Issaquah Storage	0.13 0.19	0.16 0.24	$2.65	$3.29	0.46	0.57
BEL-M	• Eastgate Storage • Issaquah Storage	0.06 0.09	0.07 0.11	$1.27	$1.52	0.65	0.78
BEL-R	• Eastgate Storage • Issaquah Storage	0.30 0.43	0.38 0.53	$6.00	$7.44	0.50	0.62
BEL-S	• Eastgate Storage • Issaquah Storage	0.35 0.50	0.44 0.62	$7.03	$8.65	0.47	0.58
BEL-T	• Eastgate Storage • Issaquah Storage	0.39 0.54	0.48 0.67	$7.63	$9.43	0.45	0.56
BEL-U	• Eastgate Storage • Issaquah Storage	0.27 0.39	0.34 0.48	$5.40	$6.68	0.53	0.66
BEL-V	• Eastgate Storage • Issaquah Storage	0.14 0.21	0.18 0.26	$2.92	$3.59	0.49	0.60
BEL-W	• Eastgate Storage • Issaquah Storage	0.11 0.17	0.14 0.20	$2.30	$2.79	0.57	0.69
BEL-X	• Eastgate Storage • Issaquah Storage	0.24 0.35	0.30 0.43	$4.89	$6.00	0.45	0.55
BEL-Y	• Eastgate Storage • Issaquah Storage	0.16 0.23	0.20 0.29	$3.22	$4.04	0.53	0.66
ISS-E	• Eastgate Storage • Issaquah Storage • Issaquah Interceptor	0.12 0.18 0.00	0.15 0.22 0.65	$2.42	$3.11	0.76	0.97
ISS-F	• Eastgate Storage • Issaquah Storage • Issaquah Interceptor	0.11 0.16 0.00	0.13 0.20 0.59	$2.18	$2.83	0.78	1.02

TABLE 6-4 (continued).
BENEFIT/COST ANALYSIS FOR INITIAL I/I REDUCTION ALTERNATIVES

Alternative	CSI Projects Affected	CSI Project Size Reduction (MG)		Total CSI Project Cost Savings ($ million)		Benefit/Cost Ratio	
		60% Effective	75% Effective	60% Effective	75% Effective	60% Effective	75% Effective
ISS-G	• Eastgate Storage • Issaquah Storage	0.03 0.05	0.04 0.06	$0.71	$0.90	0.88	1.11
BEL/ISS-B[a]	• Eastgate Storage • Issaquah Storage • Issaquah Interceptor	0.26 0.37 0.00	0.32 0.45 0.59	$5.12	$6.37	0.98	1.22
BLS-B	• Bryn Mawr Storage	0.05	0.06	$0.51	$0.63	0.17	0.21
BLS-B1	• Bryn Mawr Storage	0.05	0.06	$0.56	$0.71	0.17	0.21
BLS-B2	• Bryn Mawr Storage	0.05	0.06	$0.56	$0.71	0.19	0.24
BLS-B3	• Bryn Mawr Storage	0.05	0.06	$0.51	$0.63	0.14	0.17
BLS002 /003-C	• Bryn Mawr Storage	0.05	0.06	$0.52	$0.63	0.17	0.20
BLS-F[a]	• Bryn Mawr Storage	0.27	0.27	$5.37	$5.37	1.00[b]	1.00[b]
BLS-E[a]	• Bryn Mawr Storage	0.27	0.27	$5.37	$5.37	1.00[c]	1.00[c]

a. Indicates alternatives selected for further evaluation, as described in Chapter 7.
b. Benefit/cost ratio includes $260,000 cost-sharing with Skyway Water and Sewer District.
c. Benefit/cost ratio includes $100,000 cost-sharing with Skyway Water and Sewer District.

CHAPTER 7.
RECOMMENDED PROJECTS AND IMPLEMENTATION

7.1 RECOMMENDATIONS

Analysis indicates that cost-effective rehabilitation is feasible in only four mini-basins: Mini-Basin BEL031 in Eastgate; Mini-Basin ISS003 in Issaquah; and Mini-Basins BLS002 and BLS003 in Skyway. Figures 7-1 through 7-4 show the level-of-difficulty maps for these four mini-basins. Cost-effective rehabilitation in all other mini-basins is limited due to a low I/I allocation per property (requiring a greater number of properties to be rehabilitated) and high unit costs for rehabilitation because of difficult field conditions.

7.1.1 Comparison of Selected Alternatives

Three alternatives addressing the four selected mini-basins meet the cost-effectiveness requirements of providing a benefit/cost ratio of 1.0 or greater: The combined Eastgate/Issaquah Alternative BEL/ISS-B, in Mini-Basins BEL031 and ISS003; Skyway Alternative BLS-F, in Mini-Basin BLS002; and Skyway Alternative BLS-E, in Mini-Basins BLS002 and BLS003. (Eastgate Alternative BEL-K, which also meets the cost-effectiveness requirement, is included in Alternative BEL/ISS-B and is so not evaluated separately.) Detailed project spreadsheets for each alternative are included in Appendix C. A detailed comparison of these alternatives was performed to identify recommended alternatives. The comparison is summarized in Table 7-1.

- CSI project cost savings—The CSI project cost savings for 60-percent and 75-percent I/I removal effectiveness are as described in Chapter 6 and shown in Table 6-4. For Skyway Alternatives BLS-F and BLS-E, the CSI project cost savings are the same for 60-percent and 75-percent I/I removal effectiveness, because 60-percent removal would eliminate the need for the Bryn Mawr Storage CSI project downstream. No additional savings are realized for 75-percent removal.

7.1.2 Recommended Alternatives

Alternative BEL/ISS-B is recommended for the Eastgate and Issaquah project areas. Although this project is marginally below the cost-effectiveness threshold of 1.0 if only 60-percent I/I removal is achieved, past similar projects have shown I/I removal rates on average of 77 percent. The cost estimate for I/I reduction is also conservatively estimated, therefore the risk is minimized that the project would not achieve cost-effectiveness.

