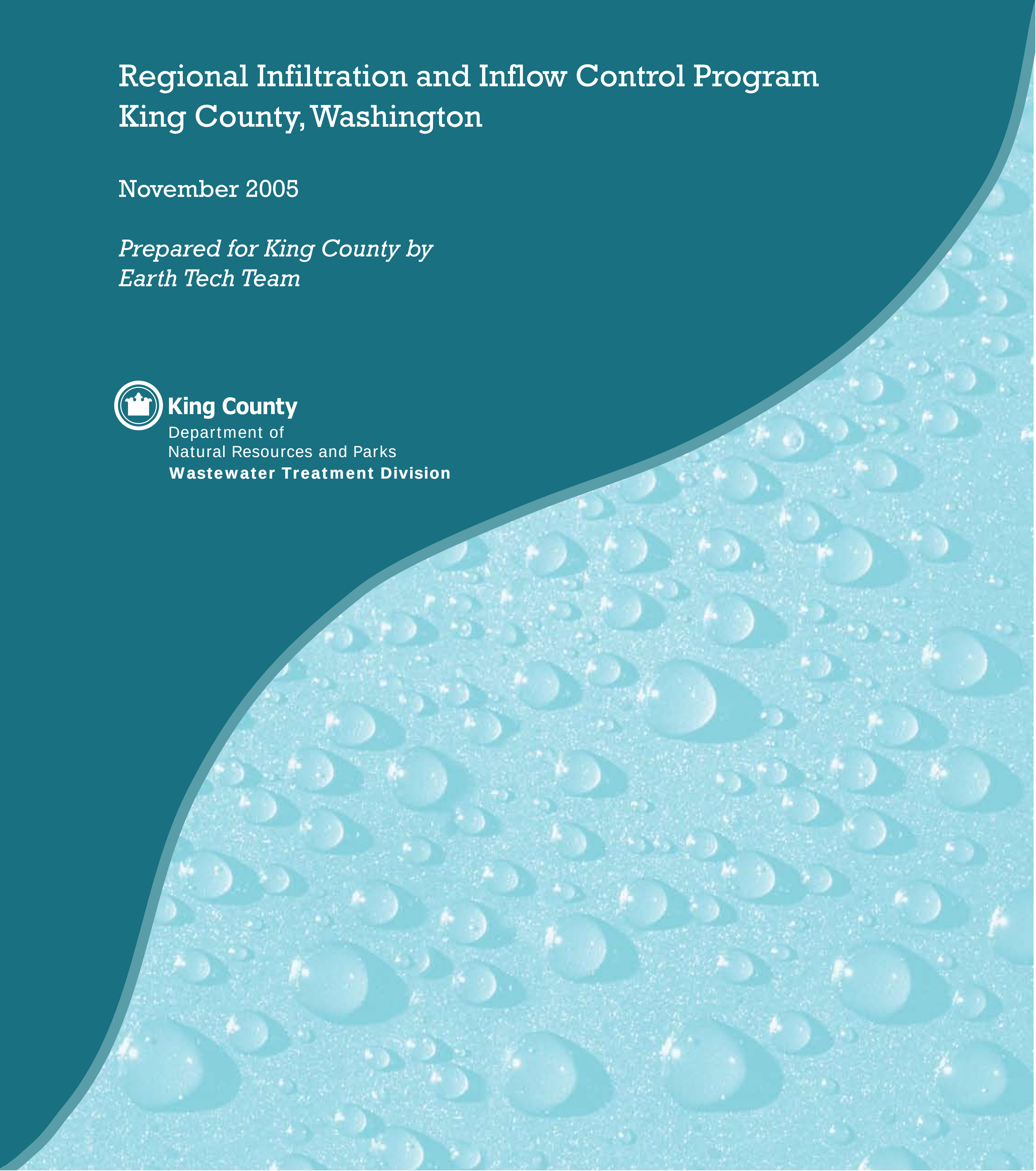
BENEFIT/COST ANALYSIS REPORT

Regional Infiltration and Inflow Control Program
King County, Washington

November 2005

Prepared for King County by
Earth Tech Team

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division



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Note: the appendices are model output data.

Acronyms and Abbreviations

B/C Tool	benefit/cost analysis tool
BI	base infiltration
CALAMAR	*Calcul de lames d'eau a l'aide du radar* (calculating rain with the aid of radar)
CSI	conveyance system improvement
DD	direct disconnect
DHI	Danish Hydraulic Institute
E&P	Engineering and Planning (Subcommittee of MWPAAC)
ETS	extended time series
FRC	Fast response component
GIS	Geographic Information System
gpad	gallons per acre per day
I/I	infiltration/inflow
km	kilometer
LOC	level of confidence
lf	linear foot
Metro	Municipality of Metropolitan Seattle
MG	million gallons
mgd	million gallons per day
MOUSE	Modeling of Urban Sewers (software by DHI)
MWPAAC	Metropolitan Water Pollution Abatement Advisory Committee
PS	pump station
RI	rapid infiltration
RNA	Regional Needs Assessment
RWSP	Regional Wastewater Services Plan
Sea-Tac	Seattle-Tacoma International Airport
SI	slow infiltration
SRC	slow response component

SS	side sewer
ULID	Utility Local Improvement District
WWTP	wastewater treatment plant

Chapter 1

Executive Summary

In December 1999, the King County Council approved the development of a Regional Infiltration and Inflow (I/I) Control Program as part of the Regional Wastewater Services Plan (RWSP). The purpose of controlling I/I is to reduce the amount of flow, thereby reducing the costs of conveying and treating wastewater. When excess I/I is present in separated sewer systems (those that are designed to carry only sewage), it takes up capacity that is needed for wastewater. In the regional system, as much as 75 percent of the flow in the conveyance system during storms (times of peak flow) is from I/I. Conveying these additional flows can drive the need for enlarging and replacing conveyance facilities (pipes and pump stations), even though this capacity is not needed all the time. If cost-effective methods for controlling I/I can be implemented, capital costs can be reduced by eliminating, delaying, or phasing conveyance system improvements.

Infiltration is subsurface flow, or groundwater, that seeps into sewers through holes, breaks, joint failures, defective connections, and other openings. Infiltration can occur throughout the year, but volumes are typically greater after large storms or prolonged wet weather periods.

Inflow is storm-related surface water that enters the sewer system via roof downspouts, yard and shallow foundation drains, catch basins, leaking manhole covers, and other sources.

In 2000, the County's Wastewater Treatment Division, in cooperation with the local component agencies that it serves, launched a 6-year, $41 million I/I control study. The study included efforts to identify sources of I/I, test the effectiveness of various I/I control technologies, prepare a regional plan for reducing I/I in local agency collection systems, and develop I/I program alternatives. These efforts provided data for conducting the benefit/cost analysis.

Completing the benefit/cost analysis of I/I reduction projects marks a major milestone in the study. The following text describes how the benefit/cost analysis was performed and the results that were achieved.

1.1 What is the Benefit/Cost Analysis?

As part of its Regional Needs Assessment, the County developed a list of conveyance system improvement (CSI) projects. These projects will help accommodate the increasing wastewater flows brought about by growth. To make the most effective use its resources, the County evaluated whether it is cost effective to eliminate or delay projects on the CSI Project List by reducing the amount of I/I in the conveyance system. The benefit/cost analysis compared the estimated costs of constructing conveyance system improvement projects with the estimated costs of I/I reduction projects.

1.2 What Information was Used for the Benefit/Cost Analysis?

To conduct the benefit/cost analysis, information was needed that could be used to address:

- The anticipated effort and cost necessary to reach target levels of I/I reduction.
- The capacity and cost-savings effects of proposed I/I reduction on the regional conveyance system.
- The cost effectiveness of implementing I/I reduction projects compared with the costs of regional conveyance system improvements.

The County and local agencies worked together to obtain this information and to develop assumptions about I/I reduction. The benefit/cost analysis used the information collected and tools developed for the Regional I/I Control Program between 2000 and 2005, including:

- **Physical characteristics of local agency collection systems** – including the size, age, material and location of pipes; points of connection between local agency and regional conveyance systems; boundaries and acreage served; topography; and land use.
- **Rainfall data** – to help understand patterns in I/I flows after storms, as well as the relationship between measured rainfall and wastewater flows.
- **Flow monitoring** – to determine the geographic distribution of I/I throughout the local agency facilities tributary to the County's collection system, to quantify I/I levels, and to subdivide the entire system of local agency sewer lines into geographic areas called mini-basins and model basins.
- **Hydrologic model** – to simulate the physical process of how rainfall ends up as I/I.
- **Hydraulic model** – to simulate the actual pipes that convey wastewater flows and I/I, and to evaluate how the system performs under existing and future demands.
- **Pilot projects** – to demonstrate the County's success in finding and reducing I/I and to obtain "lessons learned" information.
- **Regional needs assessment** – to establish the extent of required capacity improvements and to estimate the costs associated with planning, design, and construction of conveyance system improvements.
- **Assumptions** – to establish target I/I reduction levels and to agree upon what I/I reduction levels could be achieved and the associated costs.
- **Techniques** – to develop a means of decreasing I/I by replacing or rehabilitating selected components of the sewer system (for example, disconnecting and re-routing downspouts that connect to the sewer system).
- **Alternatives** – to develop a recommended I/I program for defining a target level of I/I, to determine how cost-effectiveness is measured, and to address funding options.

1.3 What is Cost Effectiveness and How was it Determined?

To evaluate cost effectiveness, a benefit/cost ratio was calculated for each of the planned conveyance system improvement projects:

Benefit/Cost Ratio = (CSI Project Savings after I/I Reduction) / (Cost of Proposed I/I Reduction Project)

A proposed I/I project was considered cost effective if the CSI savings resulting from the I/I reduction project were greater than the cost of the I/I reduction. All cost-effective projects had a benefit/cost ratio greater than 1.

A database analysis tool, the Benefit/Cost Analysis Tool, was specifically developed for the Regional I/I Control Program. It was used in association with the County's TABULA cost estimating software to compare reductions in capital costs (if any) to the cost of I/I rehabilitation. Inputs into these tools included information about the physical characteristics of the collection system, technique selected for reducing I/I, cost assumptions, results of hydraulic modeling, and information about upstream and downstream facilities.

Other factors that affected the cost effectiveness of a project included the level of confidence in the data and whether or not a threshold level of flow reduction was achieved.

1.4 What were the Results of the Benefit/Cost Analysis?

As shown in the table, nine I/I reduction projects were identified by the benefit/cost analysis as cost effective. For these projects:

- The estimated cost of implementing the I/I reduction projects is approximately $73 million.
- The anticipated I/I reduction achievable is estimated at 22 million gallons per day (mgd), or approximately 5 percent of the I/I present in the entire regional service area.
- As a result of reducing I/I flows, it is estimated that the capital cost for nine impacted regional conveyance facility improvement projects could be reduced from approximately $268 million to $164 million, resulting in regional conveyance facility improvement savings of nearly $104 million.
- The net overall savings realized from implementing the nine cost-effective I/I reduction projects is estimated at approximately $31 million.

Project (Facility)	I/I Available (mgd)[1]	I/I Reduction (mgd)[1]	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
South Renton Interceptor (RE*SRENTON.R18-16(9))	7.0	0.81	$7,270,000	$2,217,645	3.3
ULID 1 Contract 4 (RE*ULID 1-4.S-31(8))	5.5	1.08	$2,410,000	$999,123	2.4
Auburn 3 New Storage (Auburn3 Twin Tube Storage)	52.8	6.87	$22,990,000	$11,362,511	2.0
Issaquah 2 Trunk (RE*ISSAQ2.R17-40(3))	5.4	1.05	$5,770,000	$3,964,850	1.5
Bryn Mawr Storage (Bryn Mawr Tube Storage)	16.2	2.04	$8,510,000	$6,018,534	1.4
Lk Hills Trunk 3rd Barrel Upgrade (WE*LKHILLST.ENTR(3))	10.8	2.20	$14,438,000	$11,307,052	1.3
Eastgate Storage and Trunk (Eastgate Tube Storage)	8.7	3.55	$16,629,000	$14,459,862	1.2
Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-05(7))	10.4	2.39	$12,058,000	$10,550,378	1.1
Garrision Creek Trunk (RE*ULID 1-5.57I(10))	5.7	2.12	$13,660,000	$12,013,489	1.1

[1]million gallons per day

1.5 What's in the Report?

The following chapters provide more information about the benefit/cost analysis. Chapter 2 provides background and introduction to the benefit/cost analysis. Chapter 3 describes the data sources that contributed to the benefit/cost analysis and how the information was used. Chapter 4 describes the benefit/cost analysis. Chapter 5 summarizes the results of the benefit/cost analysis.

The appendices, which are included on a CD, contain detailed information that supports the material presented in the chapters.

Chapter 2

Introduction

This report documents the process and procedures used to evaluate the cost effectiveness of including infiltration/inflow (I/I) reduction projects as part of King County's conveyance system improvement (CSI) program, as called for in the Regional Wastewater Services Plan (RWSP). The CSI program identified a list of capital facility improvements that are needed to accommodate the increasing levels of wastewater flows due to changing conditions in the regional service area. One of these changes is the escalating level of I/I that enters the regional conveyance system during wet weather periods.

Figure 2-1 shows the major sources of I/I. The box below includes definitions of *infiltration* and *inflow*. To provide a consistent basis for comparing the benefits and costs of I/I reduction projects to the benefits and costs of CSI projects, data from wastewater system flow monitoring, hydrologic and hydraulic models, and pilot I/I reduction projects were collected and assumptions were developed. A database-driven benefit/cost analysis tool was developed and used to analyze these data and assumptions and to identify candidate cost-effective I/I reduction projects for additional review and consideration. Candidate I/I reduction projects were considered cost effective when the total estimated CSI project savings after I/I reduction was greater than the total estimated cost of the I/I reduction.

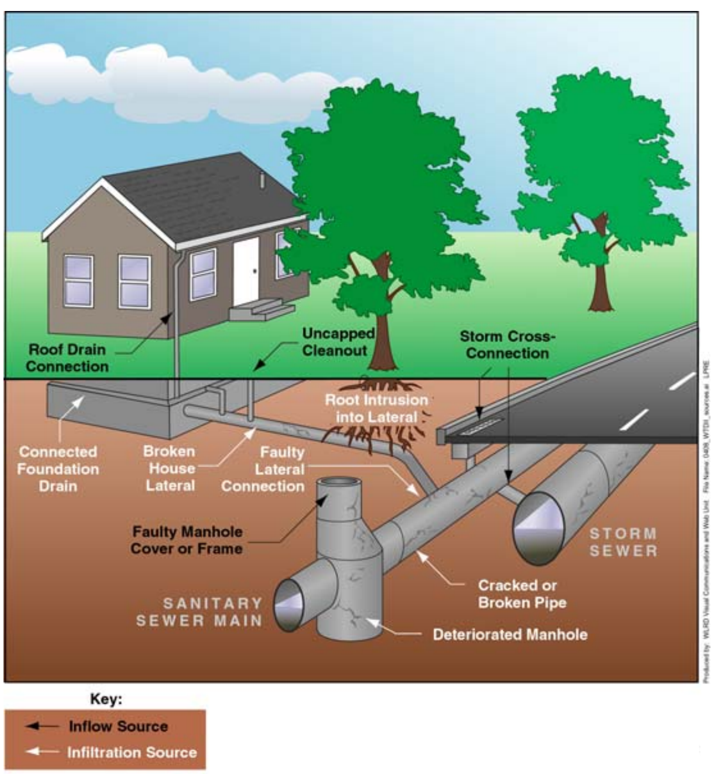

Figure 2-1. Sources of Infiltration and Inflow

Infiltration is subsurface flow, or groundwater, that seeps into sewers through holes, breaks, joint failures, defective connections, and other openings. Infiltration can occur throughout the year, but volumes are typically greater after large storms or prolonged wet weather periods.

Inflow is storm-related surface water that enters the sewer system via roof downspouts, yard and shallow foundation drains, catch basins, leaking manhole covers, and other sources.

Figure 2-1 shows the sources of infiltration and inflow.

2.1 Background

In December 1999, the King County Council approved the development of a Regional I/I Control Program as part of the RWSP. The purpose of the program is to reduce the risk of sanitary sewer overflows and the cost of adding capacity to facilities that convey wastewater to County treatment plants.

In 2000, the County's Wastewater Treatment Division, in cooperation with the local component agencies that it serves, launched the 6-year I/I control study. The study included efforts to identify sources and quantities of I/I within the regional service area, test the effectiveness of various I/I control technologies to reduce I/I, examine the benefits and costs of implementing I/I reduction measures, and prepare a regional plan for reducing I/I in local agency collection systems.

The benefit/cost analysis was completed in July 2005. The results of the analysis were incorporated into the *Executive's Preferred Plan* for reducing I/I in the County service area.

2.1.1 Regional System

The County's regional wastewater system serves approximately 1.4 million residents within a 420-square-mile service area encompassing portions of King, Snohomish, and Pierce counties. It is a large, integrated wastewater collection, conveyance, and treatment system operated by the County and 34 cities and local sewer districts collectively referred to as the local agencies. The regional conveyance system includes pipes, pump stations, and other facilities that were built as early as 1900, and substantial additions remain underway. Design standards and growth projections change over time, and this is reflected in various portions of the conveyance system.

Historically, conveyance and treatment facilities in the County service area have experienced significant I/I flows during the October-to-March wet season. I/I has a significant impact on the capacity of the regional wastewater conveyance and treatment systems because it is the largest contributor to the wastewater volumes that must be conveyed and treated during the wet season. Approximately 75 percent of the region's peak flows in the separated conveyance system is from I/I[1]. This additional volume due to I/I requires the County to develop and provide increased wastewater conveyance and treatment capacity in order to remain in compliance with regulatory agency requirements and permitting. This requires that conveyance system pipelines and treatment plants be built large enough to accommodate the high flows resulting from I/I even though this maximum capacity is not needed all the time. Updated capacity assessments and projected new conveyance facility needs were developed as part of the Regional Needs Assessment and are summarized in Section 3.2.4.9 and Table 3-12[2].

[1] *Regional Wastewater Services Plan, Executive's Preferred Plan*; April 1998, Page 14.
[2] For more detailed information about projected conveyance facility needs, see the *Regional Needs Assessment Report* (March 2005).

2.1.2 Local Agency Systems

Approximately 95 percent of the I/I discharging to the regional conveyance and treatment systems originates in collection systems owned by the local agencies and from the residents and businesses they serve. Approximately 50 percent of the I/I contributed from the local agencies is estimated to come from leaks and cracks in the sewer lines and roof drains that connect homes and businesses to local agency sewers[3]. In order to collect and develop the data needed to complete the benefit/cost analysis, an extensive effort was undertaken to locate and quantify I/I within the local agency systems and the regional conveyance service area.

The local agencies provide direct sewer collection service to the residences and businesses within their service areas. Local agency facilities include collector sewers, laterals, side sewers, and some pump stations. Private property owners typically own the side sewer pipes that connect their property to the local agency collection pipes. The total length of all local agency sewer lines that are designed to carry only sewage (separated system) in the County's service area is approximately 17.5 million feet and does not include the local agency sewers that are designed to carry both sewer and clean, storm-generated flows (combined system).

2.2 Data Needed for the Benefit Cost Analysis

Data for the Regional I/I Control Program was collected between 2000 and 2005. Data collected and developed early in the program (rainfall and flow monitoring data) provided the foundation for subsequent decision-making processes (for example, hydrologic and hydraulic modeling, and pilot project selection). In turn, these processes provided information for completing the Regional Needs Assessment, for constructing 10 pilot projects, and for evaluating alternatives and options for I/I reduction. The benefit/cost analysis was based on information obtained from these earlier efforts.

The local agencies were actively involved in developing and evaluating I/I Control Program data and milestones. This included local agency involvement in developing the assumptions, costs, and I/I reduction factors that were used in the benefit/cost analysis. Brief descriptions of the data sources are provided below with references to additional supporting documentation.

Local Agency Collection System Characteristics

A coordinated County and local agency effort identified the physical locations and characteristics (size, age, material) of local agency collection systems, property boundaries, and topography. This information was needed to subdivide the service area into mini-basins and model basins[4] for flow monitoring and modeling. The information was ultimately needed to investigate the correlation between sewer pipe age, materials, and quantity of I/I within a local agency collection

[3] *Brightwater Final Environmental Impact Statement,* Section 2.3.2, Page 2.12.
[4] *Mini-basins*, containing an average of 22,000 linear feet of sewer lines, provided manageable target areas for sewer system evaluation and rehabilitation. *Model basins,* containing an average of 1,000 sewered acres and 100,000 linear feet of pipe, facilitated modeling of I/I and sewage flows.

system. Additional information related to local agency collection system characteristics can be found in Section 3.2.1[5] of this Report.

Rainfall Monitoring and Modeling

Enhanced rainfall data for the I/I program was developed by using multiple rainfall recording stations to calibrate a radar-based rainfall technology called CALAMAR (*calcul de lames d'eau a l'aide du radar*, which translates from French as "calculating rain with the aid of radar"). The CALAMAR rainfall model was used to establish the amount of rainfall that occurred over specific geographic areas that coincided with the mini-basin and model basin configurations and the measured changes in wastewater flows during rainfall events. Additional information related to the development, calibration, and use of the CALAMAR is provided in Section 3.2.2.

Flow Monitoring

Based on the mini-basin and model basin boundaries established by the County, flow meters were installed in local agency sewer pipes during two consecutive wet weather flow periods to: (a) establish the amount of sewer flow that came from each geographic area, and (b) measure the changes in these flows when rainfall occurred. Measuring the changes in wastewater flows during rainfall events was necessary to quantify the volume of I/I originating from the specific geographic areas. A more detailed description of flow monitoring is included in Section 3.2.3.

Flow Modeling

The County utilized hydrologic and hydraulic models[6] to simulate the performance of local agency wastewater collection and County conveyance systems. These models were used to simulate sewer flows generated from each of the local agency systems and from model basins and mini-basins. Sewer flow models were developed for existing and future development conditions and also provided the estimated I/I flow quantities under these two conditions. The quantities of projected I/I flows from each modeled source was used to evaluate the flow capacity of the existing County conveyance and treatment facilities and to identify the location and extent of additional capacity requirements. This provided the basis for selecting the I/I reduction techniques used in the benefit/cost analysis. A more detailed description of the hydrologic and hydraulic modeling effort is provided in Section 3.2.4.

Planning Assumptions

To provide consistency between the planning variables common to the CSI projects and I/I reduction projects, planning assumptions were developed and accepted for use by the County and local agencies. These assumptions included, but were not limited to:

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[5] For more detailed information about the characteristics of local agency collection systems and the other topics in this section, see the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001).

[6] The *hydrologic model* was used to numerically simulate the physical process of how rainfall ends up as I/I. The *hydraulic model* was used to simulate the pipes that convey wastewater flows and the I/I generated by the hydrologic model.

- The rate at which new sewer connections take place
- The rate at which the existing and aging sewer collection system allows entry of increasing amounts of I/I
- The impact of water conservation on sewer conveyance system capacity and future needs
- Financial variables that may impact inflation and lending costs
- Financial variables that directly impact both I/I reduction and CSI project costs (for example, utility conflicts, traffic control, sales tax, contingency costs, project costs related to environmental or public impacts, and allied costs[7])[8]

Regional Needs Assessment

Based on the information developed from the hydrologic and hydraulic models, a conveyance system capacity assessment was completed to identify the need for additional conveyance system improvement (CSI) projects. The existing County conveyance system hydraulic model was utilized to analyze the capacity of the existing County conveyance system and to establish the extent of required capacity improvements. The County cost estimating model (referred to as TABULA) was used to estimate the costs associated with planning, design, and construction of the additional CSI projects. This list of CSI projects provided the baseline for conducting benefit/cost analysis of potential I/I reduction projects. As stated earlier, I/I reduction projects were considered cost effective when the total estimated CSI project savings after I/I reduction was greater than the total estimated cost of the I/I reduction. Additional information about the Regional Needs Assessment, including a summary list of needed CSI projects and costs is included in Section 3.2.4.9[9] of this Report.

Pilot Projects

The results and lessons learned from 10 pilot projects demonstrated the County's level of success in finding and reducing I/I through physical inspection of sewer collection pipes. The pilot projects also provided the opportunity to compare cost estimates developed during each project's design phase with the bid and final construction costs. The effectiveness of a variety of I/I rehabilitation methods (for example, dig and replace, pipe bursting, cured-in-place lining) was evaluated through the use of flow monitoring and hydrologic modeling conducted before (pre-rehabilitation) and after (post-rehabilitation) completing pilot project construction. The construction, flow monitoring, and modeling results from the pilot projects defined a combination of potential I/I reduction techniques that could be used for evaluating the cost effectiveness of I/I reduction. This information provided a starting point for developing the I/I rehabilitation assumptions used in the benefit/cost analysis. Additional information about the locations of the 10 pilot projects, the techniques selected for I/I reduction, and the use of the

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[7] Allied costs are those project costs associated with planning, predesign, design, construction, closeout, land acquisition, and other non-construction contingency.

[8] For more information about the development of planning assumptions, see Appendix A4 of the *Alternatives/Options Report* (March 2005).

[9] For more information about the process used to evaluate the County conveyance system and to determine the extent of needed conveyance projects, see the *Regional Needs Assessment Report* (March 2005).

hydrologic model and post-rehabilitation flow monitoring is included in Section 3.2.5[10] of this Report.

I/I Rehabilitation Assumptions

The estimated quantity of work, total cost, and I/I reduction achieved from each selected I/I reduction technique was developed and agreed-to through a County/local agency consensus process, and lead to the identification of alternatives and options for achieving I/I reduction. At the request of the local agencies, another set of rehabilitation assumptions was utilized in completing a Sensitivity Analysis of the output of the benefit/cost analysis. Additional information related to the values used for planning assumptions is included in Section 3.2.5.3 of this Report.

I/I Reduction Techniques

I/I reduction techniques[11] developed for use in the benefit/cost analysis provided a full range of responses to different identified sources of I/I. These techniques could be implemented on public or private property and could include reduction of inflow sources alone, infiltration and inflow in combination, or infiltration only. Information about the development of the I/I reduction techniques utilized in the benefit/cost analysis are included in Section 3.2.5.3 and Table 3-5 of this Report.

I/I Reduction Technique Selection

A series of threshold values for selecting four possible I/I reduction techniques was developed to allow an expedited database analysis for each I/I reduction project included in the benefit/cost analysis. The threshold values and method for selecting the initial I/I reduction technique are included in Section 3.2.5.3 and Figure 3-11 of this Report.

As the collection and development of the data sources described above evolved, each completed data source served as a checkpoint for or validation of the previously developed data. In some cases, previously developed data was revisited and confirmed prior to continuing with the next step of the analysis. Ultimately, each of the data sources was either instrumental to the development of data used in the benefit/cost analysis or was itself used to complete the analysis. Figure 3-1 shows how the numerous data sources were used in the benefit/cost analysis.

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[10] For more information about pilot project selection, design, construction, I/I reduction effectiveness, costs, and lessons learned, see the *Pilot Project Report* (October 2004).

[11] *I/I reduction technique* refers to a means of decreasing I/I by replacing or rehabilitating selected components of the sewer system (for example, replacing public sewers and direct disconnects of downspouts). *I/I rehabilitation method* refers to the technology used to repair sewer system components (for example, dig and replace, pipe bursting, slip lining).

2.3 Benefit/Cost Analysis Tool

The Benefit/Cost Analysis Tool (B/C Tool) described in Section 4.2 helped the County evaluate I/I reduction as an alternative to building new or larger CSI projects. The B/C Tool provided information for determining the optimal I/I reduction available for eliminating or downsizing a proposed conveyance system facility improvement.

2.4 Alternatives for Evaluating Benefit/Cost

Once all the associated data were collected and developed, analysis of the alternatives and options provided direction about how the data could be evaluated. The *Alternatives/Options Report* describes various I/I program alternatives, including alternatives that focus on I/I reduction projects with benefits equal to or greater than the costs of improving regional capital facilities. The local agencies agreed that the three alternatives for evaluating benefits and costs would include the following (see Section 3.2.6 for more information about alternatives):

- The estimated benefits and costs of reaching the 30-percent I/I reduction goal as it was described in the *Regional Wastewater Services Plan* (RWSP)
- The estimated benefits and costs for I/I reduction projects that are found to be cost effective on a region-wide basis (re-investing all I/I reduction savings from cost-effective projects into additional I/I reduction projects until the savings are exhausted)
- The estimated benefits and costs for I/I reduction projects that are found to be cost effective on a project-specific basis (evaluating the costs and benefits of each planned conveyance facility on its own merits)

For more detailed explanation of the three alternatives, see the March 2005 *Alternatives/Options Report*, and the attached appendices:

- Appendix A1 - Select List Cost-Effectiveness Analysis Package per MWPAAC E&P Planning Assumptions
- Appendix A2 - Regional Cost Effectiveness Analysis Package per MWPAAC E&P Planning Assumptions
- Appendix A3 - 30-Percent I/I Removal Cost Effectiveness Package per MWPAAC E&P Planning Assumptions
- Appendix B1 - Sensitivity Analysis Select List-Cost Effectiveness Analysis Packages per Initial Planning Assumptions

Chapter 3

Data Development

This chapter describes how the data that contributed to the benefit/cost analysis were developed and how they were used. It describes how information was obtained by characterizing local agency existing facilities, by monitoring flows and measuring rainfall, by simulating physical processes and system performance with hydrologic and hydraulic models, by constructing pilot projects, and by developing assumptions and alternatives for I/I reduction. Figure 3-1 shows the data development process.

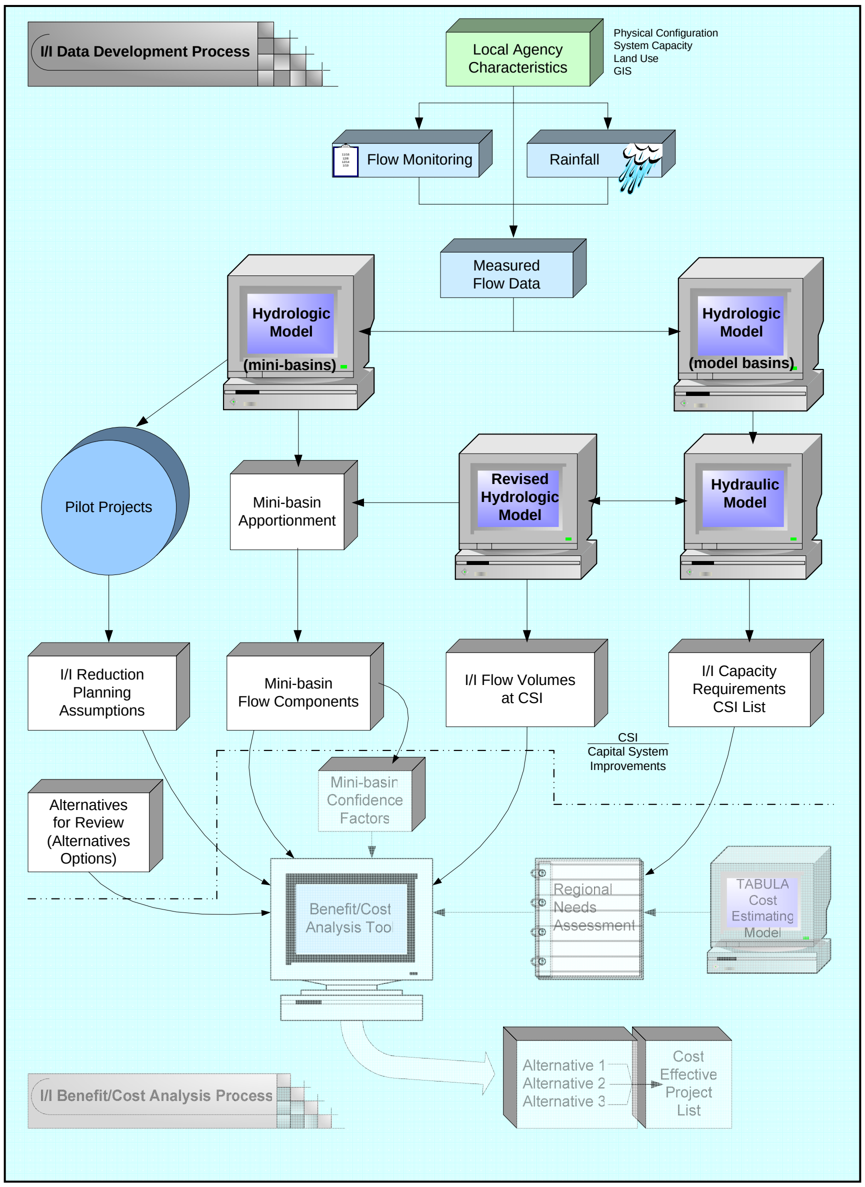


Figure 3-1. Data Development Process

In most cases, the information presented in this chapter is described in more detail in the separately published I/I reports that are referenced throughout this chapter. The reports are available online at http://dnr.metrokc.gov/wtd/i-i/library.htm.