For the Skyway project area, Alternative BLS-F is recommended over BLS-E for the following reasons:

- There is a higher degree of confidence in the flow monitoring data for Mini-Basin BLS002 than the data for BLS003. Deriving the amount of I/I in BLS003 required subtraction of upstream meter data, which has a higher likelihood of error being introduced.
- Smoke testing in Mini-Basin BLS002 resulted in the identification of significantly more direct connections and defects than in Mini-Basin BLS003.
- Alternative BLS-F concentrates construction in a single mini-basin—Mini-Basin BLS002. If additional I/I reduction is found to be needed following implementation of the initial projects, then work could be performed in Mini-Basin BLS003 without disrupting any neighborhood twice with construction.

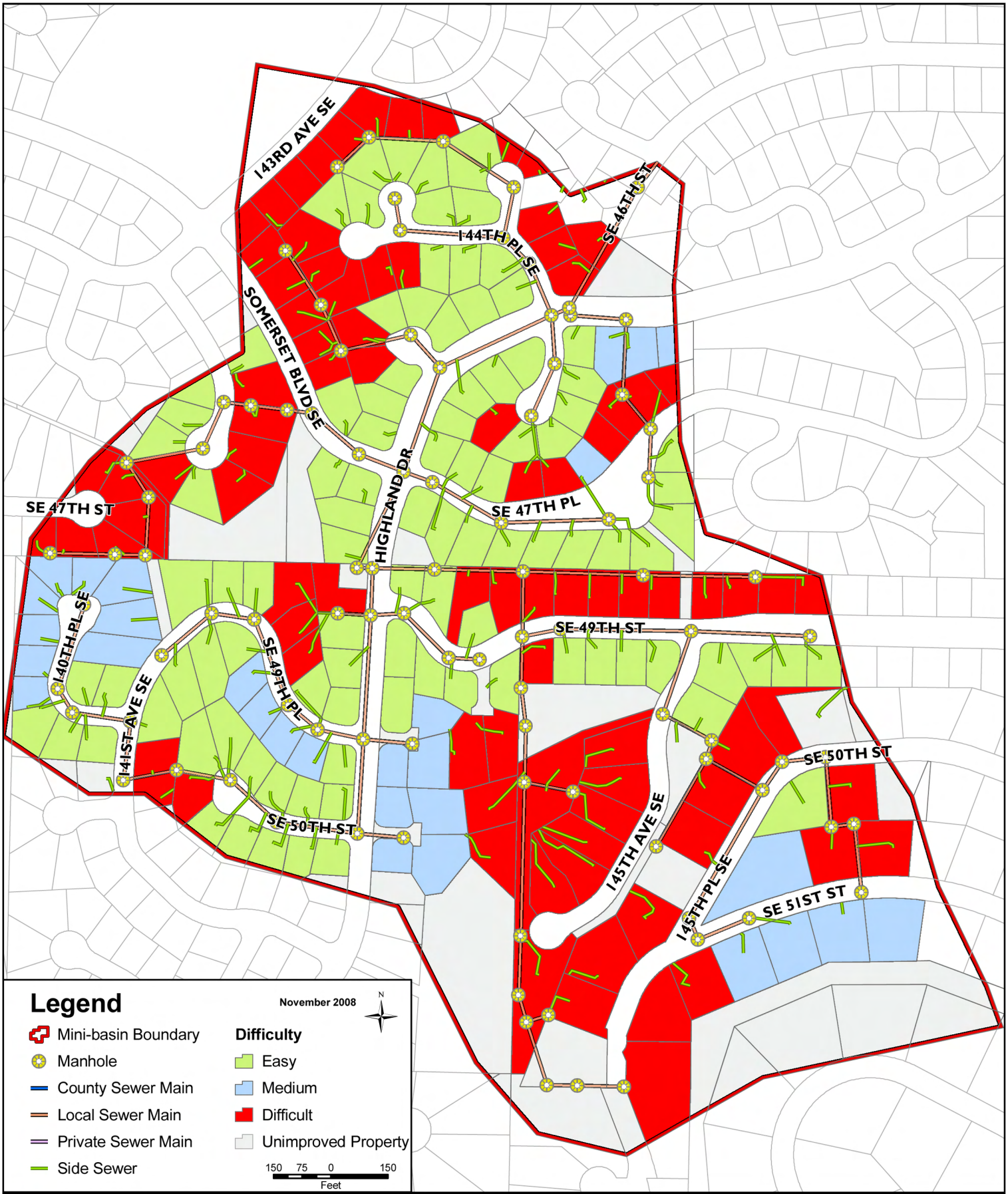
TABLE 7-1.
SUMMARY OF POTENTIAL I/I REDUCTION ALTERNATIVES

	Eastgate/Issaquah BEL/ISS-B	Skyway BLS-F	Skyway BLS-E
Description	Rehabilitate 50% of laterals and side sewers in Mini-Basin BEL031 (82 easy, 25 medium) and 85% in Mini-Basin ISS003 (37 easy, 76 medium).	Rehabilitate 89% of laterals and side sewers in Mini-Basin BLS002 (292 easy, 51 medium).	Rehabilitate 70% of laterals and side sewers in Mini-Basin BLS002 (270 easy) and 28% in Mini-Basin BLS003 (50 easy, 13 medium, 2 difficult).
Preliminary Construction Method	—— Pipe bursting, open cut where necessary ——		
Private Property Entry Agreements Needed	220	343	335
Estimated Construction Year	2012	2011	—
Estimated I/I Reduction	0.85 mgd @ 60%; 1.04 mgd @ 75%	1.82 mgd @ 60%; 2.25 mgd @ 75%	1.82 mgd @ 60%; 2.24 mgd @ 75%
Estimated Construction Cost	$3.41 million	$3.68 million	$3.57 million
Estimated Project Cost	$5.23 million	$5.63 million	$5.47 million
CSI Project Impact, 60% I/I Reduction			
Size Reduction	Eastgate Storage: 0.26 MG Issaquah Storage: 0.37 MG	Bryn Mawr Storage: 0.27 MG	Bryn Mawr Storage: 0.27 MG
Project Cost Savings	$5.12 million[a]	$5.37 million[b]	$5.37 million[c]
CSI Project Impact, 75% I/I Reduction			
Size Reduction	Eastgate Storage: 0.32 MG Issaquah Storage: 0.45 MG Issaquah Interceptor: 0.59 mgd	—	—
Project Cost Savings	$6.37 million	—[d]	—[d]
Life Cycle Cost Savings	Negligible	—	—

a. The Eastgate/Issaquah I/I project is marginally below the cost-effective threshold of 1.0 if only 60% I/I reduction is achieved. However, past similar projects have shown I/I reduction rates on average of 77%. The cost estimate for I/I reduction is also conservatively estimated, therefore the risk is minimized that the project would not achieve cost effectiveness.
b. Net savings for Skyway Alternative BLS-F assumes $260,000 cost sharing from Skyway Water and Sewer District.
c. Net savings for Skyway Alternative BLS-E assumes $100,000 cost sharing from Skyway Water and Sewer District.
d. For Skyway Alternatives BLS-F and BLS-E, the CSI project cost savings are the same for 60 percent and 75-percent I/I removal effectiveness, because 60-percent removal would eliminate the need for the Bryn Mawr Storage CSI project downstream. No additional savings are realized for 75-percent removal.

- The Skyway Water and Sewer District wishes to add additional funding to the project to rehabilitate the district's sewer mains and manholes in the impacted mini-basin areas. Concentrating work within Mini-Basin BLS002 allows the rehabilitation of more mains and manholes, increasing the likelihood of achieving the target I/I reduction.

Figures 7-5 and 7-6 show the recommended project locations.



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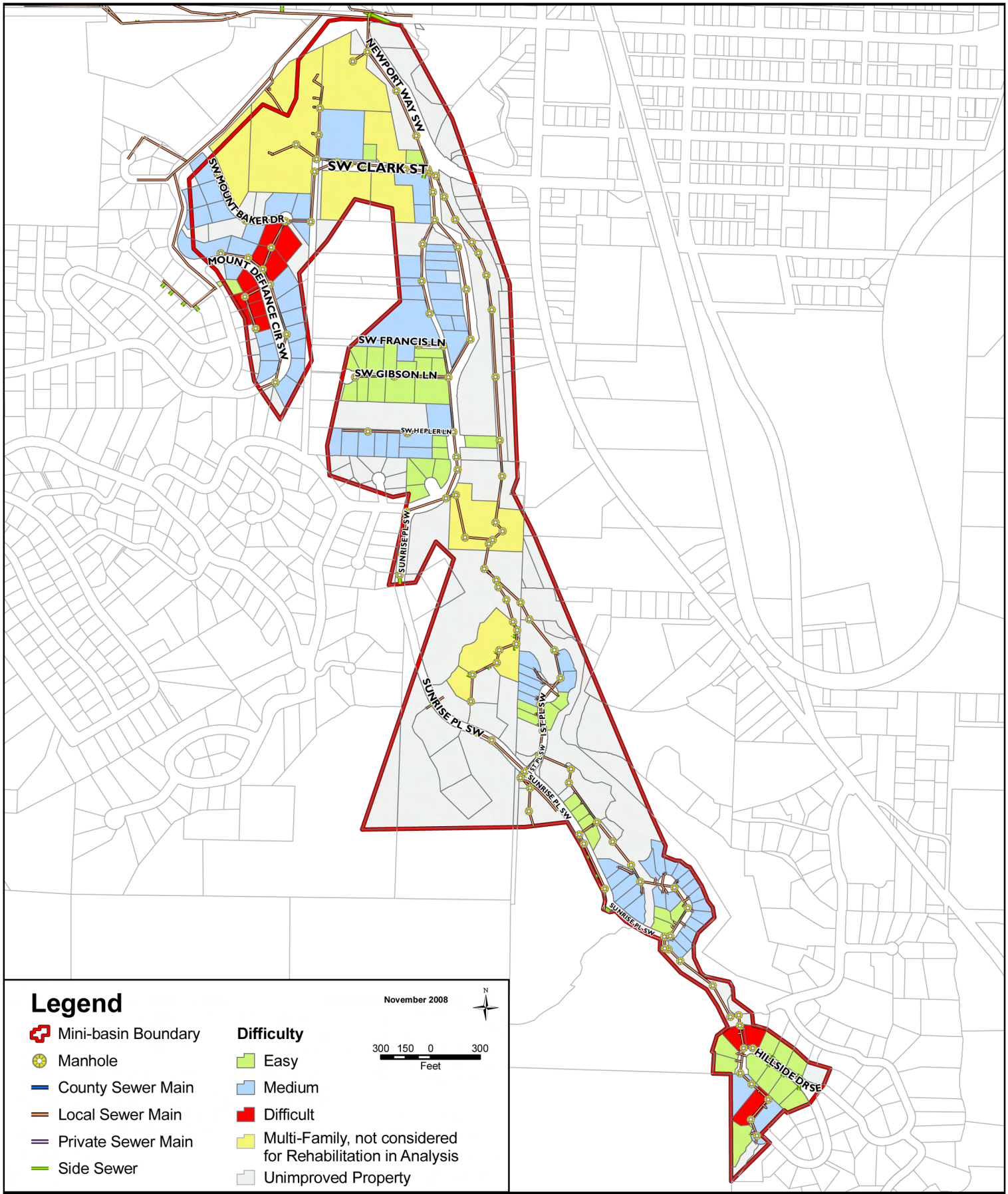
File Name: K:\kingco_ii\Bellevue\BEL31_difficulty_reportfig

Data Source: King County

Figure 7-1

Mini-Basin BEL031
Parcel Difficulty Ratings

Initial Infiltration and Inflow Reduction Alternatives Analysis Report



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Data Source: King County

Figure 7-2
Mini-Basin ISS003
Parcel Difficulty Ratings
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