3.1 Data Required for the Benefit/Cost Analysis

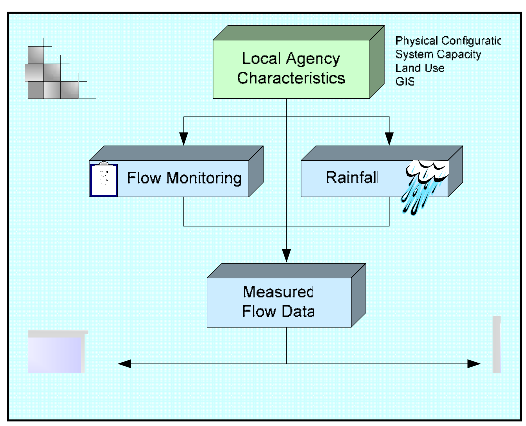
To conduct the benefit/cost analysis, specific data were needed that could be used to address:

- The anticipated effort and cost necessary to reach target levels of I/I reduction
- The capacity and cost-saving effects of proposed I/I reduction on the regional conveyance system
- The cost effectiveness of implementing I/I reduction projects compared with the costs of regional conveyance system improvements

Information about existing and future local agency wastewater facilities and land uses was used to help estimate present and future capacity needs. Rainfall data and wastewater flow monitoring provided the basis for locating and measuring wastewater flows within local agency wastewater collection systems. Once collected, this information was used in commercially available hydrologic and hydraulic models to simulate existing and future wastewater system performance, to evaluate flow data accuracy, and to establish baseline costs for evaluating the cost effectiveness of removing I/I. Cost and performance data collected from the County and local agencies and from ten I/I reduction pilot projects were used to develop I/I reduction planning assumptions for the benefit/cost analysis. A collaborative County/local agency process guided the use of the collected and developed data.

3.2 Data Sources

3.2.1 Characterizing Local Agency Facilities



To identify the physical configuration and capacity of the local agency collection system, and to define the limits of the existing and future wastewater service areas, data were needed to characterize local agency wastewater collection facilities, geography, and land use.

Information about the physical configuration of local agency facilities was accessed through the King County Geographic Information System (GIS). Data showing the physical layout of collection system pipes and existing land use were provided by local agencies and were imported into the County's GIS database. Information about local agency geography, property parcel lines, and the location of future service areas was provided by the County and verified with the local agencies. These data were used to establish:

- The boundaries of specific geographic areas used for defining mini-basins and model basins (see Section 3.2.3 for a description of mini-basins and model basins)
- Points of connection by the local agency wastewater collection system to the regional conveyance system (used to establish flow conditions)
- Lengths of sewer lines and numbers of manholes available for rehabilitation (used as the basis for the cost of possible I/I reduction projects)
- Acreage served (used to calculate the I/I flows in gallons per acre per day [gpad])
- Existing land use and zoning within the defined mini-basins and model basins (used to identify existing and future sewer service areas)
- Parcel count (used to estimate the number of existing and future side sewers)

To gather information about pipe sizes, pipe elevations, pump station capacities, etc., the County made use of conveyance system specifications from the County's GIS database or from local agencies. The specification information was a key input into the hydraulic model (see Section 3.2.4.2 for a description of the hydraulic model).

To obtain land use information for the service area, the County gathered population data, parcel numbers, aerial photos, and zoning information. Land use information was important for defining "sewered"[1] and "sewerable"[2] areas. Defining sewered areas was necessary to accurately calculate existing I/I flows (in contrast, large open spaces like parks are "unsewered" and do not contribute to I/I flows in the sewer system).[3] Defining sewerable area was necessary to calculate the estimated future I/I flows from areas that are not currently sewered. These land use data were valuable for calibrating the hydrologic and hydraulic models[4] (see Sections 3.2.4.2 and 3.2.4.4 for descriptions of the hydrologic and hydraulic models) and for applying growth assumptions.

3.2.2 Rainfall

Rainfall data were needed to help understand: (a) the I/I patterns that cause peak flows during storm events, and (b) the relationship between a given area's measured rainfall and wastewater flows. Rainfall data also provided input for calibrating the hydrologic model.

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[1] Sewered areas are served by a sanitary sewer collection system and contribute to the I/I flows in the sewer system.
[2] Sewerable areas are part of a future service area that will be served by a sanitary sewer collection system.
[3] For more information about classifying sewered and unsewered areas, see Appendix A3 of the *Regional Needs Assessment Report* (March 2005).
[4] Calibrating the hydrologic and hydraulic models involved comparing the model results to actual measured flow data and adjusting the parameters as necessary so that model outputs matched up with measured flow data.

The County maintains a system of 72 rainfall gauges throughout the service area to provide data for ongoing programs. However, the level of measurement accuracy needed for the I/I program would have required adding a significant number of new gauges, and the cost was prohibitive. Instead, the County utilized CALAMAR (*calcul de lames d'eau a l'aide du radar*, which translates from French as "calculating rain with the aid of radar"), a technology that uses radar images from the National Weather Service NEXRAD radar and the County's network of rain gauges[5]. Figure 3-2 shows the County's service area and the location of the NEXRAD radar.

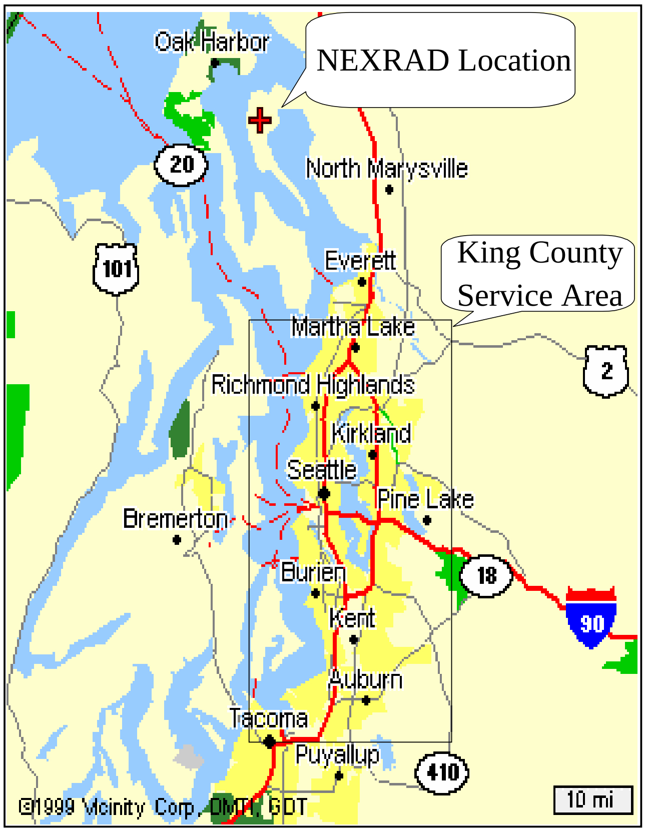


Figure 3-2. NEXRAD and King County Service Area

CALAMAR was used to calculate rainfall intensities during all storm events corresponding to two flow monitoring periods (see Section 3.2.3 for a description of flow monitoring). CALAMAR compares rain gauge values to radar reflectivity at multiple locations and statistically calibrates the radar reflectivity over a calibration zone[6]. The CALAMAR process allows a finer resolution in geographic coverage than would be obtainable with rain gauges alone.

[5] For more information about how CALAMAR was used, see pages 37 through 50 of the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001) and Appendix E of the October 2004 *Pilot Project Report.*

[6] The service area was divided into eight calibration zones of 200 to 500 square kilometers each to ensure that only rainfall within each zone was used to calibrate that zone. For more information about the calibration zones, see page 42 of the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001).

For predicting the design (20-year peak) I/I flows, a 60-year rainfall record was used to approximate future rainfall frequency and intensity. The 60-year rainfall record is an extended time series (ETS) based on precipitation records from Seattle-Tacoma International Airport (Sea-Tac). The ETS records represent the longest continuous record of rainfall data for the area[7]. For modeling purposes, it was assumed that the past ETS records are representative of future rainfall patterns likely to occur in the service area.

Eighteen significant rainfall events occurred during the second monitoring period; however, only 10 events caused a measurable and system-wide I/I response. These 10 events were used for the modeling process described in Section 3.2.4.

3.2.3 Flow Monitoring

The location and intensity of wastewater flows and I/I within the local agency systems was necessary for the benefit/cost analysis because it provided the basis for estimating the cost of regional conveyance system improvements (CSI) and I/I reduction efforts. To obtain this information, the County conducted a comprehensive flow monitoring study[8] during the winters of 2000/2001 and 2001/2002. Flow monitoring provided measured data for addressing the wet weather performance and geographic distribution of I/I throughout the local agency facilities tributary to the County's collection system. In addition, flow monitoring data provided input for developing and refining the hydrologic and hydraulic models that were used throughout the benefit/cost analysis (see Sections 3.2.4.2 and 3.2.4.4 for descriptions of the hydrologic and hydraulic models).

Flow monitoring objectives were to:

- Divide the entire system of local agency sewer lines into specific geographic areas called mini-basins and model basins.
- Quantify levels of I/I in each tributary local agency collection system.
- Track long-term flow trends within the County's conveyance system.

Mini-basins were defined to provide manageable target areas for sewer system evaluation and rehabilitation. Mini-basins contained an average of 22,000 linear feet of sewer lines. Figure 3-3 shows mini-basin locations.

Model basins were defined to facilitate modeling of I/I and sewage flows. Model basins represented the entire sewered area flowing to a specific flow meter location, and consisted of an average of 1,000 sewered acres and 100,000 linear feet of pipe. Each model basin encompassed an average of 5 to 7 mini-basins. Figure 3-4 shows model basin locations.

Three types of flow meters were placed throughout the regional and local agency service areas:

[7] For a discussion of the application of Sea-Tac rainfall records to the service area, see Appendix A2 of the *Regional Needs Assessment Report* (March 2005).
[8] For more information about the flow monitoring study, see the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001) and the *2001/2002 Wet Weather Flow Monitoring Technical Memorandum* (June 2002).

- **Long-term meters -** 75 long-term wastewater flow meters were placed at strategic locations in the County conveyance system where full-time flow data would be available for the next several years. This allowed monitoring and assessment of system operation to further calibrate and validate the hydrologic and hydraulic models.
- **Modeling meters -** 94 wastewater flow meters were placed at the model basin outlets to provide flow information for calibrating the hydrologic model. Modeling meters collected data only during the wet weather season. In addition to the 94 model basin meters, 53 of the long-term meters also functioned as modeling meters. In total, wastewater flow data were collected for 147 model basins.
- **Mini-basin meters -** 638 meters, in addition to the meters described above, were placed farther upstream in mini-basins to isolate the flow response of smaller areas. These were installed during the wettest portion of the wet weather season.

Figure 3-5 shows flow meter locations within the County service area.

During the first winter of flow monitoring, flow meters were installed in 807 mini-basins. Adjustments were made in mini-basin boundaries for the second winter of flow monitoring, and 774 mini-basins were monitored. During both winters of flow monitoring, all the basins were monitored simultaneously to achieve improved data consistency.