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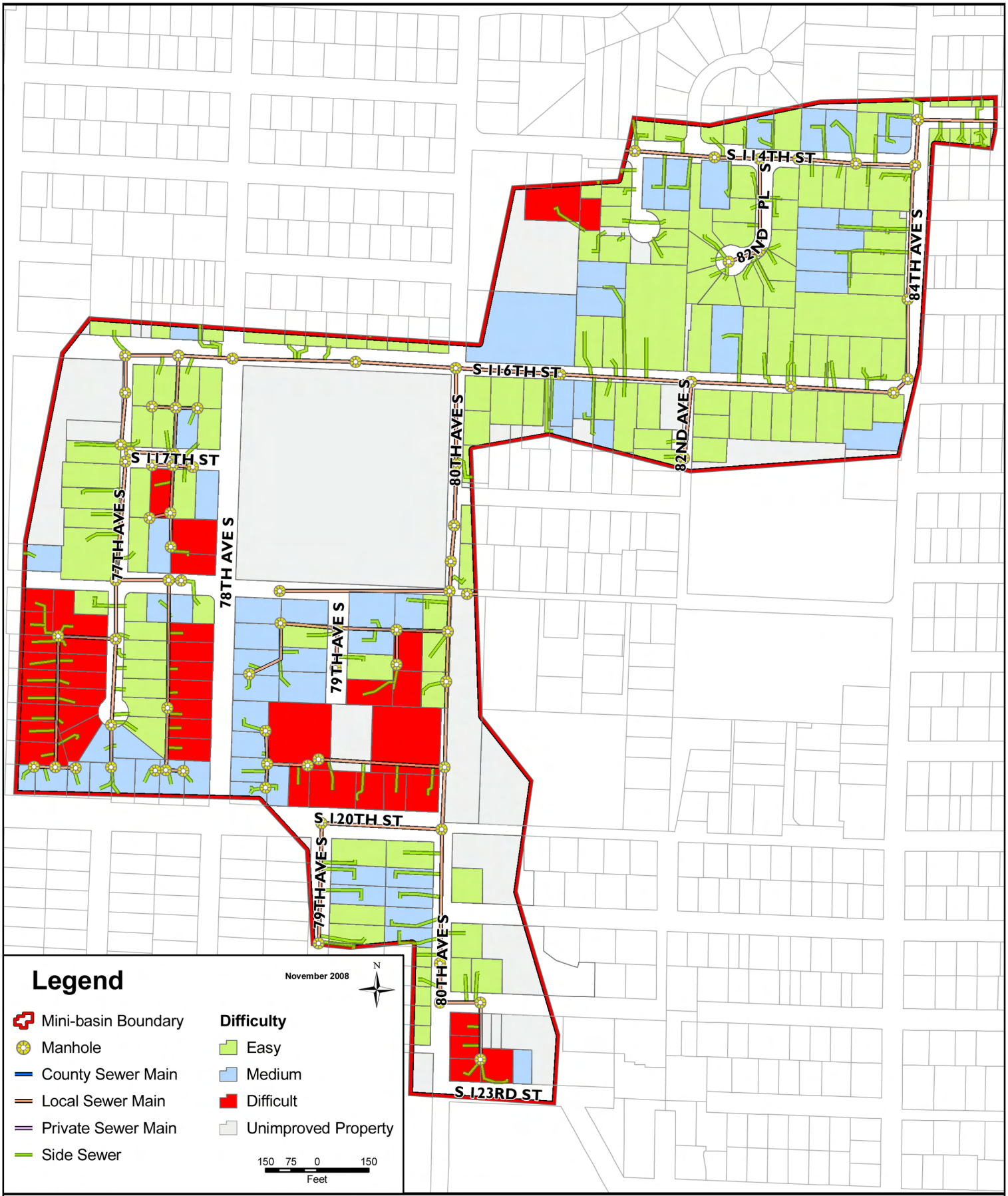
Department of Natural Resources and Parks
Wastewater Treatment Division

File Name: K:\kingco_ii\Skyway\BLS002_difficulty_reportfig

Data Source: King County

Figure 7-3
Mini-Basin BLS002
Parcel Difficulty Ratings
Initial Infiltration and Inflow Reduction Alternatives Analysis Report



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Data Source: King County

Figure 7-4
Mini-Basin BLS003
Parcel Difficulty Ratings
Initial Infiltration and Inflow Reduction Alternatives Analysis Report

7.2 PERMITTING

Several local permits will be required for the proposed project, as summarized in Table 7-2. Because no earthwork in wetlands or streams is anticipated for the recommended projects, the National Pollutant Discharge Elimination System permit is the only state permit required for the project and no federal permits are required. However, if the projects change and work in wetlands or streams is proposed in any of the basins, one or both of two other state permits would be required, as well as one federal permit from the U.S. Army Corps of Engineers. Table 7-3 summarizes state and federal permits that would be required in any basin where work in wetlands or streams was required. Further discussion of each permit is included in Appendix D.

7.3 RIGHTS OF ENTRY

A right-of-entry agreement (ROE) will be required from the property owner before rehabilitation can occur on an individual property. The simple agreement allows the county and its contractor access to a property to perform rehabilitation. Areas disturbed by construction are required to be restored in kind per the agreement. Although simple, the ROE gathering process can be time-consuming. Multiple contacts with property owners are often required before an ROE is attained.

The recommended projects include rehabilitation of approximately 565 individual properties, making the ROE gathering process a key element of project implementation. Experience on the pilot projects showed that not all property owners are willing to allow access; therefore the ROE process should target 5 to 10 percent more properties than needed for implementation. Property owners who are not agreeable to having work done on their property can then be removed from the project, and replaced with a willing property owner. Attaining sufficient ROEs will likely be most critical in Mini-Basin ISS003, as it is anticipated that the number of key target properties with high I/I levels will be lowest in this mini-basin.

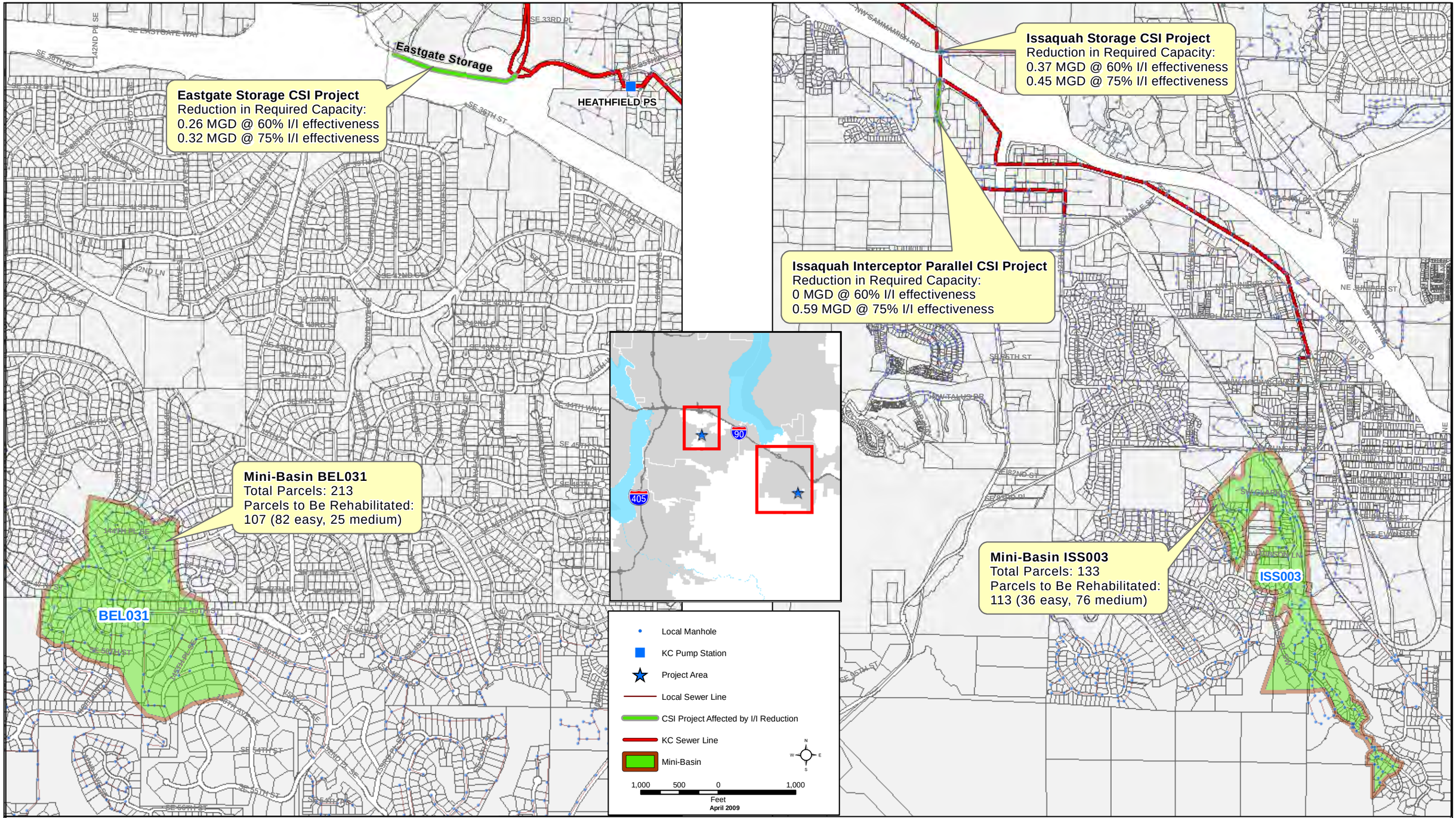
The following are typical issues that often must be addressed to attain ROEs:

- The agreement typically allows work to be accomplished over a time period of one year, but property owners often want a more definitive idea of when their property will be impacted.
- Property owners should be told what type of rehabilitation will be used and what disturbance will occur on the property.
- Residents where English is not the primary language spoken must be identified to assist in communication requirements.
- Property owners may place conditions on the agreement. For instance, a property owner may have specific concerns regarding disturbance of particular surface improvements or landscaping features that need to be addressed in the agreement.

A database tool has been created to facilitate the tracking process for ROEs that will need to be attained. The database will log which properties are targeted for ROEs; where ROEs have been attained; and any special conditions that may be attached to the agreement.

TABLE 7-2.
LOCAL PERMITTING REQUIREMENTS

Permit	Supporting Documents	Permit Application	Issuing Agency	Time to Prepare and Submit Application	Estimated Time of Permit Issuance
Shoreline Management Act Review	Ordinary High Water Mark Delineation	Shoreline Substantial Development Permit application	King County (Mini-Basin BLS002), City of Issaquah (Mini-Basin ISS003),	5 to 6 weeks after 70 percent design is complete	5 months
State Environmental Policy Act/ Critical Areas Review	Wetland Delineation, Wetland and Stream Mitigation, design and grading plans, temporary erosion and sediment control plan, Cultural Resources report (may not be required), and geotechnical report	State Environmental Policy Act Checklist	King County	5 to 6 weeks after 70 percent design is complete	45 days after application is deemed complete
Grading Permit	Grading plan and temporary erosion and sediment control plan	Clearing and Grading Permit Application	King County (Mini-Basin BLS002), City of Issaquah (Mini-Basin ISS003), City of Bellevue (Mini-Basin BEL031)	2 weeks	Reviewed concurrently with State Environmental Policy Act
Street Use Permit	Traffic Control Plan	Street Use Permit Application	King County (Mini-Basin BLS002), City of Issaquah (Mini-Basin ISS003), City of Bellevue (Mini-Basin BEL031)	2 weeks	2 to 3 weeks
Side Sewer Permit	---	Side Sewer Permit Application	Skyway Water and Sewer District (Mini-Basin BLS002), City of Issaquah (Mini-Basin ISS003), City of Bellevue (Mini-Basin BEL031)	2 weeks after rights of entry are obtained	2 to 3 weeks



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File Name: dnrp1:\\wtd\projects\II_Initial_Project\ project\TechReport\Reduction_BEL_ISS_B.mxd - peter keum
Data Source: King County & Tetra Tech inc.