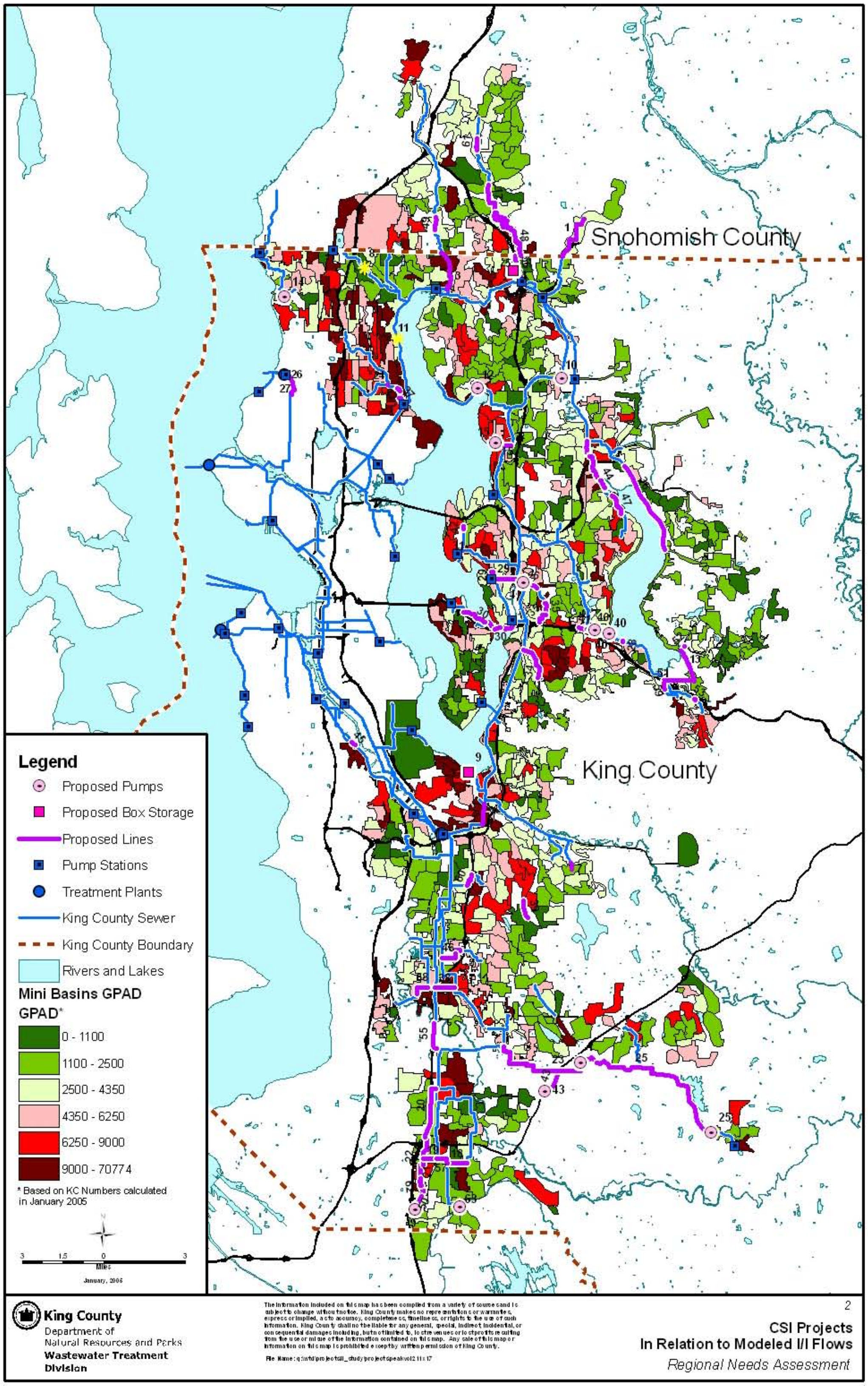


Figure 3-3. Mini-Basin Locations in Relationship to I/I Levels

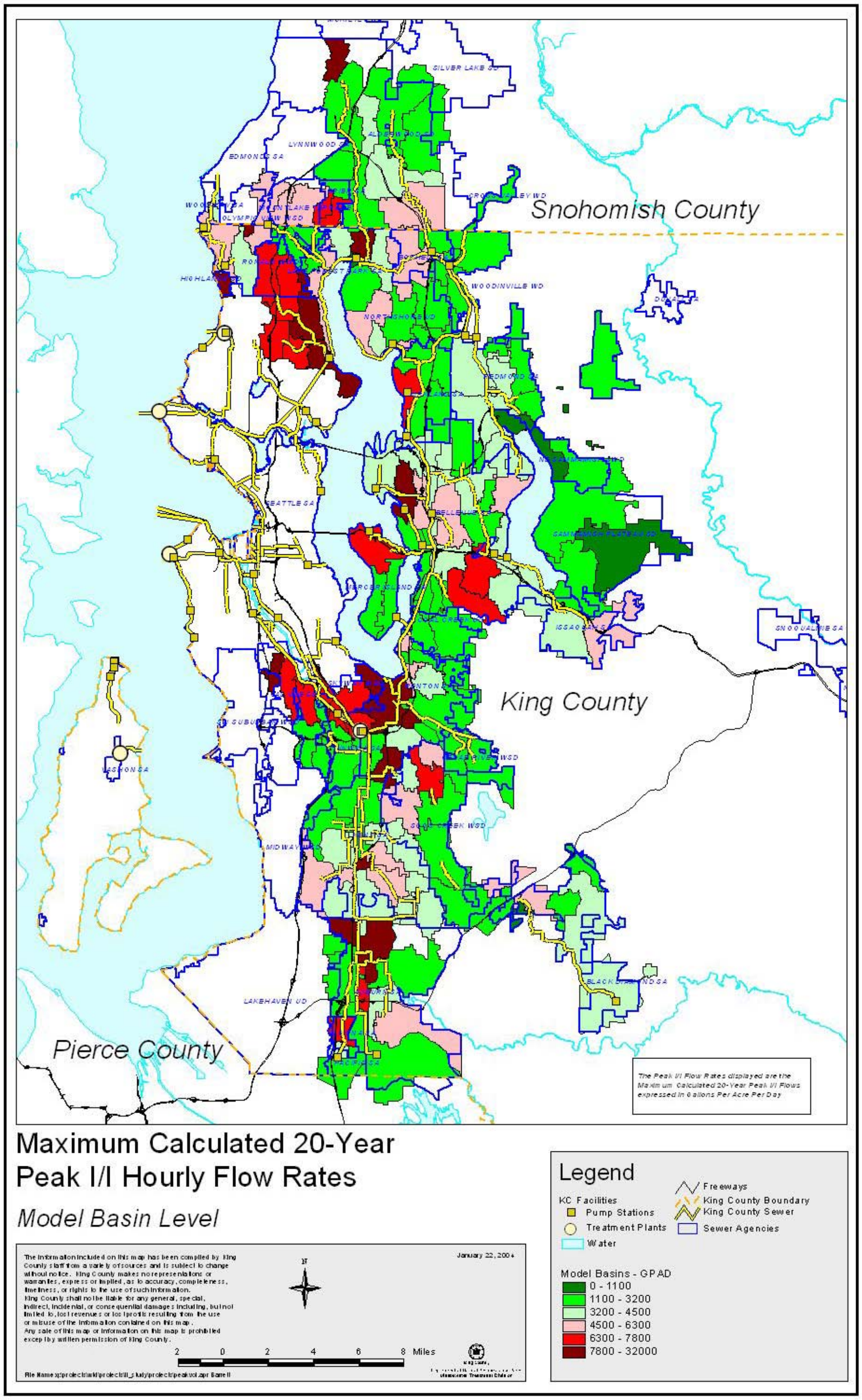


Figure 3-4. Model Basin Locations in Relationship to I/I Levels

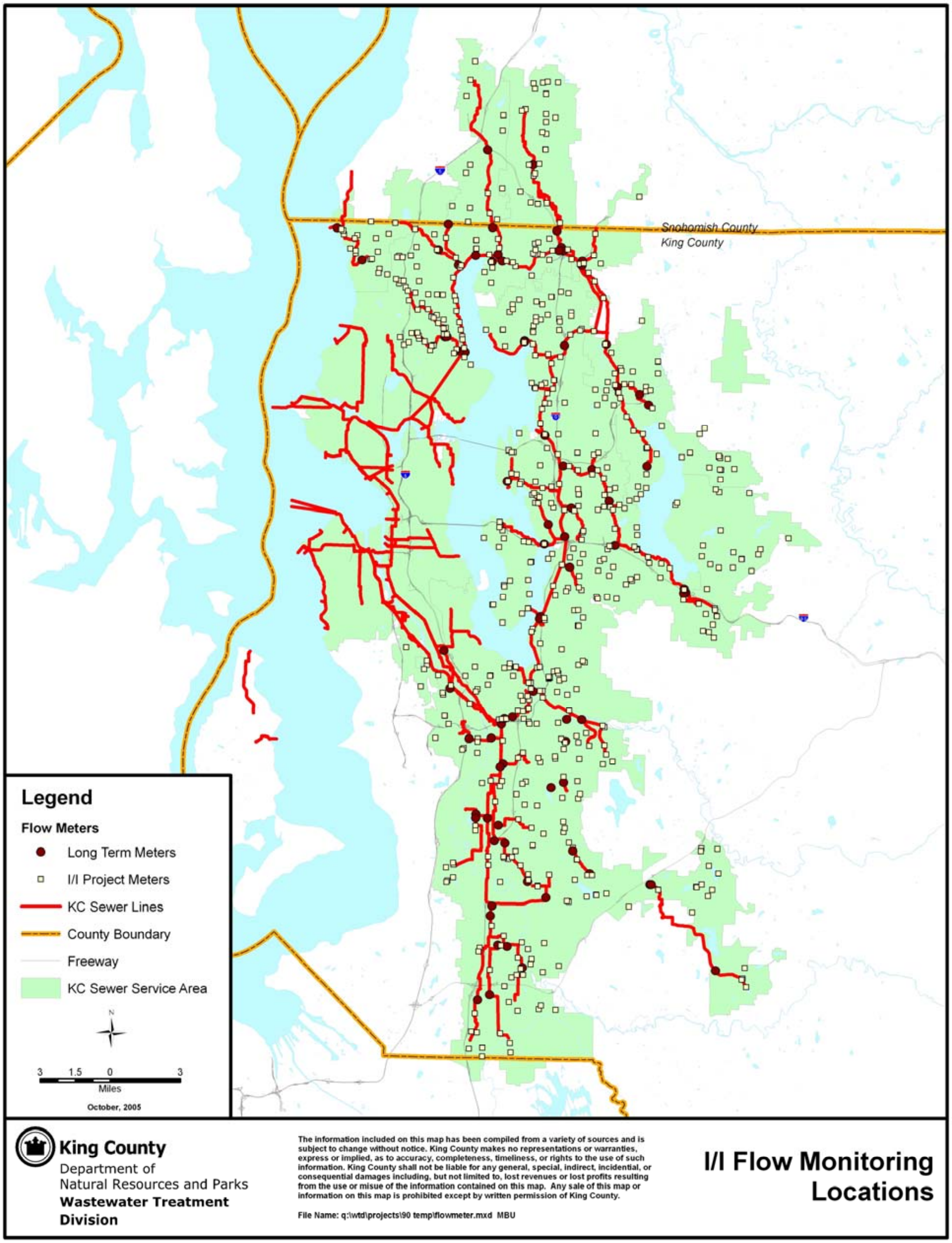
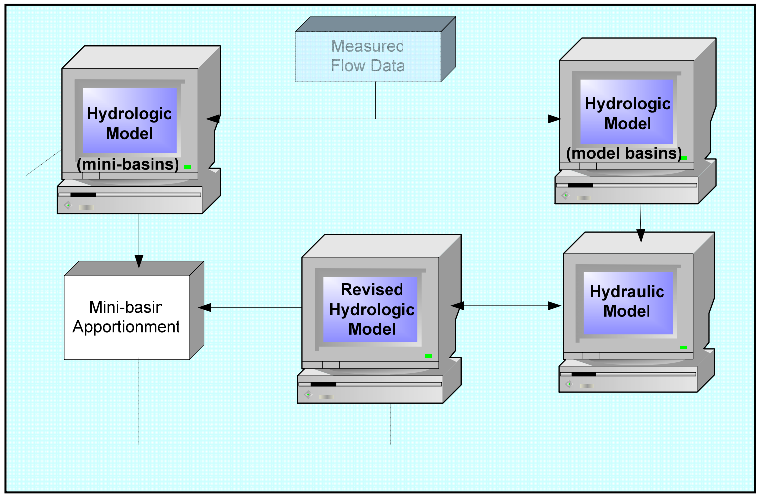


Figure 3-5. Flow Meter Locations

3.2.4 Modeling

3.2.4.1 Overview



To determine the required system capacity before and after implementing proposed I/I reduction projects, and to predict the impact of wet weather conditions on the system, the County simulated the conveyance system's processes and performance. This was accomplished by:

1. Using the measured data collected during flow monitoring and rainfall analysis to develop and calibrate a *hydrologic* model for 147 model basins in the service area (see Section 3.2.3 for a description of model basins).
2. Using a long-term (60-year) rainfall data set (see Section 3.2.2 for a description of the 60-year rainfall records from Sea-Tac) to simulate each model basin's long-term flow. The modeled long-term flows were analyzed statistically to determine the peak I/I flows produced within each model basin. The peak flows were then applied (input) to a *hydraulic* model of the County conveyance system. The hydraulic model was used to analyze how the system performed under the existing 20-year peak flow conditions.
3. Projecting future flow conditions into the previously developed hydraulic model of the regional conveyance system. The projections involved applying assumptions related to: (a) the increase in sewered areas due to growth, (b) existing I/I rates, (c) I/I rates from areas to be sewered in the future, and (d) an increase in existing and future I/I due to sewer system degradation[9]. The results of this analysis identified the need for additional or expanded conveyance system capital improvements.

3.2.4.2 Hydrologic Model

To provide the basis for cost estimates used in the benefit/cost analysis, hydrologic models were used to quantify the wastewater and I/I flow out of a basin in response to rainfall. The hydrologic model simulates the hydrologic transformation of rainfall into the I/I that enters the sewer system via cracked pipes, leaky manholes, improperly connected storm drains, downspouts, and sump pumps. The rainfall and wastewater flow data collected during the flow monitoring period were used to develop and calibrate the hydrologic model.

[9] Sewer system degradation refers to deterioration of existing pipeline conditions, allowing ever-increasing amounts of surface water and groundwater to enter the sewer system. The current rate utilized by the County is an increase in I/I at a rate of 7 percent per decade.

Hydrologic models were created for the mini-basins and 147 model basins using commercially available software called MOUSE (Modeling of Urban Sewers) from the Danish Hydraulic Institute (DHI). Each model basin contained multiple mini-basins. The hydrologic model included base sanitary flows as projected for the year 2050 based on total regional service area after buildout[10]. The County GIS provided detailed information on land use, growth projections, and septic sewer system conversions, and identified sewerable and unsewerable properties.

The calibrated model output was used to identify the estimated amount and types of I/I within local agency sanitary sewer systems under specific wet weather conditions in each model basin.

The input needed for MOUSE hydrologic models is based on the characteristics of each basin, and is briefly described below:

- **Basin description:** Basin characteristics such as total area, slope, and impervious/pervious surface area
- **Base wastewater flow data:** A flow record during dry periods to assess base wastewater discharge from industrial/commercial/residential land use, and to establish base infiltration[11]
- **Rainfall:** A continuous record of rainfall in a study area

Modeling Term Definitions:

***Hydrologic model*:** A model used to numerically simulate the physical process of how rainfall ends up as inflow and infiltration.

***Hydraulic model*:** A model of the actual pipes that convey the wastewater flows and I/I generated by the hydrologic model. The hydraulic model outputs flow depths and velocities within specific pipe segments and allows evaluation of how the system performs under existing and future demands.

Basin: A geographic area that contributes flow to a specific location, usually a flow meter or a facility. The two primary types of basins used in the assessment are **model basins** and **mini-basins**.

***Model calibration*:** The process of adjusting model parameters so the model output matches the measured sewer flow for the same time period.

***Peak flow by return period*:** A statistical analysis related to the probability that a given flow will be equaled or exceeded in a given year. The 20-year peak flow has a 1 in 20, or 5-percent chance of being exceeded in any given year.

The *hydrologic* model output is a series of hydrographs (graphs of flow versus time) for specified time periods at particular basin outlets. In turn, the hydrographs are inputs to a *hydraulic* model, which simulates the travel time[12] of flows through a conveyance system. Figure 3-6 shows a typical exchange of data between the hydrologic and hydraulic models.

Hydraulic models convey flows generated by hydrologic models from one basin to another. The models are typically based on a conveyance system's physical characteristics, such as pipe length, pipe material, pipe slope, roughness coefficient, manhole geometry, and others.

[10] Buildout is the maximum number of anticipated connections or discharges to the regional conveyance system.
[11] Base infiltration is infiltration that remains at relatively steady levels over weeks and months.
[12] Travel time is the amount of time it takes flows to travel through the conveyance system.

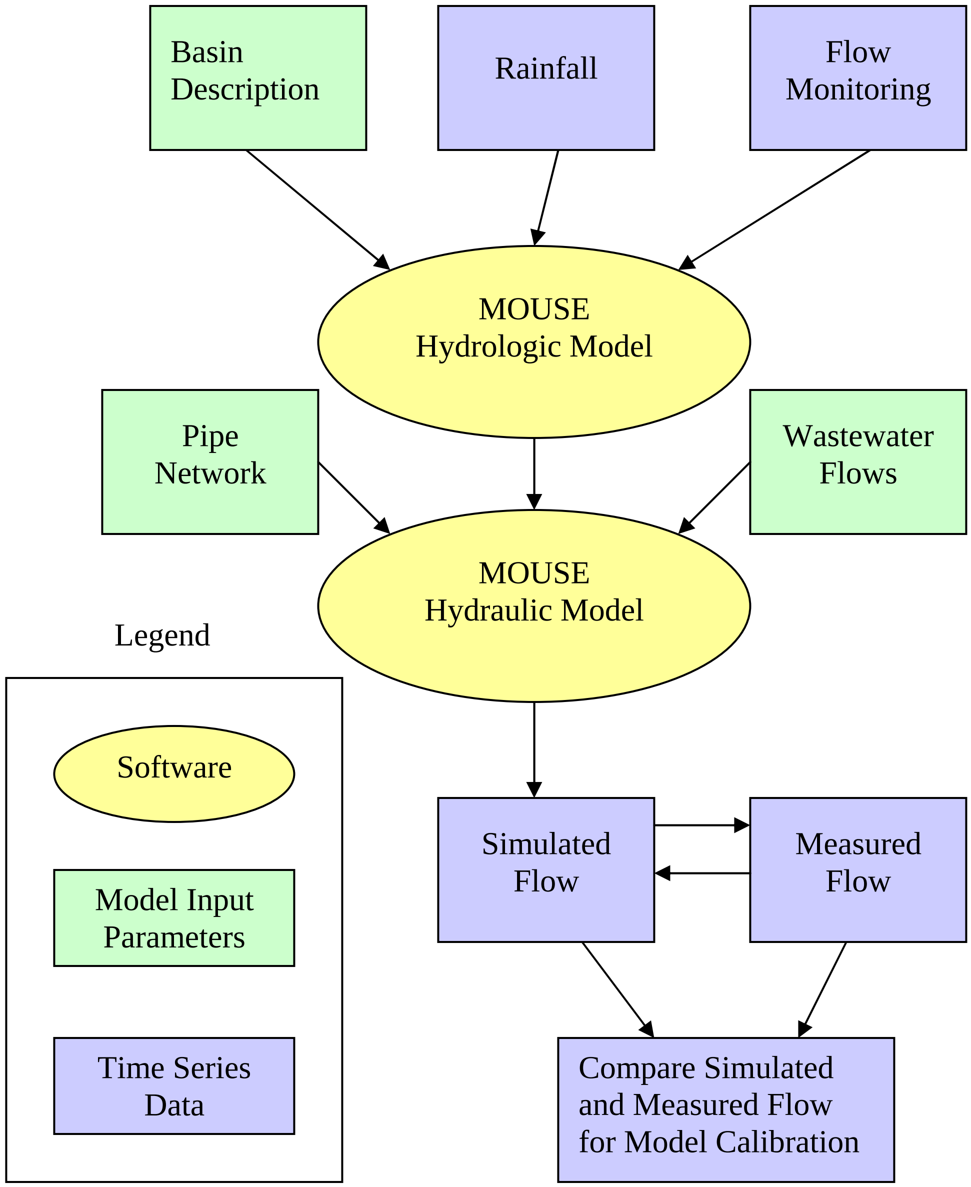


Figure 3-6. MOUSE Hydrologic and Hydraulic Model Components

3.2.4.3 I/I Flow Components

As shown in Figure 3-6, the hydrologic and hydraulic models were coupled together to represent and quantify how the regional wastewater system behaves with respect to I/I. Modeled I/I consists of multiple flow components, as shown in Figure 3-7. During dry weather, only wastewater and a relatively constant amount of clear water, or infiltration flow, are present in the wastewater system. During wet weather, basins that are impacted by I/I typically exhibit one or all of the following wastewater flow characteristics: (a) a fast response almost immediately after rainfall begins and that response may continue throughout the rainfall event and subside quickly at the conclusion of the event; (b) a response that builds and declines more slowly in response to the rainfall event.

Table 3-1 lists the I/I flow components and their likely sources. Figure 2-1 illustrates locations where I/I typically enters the sewer system.

Table 3-1. I/I Flow Components and Sources

Response Type (component)	Flow Characteristics in Response to Rainfall	Likely Sources
Fast response	Sudden increase in flow	**Inflow:** catch basins, roof drains, or other direct connections; **Infiltration:** sources that respond rapidly to rainfall, such as shallow side sewers.
Rapid infiltration	Increase in flow during and/or shortly after a rainfall event, with gradual reduction in flow over a relatively short period after the event	**Infiltration:** shallow sources such as laterals, side sewers, foundation drains; manholes and sewer mains to a lesser extent
Slow infiltration	Slow increases in flow hours or days after a storm; increased flow may take several days or weeks after a storm to decline	**Infiltration:** deep sources such as manholes and sewer mains; reflects a rising groundwater level
Base infiltration	Present regardless of individual storm events	**Groundwater-based I/I:** Generally associated with high groundwater that seeps into the sewer system through defects in pipes.