Figure 7 - 5

Initial I/I Reduction Project BEL/ISS-B

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: dnrp1:\\wtd\projects\II_Initial_Projec\project \TechReport\Skyway_ProjectArea.mxd - peter keum
Data Source: King County

Figure 7 - 6

Initial I/I Reduction Project BLS - F

Initial Infiltration and Inflow Reduction Alternatives Analysis Report

TABLE 7-3.
POTENTIAL STATE AND FEDERAL PERMITTING REQUIREMENTS

Permit	Supporting Documents	Permit Application	Issuing Agency	Time to Prepare and Submit Application	Estimated Time of Permit Issuance
National Pollution Discharge Elimination System (for construction)	Temporary Erosion and Sediment Control Plan	Storm Water Pollution Prevention Plan	Washington Department of Ecology	typically prepared and submitted by contractor	30 days
Hydraulic Project Approval	Stream Mitigation Plan and State Environmental Policy Act determination	Joint Aquatic Resource Permits Application	Washington Department of Fish & Wildlife	5 to 6 weeks after 70 percent design is complete	45 calendar days after the application is deemed complete and State Environmental Policy Act compliance is complete
Section 404 Permit (Biological Assessment to be included in Joint Aquatic Resource Permits Application submittal)	Wetland Delineation, Wetland and Stream Mitigation, and Biological Assessment	Joint Aquatic Resource Permits Application	U.S. Army Corps of Engineers	5 to 6 weeks after 70 percent design is complete	4 to 12 months, depending on project complexity
Section 401 Permit and Coastal Zone Management Act approval	Wetland Delineation and Wetland and Stream Mitigation	Joint Aquatic Resource Permits Application	Washington Department of Ecology	5 to 6 weeks after 70 percent design is complete	3 months

7.4 AGENCY COORDINATION

The recommended projects must be considered in the context of local agency planning and capital projects. Examples of this include opportunities for incorporating planned overlays or improvements by the local agencies to realize greater economy, or scheduling I/I work to minimize impacts on residents where separate local agency work is planned. King County should also expect to share with each local agency the SSES and mapping work that was performed for this alternatives analysis. The following sections describe specific agency coordination issues for the Initial I/I Reduction projects.

7.4.1 Eastgate

The following coordination issues would apply to work in Eastgate Mini-Basin BEL031:

- Coordinate with City of Bellevue Transportation Department to implement roadway overlays required for the streets in the mini basin. Overlay of the streets is required following any project that includes street trenching.
- Coordinate with City of Bellevue Utilities Department regarding potential storm drainage improvements in the area to avoid conflicts and possibly schedule work prior to overlays.

- A small segment of the southeast corner of the mini-basin is in unincorporated King County. King County Roads has near-term plans to overlay a short segment of roadway in the mini-basin along SE 51st Street. Coordinate with the County to postpone potential pavement overlay work planned for the area until the end of the sewer project.
- Coordinate with City of Bellevue Utilities Department for planned replacements of portions of AC water main in the mini-basin. The Department does not plan for this replacement work to take place in the short term. However, as the I/I project would trigger overlaying of the roadways, the Department would move the replacement project up in its schedule to accomplish the work prior to any overlay work.
- Coordinate with Bellevue Utilities Department regarding communication with district customers about direct disconnects. While the Department has no formal policy regarding this at this time, the Department understands and supports the need for disconnects and intends to help facilitate this process.
- Share SSES data and mapping with the City.

7.4.2 Issaquah

The City of Issaquah has indicated that there are no plans for pavement overlays or utility work within Mini-Basin ISS003 that would require coordination with this project. The City has expressed an interest in the following coordination issues:

- A city council briefing to explain the findings and recommendations of the alternatives analysis.
- Sharing SSES data and mapping with the City.
- A discussion of appropriate rehabilitation techniques to be used.

7.4.3 Skyway

King County Roads has near-term plans to overlay two short segments of roadway in Skyway Mini-Basin BLS002; one segment along Cornell Avenue South and a segment along Laurel Lane South. The following coordination issues would apply to work in this mini-basin:

- Coordinate with King County Roads regarding potential storm drainage improvements in the area to avoid conflicts and possibly schedule work prior to any overlays associated with the storm drainage improvements.
- Coordinate with King County Roads to postpone potential pavement overlay work planned for the area until the end of the sewer project.
- Coordinate with Skyway Water and Sewer District regarding:
  - Communication with district customers with respect to direct disconnects; the District intends to enforce disconnections.
  - Cost sharing for proposed District additions to work (sewer mains and manholes).
  - Sharing SSES data and mapping with the District.

7.5 COMMUNITY RELATIONS

Because the Initial I/I Reduction projects will involve extensive work on private property, a detailed community relations plan will be prepared for each affected mini-basin in consultation with the respective local agencies. The community relations plans will take the following considerations into account:

- The goal of community relations is to support the successful design and implementation of the Initial I/I Reduction projects by providing project information to the public and identifying and responding to community concerns and input.
- A high level of community relations work will be required during the design and construction phases of projects because of the complexity of the projects and their impact on hundreds of private properties.
- The projects will occur primarily in residential areas, although some businesses and public institutions may be included.
- Foreign languages may be the primary languages spoken in some households. This will be an important consideration in developing public information materials and planning public events as well as potentially making door-to-door visits.
- Objectives of the community relations work include:
  - Explain the respective roles and responsibilities of King County and the local agencies.
  - Explain the purpose of the projects.
  - Explain the source of funding for the projects.
  - Explain the benefits of side sewer replacement to property owners.
  - Explain the criteria that King County will use to select properties and why some properties will receive free side sewer replacement while others will not.
  - Partner with the local agencies to develop informational materials, plan public meetings, and coordinate communication with affected property owners.
- Community relations activities will include developing and distributing public information materials, holding public meetings, maintaining a project website, and responding to public inquiries.
- To support the collection of rights of entry, it will be necessary to maintain good records of communication with the public and to establish clear communication protocols for the project team.
- It may be possible to draw from the experiences of property owners who received side sewer rehabilitation during King County's I/I pilot projects.