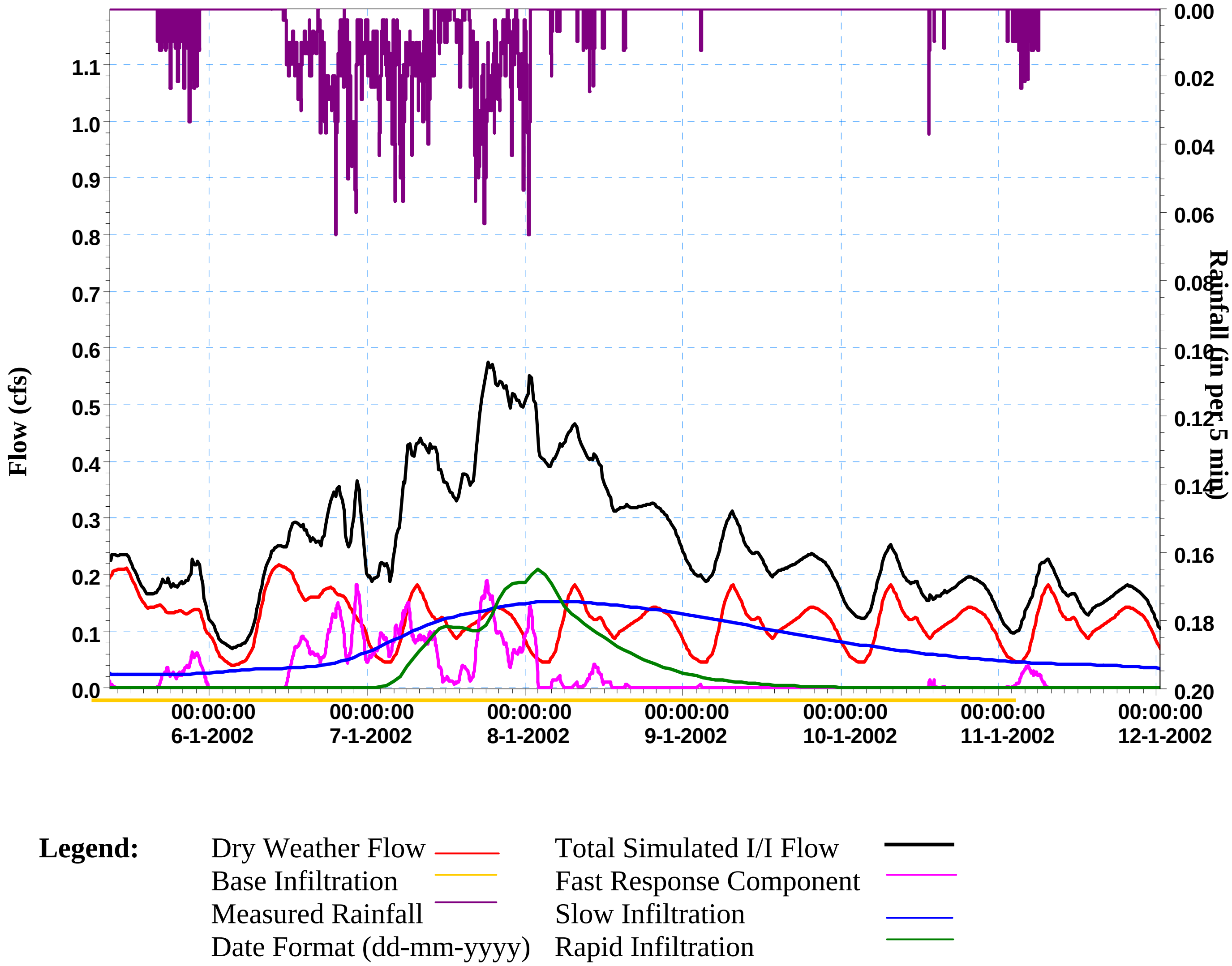


Figure 3-7. Simulated Flow Components

3.2.4.4 Hydraulic Model

Hydraulic models were used to simulate the facilities (pipes, pumps, and storage) that convey flows through the regional wastewater conveyance system. This information was then used to evaluate the capacity of the existing regional conveyance system, to estimate the size and costs for additional or expanded facilities, and to provide the basis for completing the benefit/cost analysis. For input, the hydraulic model required calibrated outputs from the hydrologic model and base sewage flow data. The hydraulic model output yielded flow depths and velocities within specific pipe segments and allowed evaluation of system performance under existing and future flow conditions.

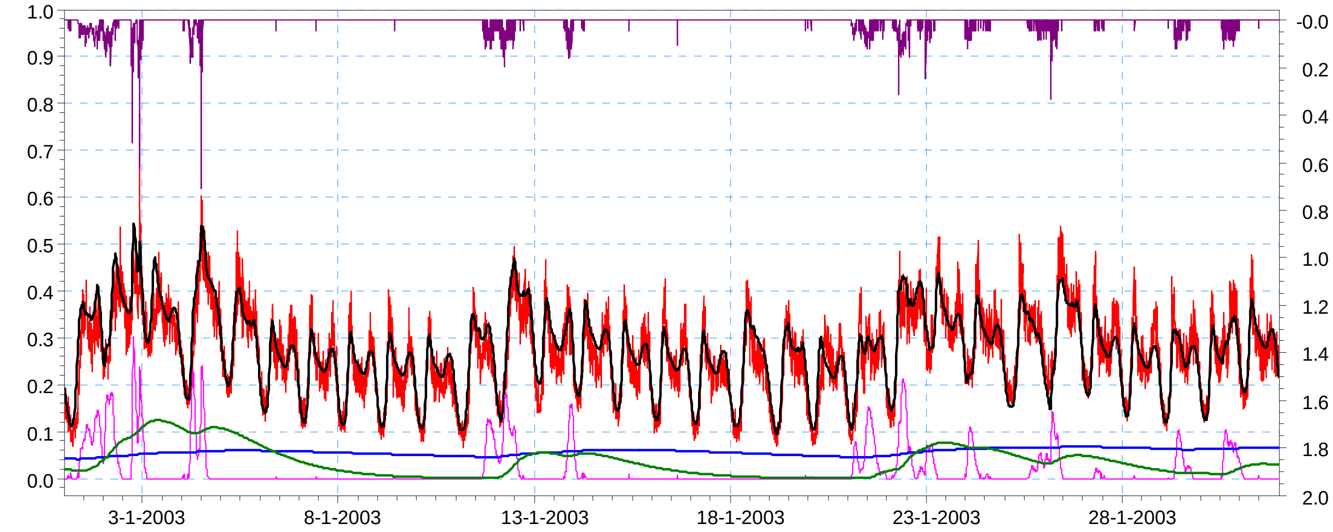
After simulating the system's physical properties with the hydrologic model and calibrating the output, the County used its existing hydraulic model to evaluate the wastewater system. The modeled (hydrologic) flows that provided input into the hydraulic model were associated with a specific physical location. This was necessary because connections to the conveyance system in the model basins varied from a single point to as many as nine points per model basin.

Using calibrated flows (see Section 3.2.4.5 for a description of the calibration process) allowed for spot-checking the original model basin calibrations by comparing combined model basin flows to actual flow measurements in the system. Comparing these measured flows allowed the County to make adjustments to both base sewage flow and I/I model parameters to better simulate the base sewage and I/I contributions to the system.

3.2.4.5 Model Calibration

Calibrating hydrologic and hydraulic models was necessary to test the accuracy of their outputs and to provide a level of confidence for a critical element used in the benefit/cost analysis. Calibration was accomplished by comparing hydrologic and hydraulic model results to actual measured flow data collected during the flow monitoring period. Both the hydrologic and hydraulic models were calibrated to the two wet seasons of flow data collected in 2000 through 2002, and to the dry-weather sewage flow pattern. Calibration involved adjusting the wet-weather flow parameters of the hydrological model until the output substantially matched actual measured wet-weather flows from the model basins. A second calibration was then completed to balance the hydrologic model with the measured flow from the 75 long-term meters located in the regional conveyance system. This effort resulted in revisions to both hydrologic and hydraulic model parameters to achieve an acceptable calibration of both models. The dry-weather flow calibration process involved taking measured sewer flow data from dry-weather periods and identifying recurring daily wastewater flows patterns based on measured flows on weekdays and weekends.

Figure 3-8 is a graphical example of how the calibrated hydrologic model output closely matched the measured flow data for a variety of storms during the 2001 through 2002 monitoring period.



Legend: Measured Flow; Measured Rainfall; Total Simulated I/I Flow; Fast Response Component; Slow Infiltration; Rapid Infiltration; Date Format (dd-mm-yyyy)

Figure 3-8. Comparison of Modeled Flow Data to Measured Flow Data

3.2.4.6 Estimated 20-Year Peak Flows

Once the hydrologic and hydraulic models were calibrated, 20-year peak flow demands on the system were simulated with the hydraulic model. The output from the long-term simulations was analyzed to determine the probability of exceeding a given peak flow during a given year.

The County adopted a 20-year flow capacity standard[13] for conveyance facilities that transport wastewater from local agencies to County treatment plants. This means that the facilities must have capacity for flows of a magnitude that can be expected on an average of once every 20 years (20-year return period). This corresponds to a 5-percent chance of such flows or higher occurring in any given year.

To maintain consistency with County capacity standards, the difference in the 20-year peak flow established for pre-rehabilitation versus post-rehabilitation was used to estimate rehabilitation effectiveness. This was done both in the pilot projects (see Section 3.2.5 for a description of the pilot projects) and in the benefit/cost analysis described in Chapter 4.

The method used to estimate the pre-rehabilitation 20-year peak flow for each basin consisted of conducting an extended simulation and performing a frequency analysis on the simulated flows. Through calibration of the continuous simulation model to measured flows, the parameters

[13] For more information about the 20-year flow capacity standards, see the *Regional Wastewater Services Plan*, available at http://dnr.metrokc.gov/wtd/rwsp/rwsp.htm.

describing each basin were adjusted to represent the processes that transform rainfall into infiltration and inflow. The model was then used to simulate flow response from a long-term rainfall time series that includes large, infrequent rainfall events. By simulating a continuous, long-term period, this approach accounted for the effects of antecedent conditions (ground moisture increases due to rainfall) on I/I volumes.

3.2.4.7 Apportioning I/I Flows to Mini-Basins

The benefit/cost analysis required that flows associated with the 20-year peak event be established at each target regional conveyance facility. Under ideal conditions, the sum of the simulated flows using individual mini-basin models should equal the simulated flows for the model basin that they comprise. However, there were typically differences between the sum of the simulated flows for the mini-basins and the simulated flows for the model basins. These differences were due largely to variability in calibration, measured flow data, and travel time for mini-basin flows through the local agency collection systems. As a result, an apportionment process was developed to resolve the differences and enable the revised mini-basin values to be used in the benefit/cost analysis.

The apportionment process applied adjustment to the identified individual I//I flow components. The I/I flow components subject to the apportionment process were identified as the Fast Response Component (FRC); Slow Response Component (SRC) (which includes Rapid Infiltration and Slow Infiltration; and Base Infiltration (BI):

- Fast Response (FRC) I/I is an indicator of direct connections of stormwater sources to the sewer system such as downspouts and flooded manholes.
- Slow Response (SRC) I/I is an indicator of stormwater entering the sewer system after either traveling overland some distance or saturating the ground and then seeping through structural defects. Slow Response (SRC) I/I was further broken down into Rapid Infiltration and Slow Infiltration. The Rapid Infiltration component was derived for each mini-basin by subtracting the Slow Infiltration component from Slow Response (SRC).
- Base Infiltration (BI) is generally associated with high groundwater that is present regardless of individual storm events, that seeps into the sewer system through defects.

Mini-basin apportioned I/I values were derived for the event selected to represent the theoretical model basin I/I peak (20-year) flow. The I/I flow components for the mini-basins, as identified by the calibrated models, were then extracted for the corresponding simulation.

The apportionment process varied slightly for the different flow component types:

- The FRC for each mini-basin was calculated as a percentage of the sum of the FRC components for all mini-basins within the model basin. The FRC percentage calculated for each mini-basin was then multiplied by the 20-year model basin FRC value to establish the apportioned FRC component value for use in the benefit/cost analysis.

- The BI for each mini-basin was calculated as a percentage of the sum of the BI components for all mini-basins within the model basin. The BI percentage calculated for each mini-basin was then multiplied by the 20-year model basin BI value to establish the apportioned BI component value for use in the benefit/cost analysis.
- SRC was further broken down into Rapid Infiltration (RI) and Slow Infiltration (SI).
- The RI for each mini-basin was calculated as a percentage of the sum of the RI components for all mini-basins within the model basin. The RI percentage calculated for each mini-basin was then multiplied by the 20-year model basin RI value to establish the apportioned RI component value for use in the benefit/cost analysis.
- The SI for each mini-basin was calculated as a percentage of the sum of the SI components for all mini-basins within the model basin. The SI percentage calculated for each mini-basin was then multiplied by the 20-year model basin SI value to establish the apportioned SI component value for use in the benefit/cost analysis.

The result of the apportionment process was an adjusted value for each of the I/I flow components within each of the mini-basins. The sum of a mini-basin's revised I/I flow components provided the mini-basin's apportioned total I/I value, which then allowed the apportioned mini-basin flows to approximate the model basin flows.

3.2.4.8 Mini-Basin Confidence Factors

Due to the number of parameters that influenced or impacted the wastewater flow and I/I values for each mini-basin, it was necessary to complete an evaluation for each mini-basin to determine its confidence for use in the benefit/cost analysis. Confidence levels varied from low to high, with low-confidence mini-basins presenting a lower potential for achieving the estimated I/I removal required. Two primary conditions had the potential to negatively impact the confidence of a mini-basin:

1. If the apportionment process between the model basin and the mini-basin resulted in changing a mini-basin's I/I value more than 20 percent, then a low level of confidence score was assigned to the mini-basin; or,
2. If the mini-basin flow data quality was poor, then a lower level of confidence was assigned to the mini-basin[14].

Mini-basin apportionment factors were of concern because mini-basins with I/I values apportioned "up" might overestimate the amount of I/I present and underestimate removal costs. Mini-basins apportioned "down" might result in missed opportunities for I//I removal and overestimation of removal costs.

[14] For additional information about conditions that impacted measured flow data, see the *2000/2001 Wet Weather Flow Monitoring Technical Memorandum* (May 2001) and the *2001/2002 Wet Weather Flow Monitoring Technical Memorandum* (June 2002).

In order to evaluate and categorize the modeling results for the various basin models, a level of confidence (LOC) analysis was performed for all mini-basins that had simulated flow of 3,500 gpad or more[15]. The LOC analysis included a review of the following:

- Calibration flow data quality
- Quality of simulation match to measured flow
- Derived mini-basin apportionment factor
- Magnitude of dry weather flow
- Number of subtractions used to derive calibration flow data

Based on the review, each mini-basin was then placed in one of the following categories:

- High confidence
- Moderate to high confidence
- Moderate confidence
- Moderate to low confidence
- Low confidence
- No confidence

For use in the benefit/cost analysis, it was preferred to select mini-basins as potential I/I reduction projects with at least a “moderate” level of confidence or better unless no other alternative mini-basins were available. In those cases when a mini-basin with a “low” level of confidence needed to be used to make an I/I reduction project cost effective, it was specifically noted as such and flagged for additional review and consideration prior to further investigation and implementation. A total of 10 mini-basins with low levels of confidence were used in the benefit/cost analysis and they impacted 8 of the 9 cost-effective projects (see Section 5.1 for more information about the 9 cost-effective projects; see Appendix A1 for details about confidence levels).

3.2.4.9 Planning Assumptions for I/I Modeling

A number of conditions drive the timing, sizing, and costs of facilities that occur in the future and each requires assumptions to arrive at a value. To accurately project conveyance system improvement (CSI) needs, the County used assumptions specifically developed for the I/I control program. After completing the I/I reduction pilot projects (see Section 3.2.5 for more

[15] A 3,500-gpad threshold was established based on the results of the 10 pilot projects; in some mini-basins, rehabilitation of sewer system components did not result in I/I reduction levels of less than 3,500 gpad. For more information about I/I reduction and rehabilitation effectiveness, see Sections 8.6 and 8.7 of the *Pilot Project Report* (October 2004).

information about the pilot projects), local agencies and the County collaborated to develop these assumptions. Table 3-2 summarizes several of the more significant planning assumptions[16].

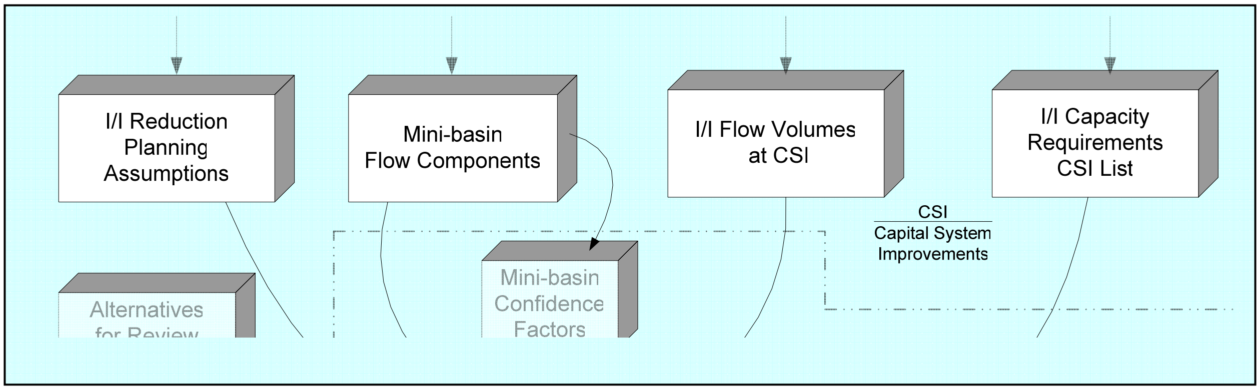


Table 3-2. Planning Assumptions for I/I Modeling

Sensitivity Factor	I/I Modeling Assumption
Water conservation (base flow projections)	10% reduction by 2010, no additional reduction thereafter
Septic conversion	90% of unsewered but sewerable area in 2000 sewered by 2030; 100% by 2050
New system I/I allowance	1,500 gallons per acre per day (gpad)
Design flow	20-year peak flow, based on Sea-Tac 60-year rainfall record, adjusted per annual average rainfall over each part of the service area
Degradation	7% per decade starting in 2000 up to 28% for existing pipe; 7% per decade starting after date of construction up to 28% for new construction
Sizing of facilities	Design flow at saturation plus 25% safety factor (when sizing facilities, a safety factor of 25% of additional capacity will be used)
Discount rate	6%
Inflation rate	3%

[16] For more information about planning assumptions, see Appendix A5 of the *Regional Needs Assessment Report* (March 2005).

Sensitivity Factor	I/I Modeling Assumption
Operation and maintenance analysis	Update the following from the *Regional Wastewater Services Plan* (RWSP): • New pipes: $0.15 per linear foot annually • New pump stations: $4,104 per million gallons per day (mgd) + $60,384 • New storage facilities: $34,091 per million gallons (MG) + $4,546 • Treatment plants: $15,000-$30,000 per mgd of average annual flow reduction (plant specific); covers energy and disinfection costs

Table 3-3 lists the assumptions made about conveyance facility construction and allied costs. These costs were generated by TABULA, a planning level software tool developed by the County, which extends unit costs and applies construction cost indices.

Table 3-3. Conveyance Facility Construction and Allied Cost Assumptions

Cost Item	Costs Factor
Construction estimate	Based on TABULA with factors for traffic, utility conflicts, and groundwater
Utility conflicts	None: $0 Average: $20/linear foot Heavy: $40/linear foot
Traffic control	None: $0 Average: $5/linear foot of main Heavy: $10/linear foot of main
Dewatering	None: $0 Average: $20/linear foot Heavy: $50/linear foot
Sales tax	8.8% of construction estimate
Planning, predesign, design, construction, closeout, land acquisition, construction contingency	51.4% of construction estimate
Project contingency	30% of construction estimate
Mitigation (environmental, land use, public disruption, private property, etc.)	Project-specific

Regional Conveyance System Needs List

The County identified 63 CSI projects necessary to manage projected 20-year peak flows. These projects (listed in Table 3-12 included at the end of this chapter) have an estimated total capital cost of approximately $780 million (2003 dollars) and address the region's projected capacity needs through 2050[17].

The CSI project locations in the County service area are shown in Figure 3-9. The projects, along with estimated costs and online dates, are based on projected 20-year peak flow volumes and provide the basis for conducting benefit/cost analyses of potential I/I reduction projects. For this benefit/cost analysis, I/I reduction projects were considered cost effective when the total estimated CSI project savings after I/I reduction were greater than the total estimated cost of the I/I reduction.

[17] For more detailed information regarding the development of the list of CSI projects, see the *Regional Needs Assessment Report* (March 2005).

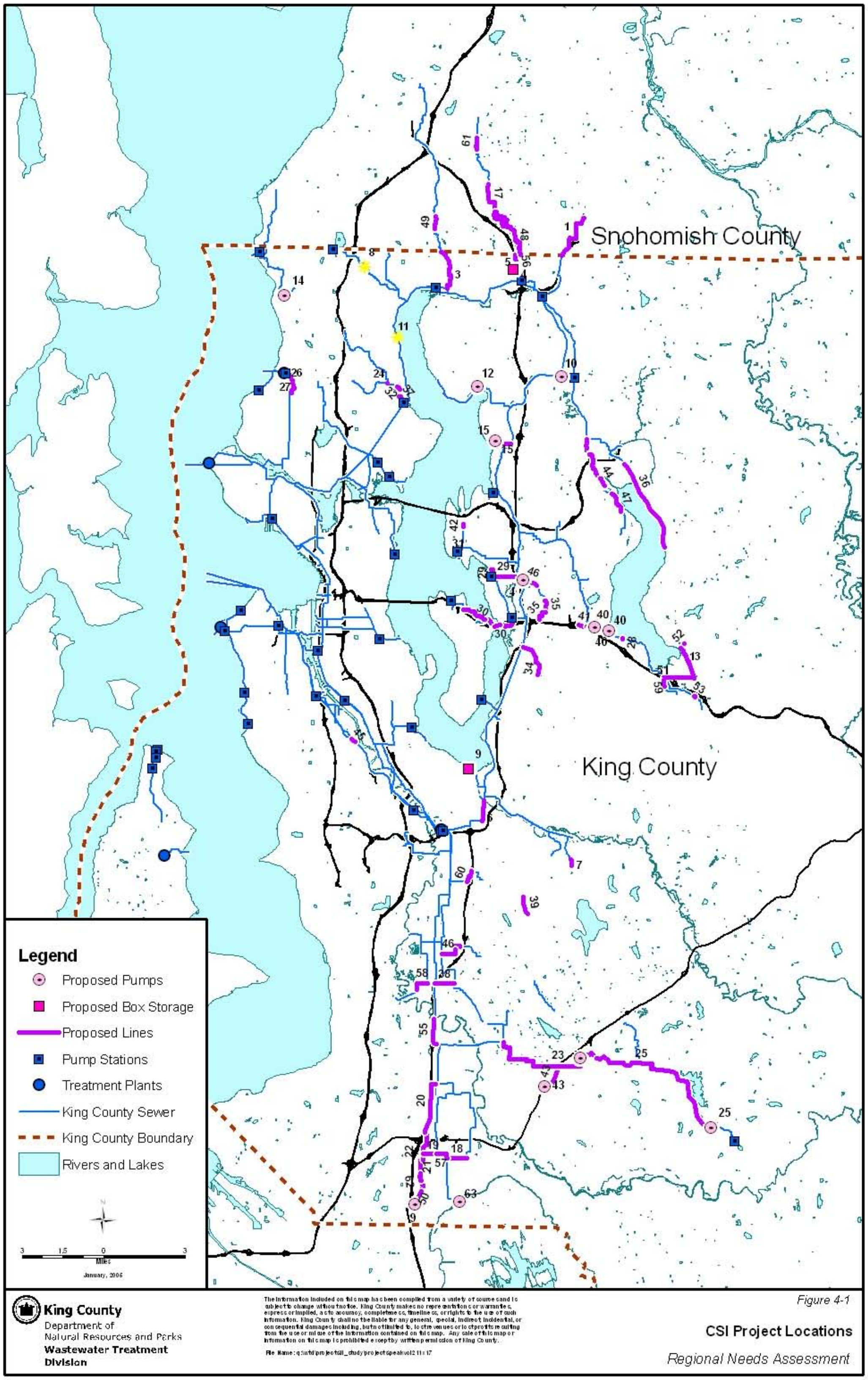
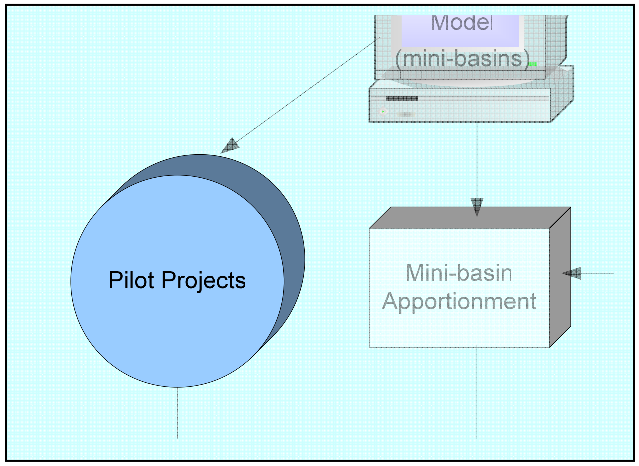


Figure 3-9. Conveyance System Improvement Project Locations

3.2.5 Pilot Projects

3.2.5.1 Overview



To gain a better understanding of the costs and I/I reduction rates associated with implementing I/I reduction projects and to establish target I/I reduction levels, the County constructed 10 pilot projects in local agency systems[18]. The information obtained via the pilot projects was used, in part, to develop planning assumptions related to project cost and I/I reduction rates for this benefit/cost analysis.

The overall objectives of the pilot projects were to demonstrate that:

- I/I can be found.
- I/I reduction can be achieved.
- Project costs can be accounted for.

Work on each pilot project consisted of identifying I/I sources through field investigations, designing and constructing rehabilitation improvements, and monitoring post-construction flows to determine the effectiveness of the rehabilitation.

The selected pilot projects (see Figure 3-10) included a mix of projects on public and private property in 12 local agency jurisdictions: City of Auburn, City of Brier, Skyway Water and Sewer District (formerly known as Bryn Mawr), Coal Creek Utility District, City of Kent, City of Kirkland, City of Lake Forest Park, City of Mercer Island, Northshore Utility District, City of Redmond, Ronald Wastewater District (formerly known as Shoreline Wastewater Management), and Val Vue Sewer District. The combined Coal Creek, Northshore, and Val Vue projects made up the "Manhole Project."

The pilot projects were located within defined mini-basins (see Section 3.2.3 for a description of mini-basins). Within the mini-basin, the specific location where the rehabilitation work took place was termed a "pilot basin". To obtain data that could be compared to the pilot basin data, "control basins" were simultaneously monitored in the vicinity of the pilot basins. No rehabilitation work was done in the control basins.

The selected technologies included lining pipes using a cured-in-place material; replacing pipes by pipe bursting or open-cut methods; replacing manholes; rehabilitating manholes using chemical grouting, coatings, or cured-in-place liners and adjusting frames and covers; and installing cleanouts.

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[18] For more information about the pilot projects, see the *Pilot Project Report* (October 2004).

To compare I/I removal effectiveness based on the rehabilitation of specific system components (sewer mains, manholes, laterals, and side sewers), only selected components and combinations of components were rehabilitated (see Table 3-4).

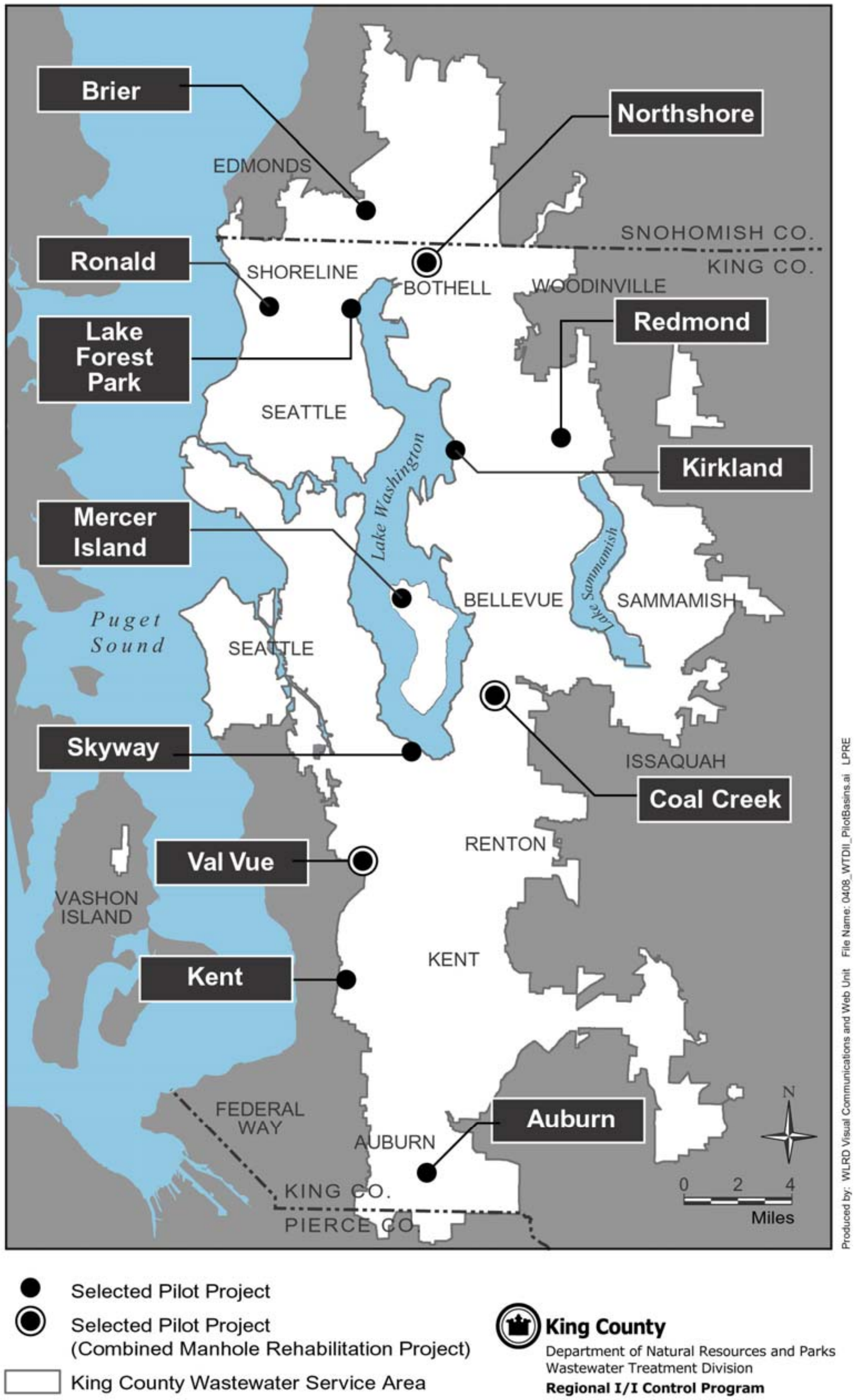


Figure 3-10. Pilot Project Locations

Table 3-4. Sewer System Components Selected for Rehabilitation

Pilot Project	Sewer Main	Manhole	Lateral	Side Sewer
Auburn Pilot A	•	•	•	•
Auburn Pilot B		•		
Brier	•	•		
Kent			•	•
Kirkland	•	•	•	
Lake Forest Park	•	•		
Manhole - Coal Creek		•		
Manhole - Northshore		•		
Manhole - Val Vue		•		
Mercer Island Pilot A	•			
Mercer Island Pilot B	•			
Redmond Pilot A	•	•	•	
Redmond Pilot B	•	•	•	
Ronald				•
Skyway	•	•	•	•

3.2.5.2 I/I Reduction Estimated with Modeling

To quantify I/I reduction, the change in flow response of the pilot basin between the pre-rehabilitation and post-rehabilitation monitoring seasons was compared with the change in flow response of a control basin without I/I reduction (see Section 3.2.3 for a description of flow monitoring).

Hydrologic and hydraulic models (see Section 3.2.4 for a description of modeling) were developed and then calibrated to the pre- and post-measured flow responses to a continuous 60-year record of rainfall. The primary purpose for quantifying rainfall in each pilot and control basin was to develop input for flow modeling (see Section 3.2.2 for a description of rainfall analysis and the use of CALAMAR technology). Flow modeling of the pilot and control basins was used to determine whether rehabilitation improvements resulted in reduced peak I/I (see Section 3.2.4 for a description of modeling and the use of MOUSE software). In addition to providing information related to I/I reduction costs and reduction rates, the data collected during the pilot projects were used in the hydrologic and hydraulic models to help establish a common basis for determining I/I reduction effectiveness and to project the 20-year peak flow rates in each basin.

3.2.5.3 I/I Rehabilitation Assumptions

To establish target I/I reduction levels, the County needed to develop assumptions about what I/I reduction levels could be achieved with selected I/I reduction techniques. A range of I/I reduction techniques was considered and selected. The County and its consultant identified six candidate I/I reduction techniques for the benefit/cost analysis, as shown in Table 3-5. The techniques included a full range of responses to different types of I/I, from inflow alone (Technique 1), through infiltration and inflow on public right-of-way (Techniques 2 through 4) and private property (Techniques 5 through 6).

Table 3-5. Candidate I/I Reduction Techniques

Technique	Description	Comments
1	Direct disconnects[19]	Downspouts, catch basins, yard drains, and manholes
2	Replace everything and direct disconnects	Sewer mains, laterals, side sewers, manholes, and direct disconnects
3	Rehabilitate public sewers	Sewer mains, laterals, and manholes
4	Replace public sewers and direct disconnects	Sewer mains, laterals, manholes, and direct disconnects
5	Private property and some laterals	Side sewers and some laterals
6	Private property and some laterals and direct disconnects	Side sewers, some laterals, and direct disconnects

Initial Assumptions

The six candidate I/I reduction techniques were evaluated so that assumptions could be made about the hydraulic and cost estimating programs used by the County. The information sources for these Initial Assumptions were the pilot project results, research into other I/I programs throughout the U.S.[20], and input from the local agencies.