Each mini-basin is briefly described below with references to potential community relations issues, challenges, and opportunities.

7.5.1 Eastgate Mini-Basin BEL031

Owners of residential properties are the key target audience for this project in Mini-Basin BEL031. Neighborhood, community and homeowner associations are prevalent in the Eastgate area of Bellevue, and those that represent property owners in BEL031 will be targeted for outreach. Preliminary research indicates the following:

- The entire basin is within Bellevue city limits.
- The majority of properties are single-family residences.
- This basin may include higher end properties with landscaping that will be costly to replace.
- English is the primary language spoken in the mini-basin.

The goal of this project is to rehabilitate side sewers on 107 of 213 properties in BEL031. Because of steep slopes and other challenging topography in the mini-basin, there are limited properties that lend themselves to I/I rehabilitation. It will be critical to have as much participation as possible from the targeted property owners.

7.5.2 Issaquah Mini-Basin ISS003

Owners and residents of residential properties are the key target audience for this project in Mini-Basin ISS003. Preliminary research indicates the following:

- The entire basin is within Issaquah city limits.
- The majority of properties are single-family residences and condominium/apartment complexes.
- The area immediately to the east of the basin is zoned for retail uses. Construction impacts on local roads may be of interest to businesses in this area.
- English is the primary language spoken in the mini-basin, but there may be some households where Spanish is the primary language spoken.
- Issaquah Creek flows through the mini-basin. The community is very interested in the health of Issaquah Creek, particularly in its role as a salmon-bearing stream. The mini-basin is immediately adjacent to the Issaquah Salmon Hatchery on Issaquah Creek. Local citizens may have concerns about the impacts of I/I rehabilitation work on the creek.
- Tree preservation is important to this community.

The project goal is to rehabilitate side sewers on 113 of 133 properties in ISS003. It will be critical to have as much participation as possible from the targeted property owners.

7.5.3 Skyway Mini-Basin BLS002

Owners and residents of residential properties are the key target audience for this project in Mini-Basin BLS002. This mini-basin is located in unincorporated King County.

The Skyway Water and Sewer District collected ROE agreements and managed the side sewer rehabilitation work done as part of the 2003 pilot project. The project team needs to be aware of perceived surface water issues that have emerged since the pilot project was completed. Mini-Basin BLS002 is adjacent to the pilot project area and it is likely that some property owners in Mini-Basin BLS002 are aware of this problem.

Preliminary research indicates that English is the primary language spoken in the mini-basin, but that a small percentage of Skyway area residents do not speak English well. The project team will coordinate closely with the Skyway Water and Sewer District to identify the most appropriate methods of communication.

The project goal is to rehabilitate side sewers on 343 of 386 properties in BLS002. It will be critical to have as much participation as possible from the targeted property owners.

7.6 RISK MITIGATION

Risk assessment is the identification of potential events that would have a negative impact on a project. A risk analysis consists of three parts—risk identification, qualitative assessment of risk impacts and

probability, and quantitative risk assessment. Risk assessment for the Initial I/I Reduction project was developed by consensus of King County and design team staff at a series of workshops.

7.6.1 Risk Identification

Risk assessment workshop participants identified 48 potential risks for the proposed I/I removal improvements in the following general categories:

- Right of way, easement and property acquisition (six risks identified)
- Permit acquisition (four risks identified)
- Environmental and public impact (four risks identified)
- Engineering and design (four risks identified)
- General construction and sub-surface site issues (16 risks identified)
- Contracting (one risk identified)
- Public relations and community action (nine risks identified)
- Safety and security (one risk identified)
- Policy (three risks identified).

7.6.2 Qualitative Assessment of Probability and Impact

Workshop participants reviewed all identified risks and, by consensus, assigned each two qualitative ratings:

- Potential Impact Rating—The potential overall project impact of each risk was rated as low (L), medium (M) or high (H) based on consideration of how the risk would affect project cost, schedule, scope and quality.
- Probability Rating—The likelihood of each risk occurring was rated as low (L), medium (M) or high (H) based on workshop participants' experience.

7.6.3 Quantitative Risk Assessment

The quantitative assessment of risk-related cost was performed only for the risks that had received medium or high qualitative ratings for both potential impact and probability. For these risks, workshop participants assigned a specific percent probability of the risk occurring and then developed estimates of the potential cost associated with occurrence of the risk. This "impact cost" was multiplied by the risk's probability to calculate a "risk cost." The complete results of the risk identification, qualitative assessment and quantitative assessment are included in Appendix E.

7.6.4 Risk Mitigation

Risks can be mitigated by eliminating them, reducing their probability of occurrence, or reducing their potential impacts:

- Risk Elimination—Aggressive, proactive mitigation for high risks is essential to achieve the full benefits of risk management. It is preferred that critical risks be eliminated entirely, as they will have the greatest negative impact on the project. Risk elimination requires carrying out the necessary actions to completely remove the identified issue from the project.
- Risk Reduction—A reduction of the likelihood of occurrence or lessening of the impact can be attained by actions early in the project.

Suitable mitigation measures for risks with medium or high impact potential and probability were developed by the workshop participants. Table 7-4 lists these risks, their qualitative ratings, their risk cost, and potential mitigation measures.

7.6.5 Risk Mitigation Conclusions

Although a number of significant risks to achieving cost-effectiveness were identified, the consensus among King County staff, the project team and the E&P Subcommittee is that these risks are tolerable. One of the primary objectives of the Initial I/I Reduction projects is to prove whether I/I reduction can be cost-effective on a more large-scale basis than tested during the pilot projects. Project implementation will provide more definitive results on the validity of these risks and whether they can be overcome; and will provide a baseline for future I/I control efforts by the county.