The Initial Assumptions for each technique are shown in Table 3-6, and include the percent of a mini-basin rehabilitated and the resulting I/I reduction. I/I reduction assumptions for the six

[19] Direct disconnects occur when “illicit” connections to the sewer system (that is, pipes carrying something other than sewage) are disconnected and routed to an alternative disposal system such as a ditch or storm sewer.

techniques range from 15 to 80 percent based on an I/I threshold value[21] of 1,500 gallons per acre per day (gpad)[22].

Table 3-6. Initial Assumptions

Technique	Description	% Basin Rehabilitated	% I/I Reduction
1	Direct disconnects (DD)	4%	15%
2	Replace everything and direct disconnects	95% plus DD	80%
3	Rehabilitate public sewers	50%	40%
4	Replace public sewers and direct disconnects	50% plus DD	45%
5	Private property and some laterals	70% Side sewers (SS) 25% Laterals/SS	70%
6	Private property and some laterals and direct disconnects	70% Side sewers 25% Laterals/SS plus DD	75%
	Minimum remaining I/I after rehabilitation	1,500 gpad	

E&P Assumptions

At a meeting of the County and the Metropolitan Water Pollution Abatement Advisory Committee's (MWPAAC's) Engineering and Planning (E&P) Subcommittee (May 26, 2004), it was determined that the Initial Assumptions needed revision to be more conservative. This considered the fact that the pilot projects were relatively small in scale; a larger program effort could be more expensive and not as effective in removing I/I.

In addition, the six techniques were re-configured into four by eliminating Techniques 3 and 5. Techniques 3 and 5 of the Initial Assumptions (see Table 3-6) did not include direct disconnects;

[20] For information about research conducted into other I/I programs, see the description of the National I/I Program Review in the *Regional Wastewater Services Plan Annual Report, 2001*.

[21] The *Regional Wastewater Services Plan* requires that establishment of a mandatory I/I threshold be considered for local agencies. Such a threshold would set a maximum allowable level of I/I that could enter the regional treatment and conveyance system during periods of peak flow. For more information about I/I thresholds, see Section 1.3.1 of the *Alternatives/Options Report* (March 2005).

[22] 1,500 gpad is the current threshold value used for County conveyance system planning and modeling. In its planning efforts, the County assumes that this volume of I/I will come from land that is currently unsewered once development occurs.

however, the E&P Subcommittee agreed that each I/I reduction technique should involve direct disconnects. Technique 6 was modified for the amount of basin rehabilitation work and the assumed I/I reduction percentages were lowered. The resulting final E&P Assumptions used in the benefit/cost analysis are shown in Table 3-7. I/I reduction assumptions ranged from 10 to 80 percent based on an I/I threshold value of 3,500 gpad.

Table 3-7. E&P Assumptions

Technique	Description	% Basin Rehabilitated	% I/I Reduction
1	Direct disconnects	4%	10%
2	Replace everything and direct disconnects	95% Sewer mains 95% Manholes 95% Laterals and side sewers 4% Direct disconnects	80%
3	Replace public sewers and direct disconnects	50% Sewer mains 50% Manholes 50% Laterals 4% Direct disconnects	40%
4	Private property and some laterals and direct disconnects	50% Laterals and side sewers 45% Side sewers only 4% Direct disconnects	60%
	Minimum remaining I/I after rehabilitation	3,500 gpad	

Sensitivity Analysis (Initial) Assumptions

A Sensitivity Analysis was conducted using the Initial Assumptions to determine the effect on the benefit/cost analysis results (see Section 4.6 for a discussion of the Sensitivity Analysis). The Sensitivity Analysis Assumptions are shown in Table 3-8. The Sensitivity Analysis Assumptions utilized: (a) the percentages from the Initial Assumptions for "percent basin rehabilitated" and "percent I/I reduction", and (b) the four techniques as listed for the E&P Assumptions.

Table 3-8. Sensitivity Analysis (Initial) Assumptions

Technique	Description	% Basin Rehabilitated	% I/I Reduction
1	Direct disconnects	4%	15%
2	Replace everything and direct disconnects	95% Sewer mains 95% Manholes 95% Laterals and side sewers 4% Direct disconnects	80%
3	Replace public sewers and direct disconnects	50% Sewer mains 50% Manholes 50% Laterals 4% Direct disconnects	45%
4	Private property and some laterals and direct disconnects	25% Laterals and side sewers 70% Side sewers only 4% Direct disconnects	75%
	Minimum remaining I/I after rehabilitation	1,500 gpad	

Technique Selection

A selection tree/logic diagram was developed to select I/I reduction techniques for the benefit/cost analysis. The diagram for the E&P Assumptions is shown in Figure 3-11. It is based on a threshold I/I value of 3,500 gpad. The selection tree chooses from the four I/I reduction techniques based on system age (pre- or post-1961[23]) and the combination of I/I types within a mini-basin, as determined by the hydraulic model.

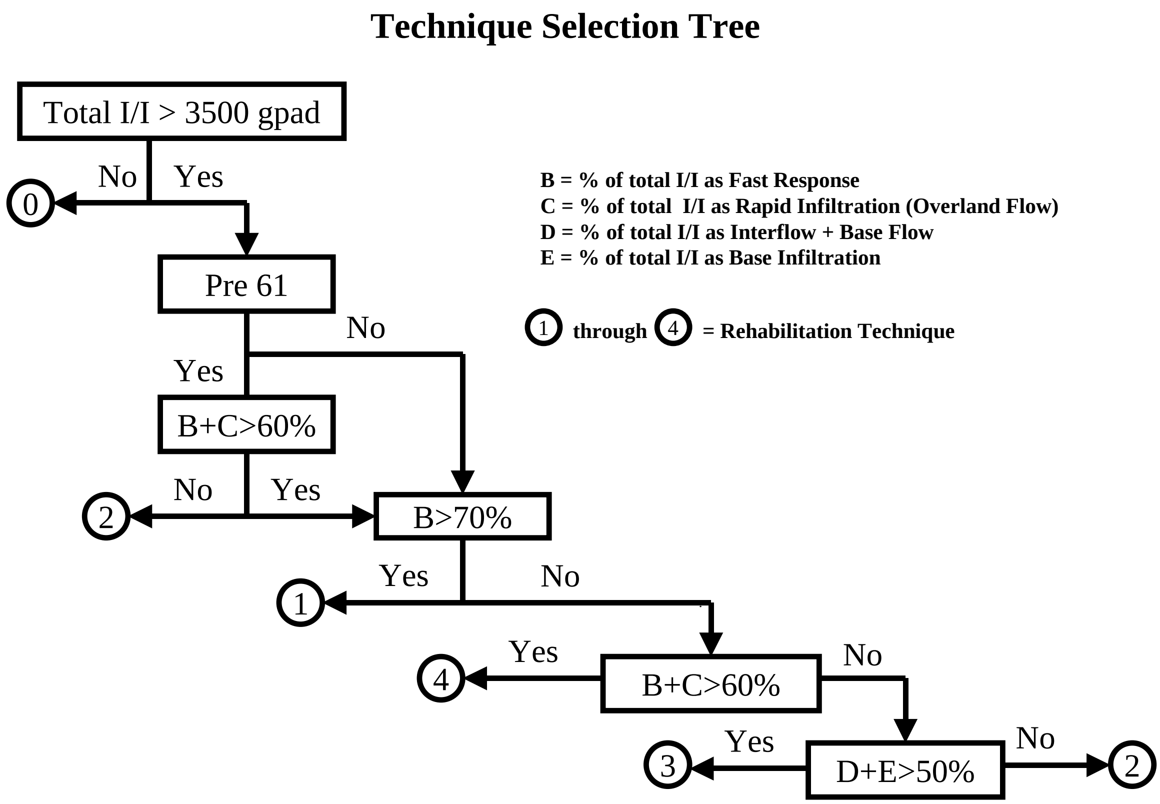


Figure 3-11. Technique Selection Tree

3.2.5.4 Cost Assumptions

Unit costs for I/I reduction techniques were developed based on: (a) the I/I pilot project costs, and (b) historic sewer rehabilitation costs available locally and nationally. These costs were

[23] The regional conveyance system was established in 1961 when local agencies signed contracts with the Municipality of Metropolitan Seattle (Metro) to send their wastewater to Metro's treatment plants. The contract provisions exempt pipelines built before 1961 from standards and fees associated with "clean" water (groundwater or surface water) entering the sewer system. Pipelines built before 1961 can be significant contributors to I/I and may affect the feasibility of establishing a maximum I/I threshold. For more information about including pre-1961 pipe systems in the I/I program, see Section 4.3.2 of the *Alternatives/Options Report* (March 2005).

reviewed by the E&P Subcommittee, and unit cost assumptions were established as shown in Table 3-9 (E&P consensus).

Table 3-9. Unit Costs, E&P Consensus

Technique	Description	Assumed Unit Costs
1	Direct disconnects	$3,000 each
2	Replace everything and direct disconnects	Sewer mains: $110/linear foot Manholes: $3,600 each Laterals and side sewers: $6,800 each Direct disconnects: $1,000 each
3	Replace public sewers and direct disconnects	Sewer mains: $110/linear foot Manholes: $3,600 each Laterals: $3,900 each Direct disconnects: $1,000 each
4	Private property and some laterals and direct disconnects	Laterals: $3,900 each Side sewers: $3,500 each Laterals and side sewers: $6,800 each Direct disconnects: $3,000 each

Table 3-10 lists the allied costs used in the benefit/cost analysis for I/I reduction projects.

Table 3-10. Allied Costs, E&P Consensus

Allied Cost Item	Costs Factor
Utility conflicts	None: Trenchless construction assumed
Traffic control	None: $0 Average: $5/linear foot of sewer main Heavy: $10/linear foot of sewer main
Dewatering	None: Trenchless construction assumed
Sales tax	8.8% of construction estimate
Planning, predesign, design, construction, closeout, land acquisition, non-construction contingency	Techniques 1, 3, and 4: 52% of construction estimate Technique 2: 30% of construction estimate
Project contingency	30% of construction estimate for E&P analysis 0% of construction estimate for sensitivity analysis
Mitigation (environmental, land use, public disruption, private property, etc.)	Project-specific

The I/I reduction unit costs were input into the Benefit/Cost Analysis Tool described in Section 4.2.

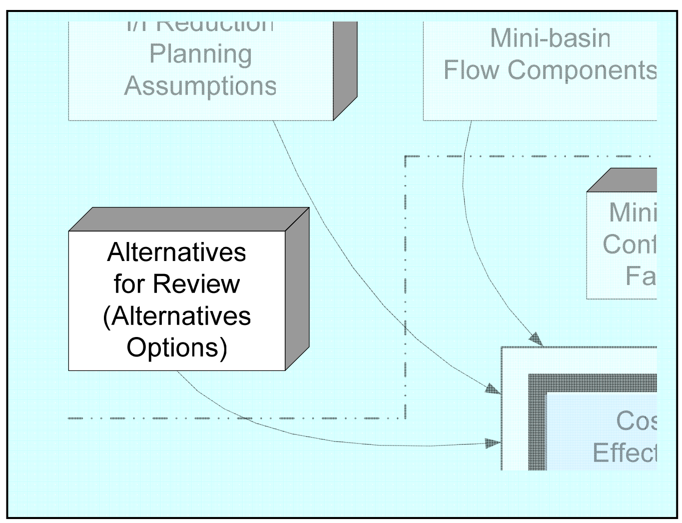
The unit cost assumptions used in the sensitivity analysis are shown in Table 3-11. The Sensitivity Analysis is discussed in Section 4.6.

Table 3-11. Unit Costs, Sensitivity Analysis

Technique	Description	Assumed Unit Costs
1	Direct disconnects	$1,000 each
2	Replace everything and direct disconnects	Sewer mains: $90/linear foot Manholes: $2,800 each Laterals and side sewers: $3,900 each Direct disconnects: $1,000 each
3	Replace public sewers and direct disconnects	Sewer mains: $90/linear foot Manholes: $2,800 each Laterals: $3,900 each Direct disconnects: $1,000 each
4	Private property and some laterals and direct disconnects	Laterals: $3,900 each Side sewers: $2,800 each Direct disconnects: $1,000 each

3.2.6 Alternatives

To consider alternative approaches to I/I reduction[24] and to begin developing a recommended I/I program, the County collaborated with local agencies through the E&P Subcommittee. Lessons learned from the pilot projects were also used in developing the alternatives and program components.



Each of the three alternatives chosen for evaluation includes these core elements:

- A distinct approach to defining the target level of I/I reduction
- Measures of cost-effectiveness for I/I reduction projects
- Methods for funding I/I reduction projects

[24] For more information about alternatives, see the *Alternatives/Options Report* (March 2005).

Alternative 1: 30-Percent Removal – Reduce peak I/I by 30 percent in the regional service area from the peak 20-year level.

Alternative 1 emphasizes a 30-percent reduction in 20-year peak I/I flows on a regional basis. It is taken from the overall I/I control objective articulated in the *Regional Wastewater Services Plan* (RWSP) Policy I/IP-2.4[25]. Thus, the goal for this alternative is removal of 135 million gallons per day (mgd) of I/I from the County system. This gallon-per-day estimate is based on a total estimated I/I flow contribution of 450 mgd.

Alternative 2: Regional – Implement I/I reduction projects that are found to be cost effective based on a *region-wide* evaluation.

Alternative 2 emphasizes I/I reduction projects that are cost effective based on a region-wide evaluation. It is based on RWSP Policy I/IP-1[26], wherein I/I reduction projects are implemented as long as they are more cost effective than conveying and treating the I/I flow in the County's regional system. Under Alternative 2, all I/I reduction projects with a benefit-to-cost ratio greater than 1[27] are implemented. Cost savings realized from the cost-effective projects are re-invested to fund additional I/I reduction projects as needed until the savings are used up and the overall cost of I/I reduction equals the cost of regional conveyance and treatment of equivalent I/I flows.

Alternative 3: Project-Specific – Implement I/I projects that are found to be cost effective based on a *project-specific* evaluation.

This alternative reflects RWSP Policy I/IP-1, as described in Alternative 2 above. However, it is different, and less expensive, than Alternative 2. Alternative 3 emphasizes implementation of specific I/I reduction projects that are cost effective based on their own cost savings, compared with conveying and treating their own I/I flows. Under Alternative 3, only I/I reduction projects with a benefit-to-cost ratio greater than 1 are implemented. Cost savings are not used to fund additional I/I reduction projects that are not cost effective.

The benefit/cost analysis for each of the alternatives is discussed in Chapter 4.

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[25] RWSP Policy I/IP-2.4: "The overall goal for peak I/I reduction in the service area should be thirty percent from the peak twenty-year level identified in the report."

[26] RWSP Policy I/IP-1: "King County is committed to controlling I/I within its regional conveyance system and shall rehabilitate portions of its regional conveyance system to reduce I/I whenever the cost of rehabilitation is less than the costs of conveying and treating that flow."

[27] The benefit/cost ratio is the cost of the regional conveyance system improvement project divided by the cost of the proposed I/I reduction project. See Section 4.1 for more information about the benefit/cost ratio.

Table 3-12. Conveyance System Improvement (CSI) Projects and Estimated Project Costs[28]

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
1	Bear Creek Interceptor Extension	Gravity Line	1998	$400,000
2	Alderwood	Acquisition of Facilities	2001	$16,700,000
3	Swamp Creek	Gravity Line	2003	$10,700,000
4	ESI-11 - Wilburton Siphon/Wilburton Odor Control	Gravity Line	2003	$3,900,000
5	Off-line Storage at North Creek	Storage Facility	2004	$33,800,000
6	ESI-1 (2)	Gravity Line	2004	$8,700,000
7	Fairwood Interceptor (formerly Madsen Creek)	Gravity Line	2005	$21,600,000
8	McAleer I/I Work	I/I rehab work (opportunity)	2005	$3,200,000
9	Pacific Pump Station	Pump Station Upgrade	2006	$7,800,000
10	York PS Subtotal	Pump Station Upgrade	2007	$10,000,000
11	Lake Line Connections and Flap Gates	Gravity Line	2007	$1,400,000
12	Juanita Bay Pump Station	Pump Station	2007	$33,100,000
13	Sammamish Plateau WSD	Acquisition of Facilities	2007	$9,400,000
14	Hidden Lake PS/Boeing Trunk	Pump Station Upgrade and Gravity Line	2008	$28,500,000
15	Kirkland Pump Station and Force Main Upgrade	Pump Station and Force Main Upgrade	2008	$9,600,000
16	Auburn	Interceptor Extension	2008	$11,500,000
17	[CSI] North Creek 1-A	Gravity Line	2009	$16,900,000
18	[CSI] Stuck River Diversion 1	Gravity Line	2009	$5,200,000
19	[CSI] Stuck River Diversion 2	Gravity Line	2009	$2,300,000
20	[CSI] Auburn West Valley Replacement - Section C	Gravity Line	2009	$12,400,000
21	[CSI] Auburn West Valley Replacement - Section A	Gravity Line	2009	$2,900,000
22	[CSI] Auburn West Valley Replacement - Section B	Gravity Line	2010	$25,200,000

[28] See Section 3.2.4.9 for a discussion of this table.