7.7 RECOMMENDATION SUMMARY AND NEXT STEPS

The alternatives analysis identified two alternatives to be implemented as initial I/I reduction projects and estimated key costs and I/I reduction results for each:

- Eastgate/Issaquah Alternative BEL/ISS-B would rehabilitate 85 percent of laterals and side sewers in Mini-Basin BEL031 and 50 percent in Mini-Basin ISS003, at an estimated project cost of $5.23 million. The results of this project, depending on I/I reduction effectiveness, are estimated as follows:
  - 60-percent effectiveness—I/I reduction of 0.85 mgd; Eastgate Storage size reduction of 0.26 MG; Issaquah Storage size reduction of 0.37 MG; CSI project cost savings of $5.12 million
  - 75-percent effectiveness—I/I reduction of 1.04 mgd; Eastgate Storage size reduction of 0.32 MG; Issaquah Storage size reduction of 0.45 MG; Issaquah Interceptor size reduction of 0.59 mgd; CSI project cost savings of $6.37 million
- Skyway Alternative BLS-F would rehabilitate 89 percent of laterals and side sewers in Mini-Basin BLS002, at an estimated project cost of $5.63 million. The Skyway Water and Sewer District will contribute up to $260,000 to make this project cost-effective. The results of this project, depending on I/I reduction effectiveness, are estimated as follows:
  - 60-percent effectiveness—I/I reduction of 1.88 mgd; elimination of the Bryn Mawr Storage project; CSI project cost savings of $5.37 million
  - 75-percent effectiveness—I/I reduction of 2.29 mgd; elimination of the Bryn Mawr Storage project; CSI project cost savings of $5.37 million

TABLE 7-4.
MEDIUM- AND HIGH-RATED RISK ELEMENTS AND MITIGATION MEASURES

Risk Element	Probability /Impact Rating	Risk Cost	Potential Risk Mitigation / Response
Sufficient rights-of-entry for low and medium properties are not attained, requiring higher difficulty properties to be rehabbed, at a higher cost.	M/H	$183,040	• Obtain sufficient rights-of-entry to allow for addition of properties to reach reduction targets.
Sufficient rights-of-entry are not attained for the planned amount of private property rehabilitation. Project cannot proceed to implementation. (Skyway only)	H/H	$250,000	• Obtain sufficient rights-of-entry to allow for addition of properties to reach reduction targets.
I/I is not uniformly distributed across project areas as assumed; and reduction targets are not achieved in the project area.	M/H	$471,375 (Eastgate, Issaquah) $410,250 (Skyway)	• Work in additional areas to get a greater I/I reduction. Determine during design if this would be cost-effective. • Continue to compare I/I project to capital projects during design to check for cost-effectiveness.
I/I removal targets in mini-basins are achieved; however, a lesser reduction rate at the location of the downstream CSI project is realized because additional flows enter the system from other tributary areas	M/H (Eastgate, Issaquah) H/H (Skyway)	$471,375 (Eastgate, Issaquah) $820,500 (Skyway)	• Work in additional areas to get a greater I/I reduction. Determine during design if this would be cost-effective. • Continue to compare I/I project to capital projects during design to check for cost-effectiveness. • Obtain sufficient rights of entry to allow for addition of properties to reach reduction targets.
Peak I/I rates have been over-estimated in a mini-basin selected for implementation. Following rehabilitation, target reductions are not achieved (Eastgate & Issaquah)	M/M	$377,100	• Perform more metering throughout the mini-basin and refine the model. Ensure that modeling results have been verified with real-world rainfall and flow measurement data. • Work in additional mini-basins to get a greater I/I reduction. Determine during design if this would be cost-effective. • Continue to monitor and model flows during design to gain greater confidence in flow estimates. • Continue to compare I/I project to capital projects during design to check for cost-effectiveness.
High Bids	M/M	$210,000	• Early bid and award timing before contractors are booked for upcoming construction season. • Bid marketing, advance notice to contractors. • Structure bid packages to allow for release of smaller packages to more contractors if necessary.

Estimates and project details will be refined through the predesign process in 2009 and the final design in 2010. The predesign will identify exact parcels for rehabilitation and confirm the preferred construction method. During final design, contract documents will be prepared, rights of entry will be acquired, and the public participation program will be carried out. Construction of the projects will take place in 2011 and 2012.

As projects intended to demonstrate the feasibility of I/I reduction measures for future use county-wide, the Initial I/I Reduction projects will require detailed post-project evaluation to determine their effectiveness and identify the strengths and weaknesses of the approach developed in this alternatives analysis. The post-project evaluation will be performed in 2013, and will include the following:

- New flow monitoring will assess the actual impacts on I/I due to implementation of the recommended projects. King County staff will place flow meters in the mini-basins and monitor flow conditions over a winter season. The resulting data will be used to recalculate per-parcel I/I in each mini-basin and the net flow reduction at the upstream end of affected CSI projects. These results, together with final project costs, will be used to recalculate benefit/cost ratios. Unit costs for individual elements of the I/I reduction work, stormwater work required during or shortly after construction, and allied costs will be documented for the benefit of future I/I reduction projects.
- King County, local agency and design consultant staff will hold a debriefing meeting to assess the outcome of project implementation for each mini-basin. Lessons learned and comments from these meetings will be documented. The design consultant will prepare a post-project evaluation report providing a description of each initial project, and documenting lessons learned during the SSES and the alternatives analysis. Lessons learned will be documented and evaluated for their value to future King County I/I Program rehabilitation work. The report will present recommendations based on these lessons learned for application in future I/I reduction projects.
- A list of rehabilitated sewer system components for warranty inspection will be prepared, based on problems identified by local agencies, potential problems noted by construction inspectors during construction, and a random sampling of work done in all the project areas. An SSES contractor will perform the warranty inspections. This work will identify a list of defects and their severity so that repair work can be carried out. Defects and repairs will be identified and documented in a warranty inspection report. Warranty inspection and repairs will take place two years after completion of the Initial I/I Reduction projects.

Results of the post-project evaluation will be presented to the King County Executive for review in 2013, and the executive will submit recommendations to the County Council in 2013.

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