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
23	[CSI] Soos Alternative 3A(3) - PS D w/ Conveyance	New Pump station, Force Main and Gravity Sewers	2010	$35,700,000
24	South Lake City: NWW13-02 TO NWW10-01	Gravity Line	2011	$100,000
25	[CSI] Soos Alternative 3A(3) - PS H w/ Conveyance	New Pump station, Force Main and Gravity Sewers	2011	$42,700,000
26	Piper Creek: T-12 to T-5	Gravity Line	2012	$500,000
27	Piper Creek: T-23 D TO T-12	Gravity Line	2013	$2,200,000
28	Issaquah1 Trunk Pipeline Bifurcation	New Gravity Line	2014	$1,400,000
29	Bellevue Influent Trunk	New Gravity Line	2015	$2,600,000
30	North Mercer and Enatai Interceptors	New Gravity Line	2016	$10,800,000
31	Medina Trunk Minor Upgrade	New Gravity Line	2019	$100,000
32	[CSI] Thornton Creek Interceptor - Sections 1 & 2	New Gravity Line	2019	$3,300,000
33	Bryn Mawr Storage	New Storage Facility	2020	$8,200,000
34	[CSI] Coal Trunk Replacement	New Gravity Line	2020	$6,800,000
35	Factoria Trunk and Wilburton Upgrade	New Gravity Line, Pump Station Upgrade	2020	$27,900,000
36	[CSI] Sammamish Plateau Diversion	New Gravity Line	2020	$18,800,000
37	[CSI] Thornton Creek Interceptor - Section 3	New Gravity Line	2022	$2,400,000
38	[CSI] Mill Creek Relief Sewer	New Gravity Line	2022	$5,000,000
39	North Soos Creek Interceptor	New Gravity Line	2022	$5,600,000
40	Heathfield/Sunset Pump Station and Force Main Upgrade	New Force Main, Pump Station Upgrade	2022	$16,000,000
41	Eastgate Trunk	New Gravity Line	2022	$1,800,000
42	Medina New Storage	New Storage Facility	2023	$3,600,000
43	[CSI] Soos Alternative 3A(3) - PS B w/ Conveyance	New Force Main, New Pump, New Gravity Line	2023	$10,600,000
44	Northwest Lake Sammamish Interceptor	New Gravity Line	2024	$28,900,000
45	Rainier Vista Trunk	New Gravity Line	2024	$600,000
46	Garrison Creek Trunk	New Gravity Line	2024	$12,900,000

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
47	Lake Hills Trunk Fourth Barrel Addition	New Gravity Line	2025	$12,400,000
48	[CSI] North Creek 2-A	Gravity Line	2026	$45,500,000
49	[CSI] Swamp Creek Parallel - Section 1B	New Gravity Line	2026	$7,300,000
50	Algona Pacific Trunk Stage 1	New Gravity Line	2026	$4,300,000
51	[CSI] Issaquah New Storage	New Storage Facility	2026	$15,100,000
52	[CSI] Sammamish Plateau Storage	New Storage Facility	2027	$20,500,000
53	Issaquah Creek Highlands New Storage	New Storage Facility	2029	$3,900,000
54	Planning, Studies, Administration, and Program Development	Ongoing Program	2030	$15,200,000
		Sub-Total of Projects Needed by 2030		***$648,000,000***
55	Auburn3 New Storage	New Storage Facility	2030-2050	$33,800,000
56	[CSI] North Creek 3-A	New Gravity Line	2030-2050	$6,700,000
57	Lakeland Trunk	New Gravity Line	2030-2050	$4,800,000
58	ULID 1 Contract 4	New Gravity Line	2030-2050	$2,300,000
59	Issaquah2 Trunk	New Gravity Line	2030-2050	$2,300,000
60	South Renton Interceptor	New Gravity Line	2030-2050	$6,900,000
61	North Creek Trunk	New Gravity Line	2030-2050	$4,000,000
62	Algona Pacific Trunk Stage 2	New Gravity Line	2030-2050	$1,300,000
63	Lakeland Hills Pump Station Upgrade	New Force Main, Pump Station Upgrade	2030-2050	$3,700,000
34-2nd phase	[CSI] Coal Trunk Replacement	New Gravity Line	2030-2050	$7,000,000
30-2nd phase	North Mercer and Enatai Interceptors	New Gravity Line	2030-2050	$12,000,000
36-2nd phase	[CSI] Sammamish Plateau Diversion	New Gravity Line	2030-2050	$4,600,000
40-2nd phase	Heathfield/Sunset Pump Station and Force Main Upgrade	New Force Main, Pump Station Upgrade	2030-2050	$21,900,000
52-2nd phase	[CSI] Sammamish Plateau Storage	New Storage Facility	2030-2050	$7,200,000
51-2nd phase	[CSI] Issaquah New Storage	New Storage Facility	2030-2050	$4,900,000
48-2nd phase	[CSI] North Creek 2-A	Gravity Line	2030-2050	$7,200,000

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
	Sub-Total of Projects Needed between 2031 & 2050			***$130,600,000***
	Total of Project Cost Estimates[1]			**$778,600,000**

[1] Year online balances capacity needs with estimated funding availability.
[2] All estimated costs are in 2003 dollars.

Chapter 4

Benefit/Cost Analysis

The data described in Chapter 3 provided the basis for performing the benefit/cost analysis, which compared the estimated costs of I/I reduction to the estimated costs of planned conveyance system improvement (CSI) projects[1].

This chapter describes how the benefit/cost ratio for a proposed I/I reduction project was calculated and how cost effectiveness was defined. It explains how the Benefit/Cost Analysis Tool (B/C Tool) was used to identify a proposed cost-effective I/I reduction project. In addition, this chapter describes variables that impact the cost effectiveness of a proposed I/I reduction project, including: the methods used to identify CSI projects that would no longer be needed or could be downsized, methods used for selecting specific mini-basins and techniques for I/I reduction, and the factors that influenced the use of data in the benefit/cost analysis.

The benefit/cost analysis results presented in this chapter identify cost-effective I/I reduction projects that would be necessary to implement the three I/I reduction alternatives described in Section 3.2.6. These include: (1) evaluating the cost-effectiveness of achieving a regional I/I reduction goal of 30 percent; (2) evaluating I/I removal from a regional approach (re-investing all savings from cost-effective I/I reduction projects in additional I/I reduction projects until the savings are exhausted); and (3) evaluating I/I removal on a project-specific basis (evaluating each planned conveyance facility on its own merit).

This chapter also presents the results of a Sensitivity Analysis performed at the request of the E&P Subcommittee. The Sensitivity Analysis demonstrates the impact that a different set of effectiveness and cost assumptions would have on the cost-effectiveness results. Figure 4-1 shows how the data described in Chapter 3 provided input to the benefit/cost analysis.

[1] This refers to the CSI projects as presented in Chapter 3 of this Report and as described in detail in the March 2005 *Regional Needs Assessment Report*.

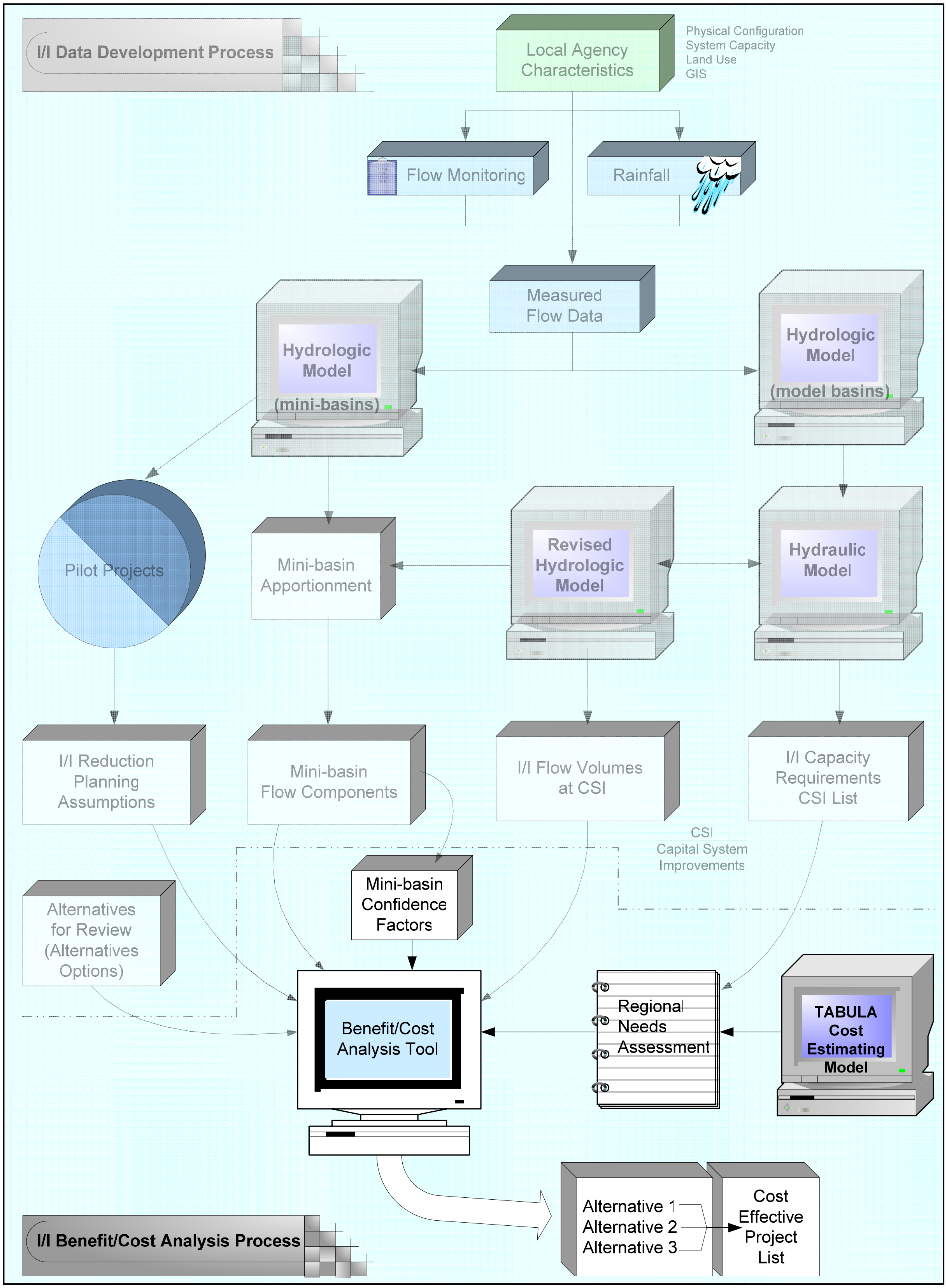

Figure 4-1. Benefit/Cost Analysis Process

4.1 What Defines Cost Effectiveness?

To evaluate cost effectiveness, a benefit/cost ratio was calculated for each candidate conveyance system improvement (CSI) project[2]:

Benefit/Cost Ratio = (CSI Project Savings After I/I Reduction) /
(Cost of Proposed I/I Reduction Project)

A proposed I/I project was considered cost effective if the CSI savings resulting from the I/I reduction project were greater than the cost of I/I reduction. All cost-effective projects had a benefit/cost ratio greater than 1.

For some cost-effective projects, the need for a CSI project could be eliminated; in other cases, the CSI projects could be significantly downsized, but some CSI work would still be needed. In all cases, for a project to be considered cost effective, the cost of I/I reduction plus the cost of any remaining CSI work had to be less than the cost of the originally planned CSI project without I/I reduction. Examples of how projects were evaluated for cost effectiveness are included below.

Example 1: Project-Specific Evaluation of Cost Effectiveness

Based on the definition of project-specific (Alternative 3; see Section 3.2.6 of this Report) cost effectiveness used for this analysis, all projects considered cost-effective had a benefit/cost ratio greater than 1. An example of a hypothetical project-specific cost-effective project using this definition is provided below.

Original CSI project cost:	$30 million
Cost to do I/I reduction work:	$10 million (cost)
Savings to CSI project resulting from I/I reduction (that is, project is downsized):	$15 million (benefit)
Benefit/cost ratio:	1.5

In this example, the *benefit* is the $15 million saved. This number was compared to the *cost* of the I/I reduction work. The benefit/cost ratio is therefore $15 million divided by $10 million, which equals a benefit/cost ratio of 1.5.

Example 2: Regional Evaluation of Cost Effectiveness

When evaluating I/I reduction for cost effectiveness from a regional standpoint (Alternative 2; see Section 3.2.6 of this Report), I/I reduction was considered cost effective if the total CSI savings resulting from the I/I reduction projects was equal to the cost for I/I reduction.

[2] This refers to the CSI projects as presented in Chapter 3 of this Report and as described in detail in the March 2005 *Regional Needs Assessment Report*.

For example, a series of I/I projects would be considered cost effective if the combined CSI savings resulting from the I/I reduction project was equal to the cost of the combined I/I reduction. Based on the definition of regional cost effectiveness used for this analysis, the combined regional cost-effective projects must have a benefit/cost ratio greater than or equal to 1. An example of a hypothetical regional cost-effective project using this definition is shown below.

Project 1:

Original CSI Project 1 cost:	$30 million
Cost to do Project 1 I/I reduction work:	$10 million (cost)
Savings to CSI project resulting from I/I reduction (that is, Project 1 is downsized):	$15 million (benefit)

Funds available for regional reinvestment are $5 million ($15 million minus $10 million).

Project 2:

Original CSI Project 2 cost:	$20 million
Cost to do Project 2-I/I reduction work:	$10 million (cost)
Savings to CSI project resulting from I/I reduction (that is, Project 2 is downsized):	$5 million (benefit)
Project 2 I/I reduction project overage:	$5 million (excess)

Using the Regional approach, the excess savings from Project 1 ($5 million) are reinvested in Project 2 ($5 million).

Net Cost to do Project 1 & 2I/I reduction work:	$20 million (cost)
Net Savings to CSI Projects 1 & 2 from I/I reduction (that is project 1 & 2 downsized:	$20 million (benefit)
Benefit/cost ratio:	1

The benefit/cost ratio is equal to 1; therefore, the regional approach to implementing I/I reduction for Project 1 and Project 2 is cost effective.

Example 3: 30-Percent Evaluation of Cost Effectiveness

When evaluating the cost effectiveness of achieving a regional I/I reduction goal of 30 percent, the benefit/cost ratio was calculated to determine if it exceeded a ratio of 1:1. A benefit/cost ratio of less than 1 for achieving 30-percent I/I reduction was not considered cost effective.

An example of a hypothetical 30-percent I/I reduction project is shown below.

Amount of I/I reduction (30 percent):	100 million gallons
Cost to achieve 30-percent reduction:	$500 million (cost)
Capital facilities improvement reduction:	$300 million (benefit)
Benefit/cost ratio:	0.6

The benefit/cost ratio is less than 1; therefore, the 30% I/I reduction project is not cost effective.

The three alternative approaches for evaluating the cost effectiveness of I/I removal (project-specific, regional, and 30-percent target goal) are presented in Section 4.6 for the E&P Assumptions and the Sensitivity Analysis Assumptions.

4.2 Benefit/Cost Analysis Tool Process Steps

The Benefit/Cost Analysis Tool (B/C Tool) is a database analysis tool that evaluates I/I reduction as an alternative to building new or larger CSI projects. The County determined that using the B/C Tool was the best method for evaluating identified CSI facilities, model basins, mini-basins, alternative cost-effectiveness approaches, and large numbers of additional variables.

The B/C Tool helped determine the optimal I/I reduction available to eliminate or downsize a proposed CSI project. The B/C Tool estimated the costs and/or savings of completing an I/I rehabilitation project. It was developed using a Microsoft® Access platform. Using this software platform was necessary for storing the large quantities of information required for calculating the cost effectiveness of an I/I rehabilitation project.

The B/C Tool tested a method for I/I remediation based on the number of laterals, pipe age, and total I/I available in a basin. This selection could be overridden by the analyst in the B/C Tool if necessary to achieve a greater amount of I/I reduction. Factors that could impact the selection of alternative I/I reduction methods included variables such as cost factors, level of confidence for the mini-basin data, or modified I/I reduction approaches.

With the mini-basins and a remediation technique selected, the B/C Tool generated the estimated cost necessary to perform the proposed I/I reduction work. Specific cost assumptions included in the B/C Tool were those adopted by the E&P Subcommittee (see Table 3-9 for E&P assumed unit costs and Table 3-10 for allied costs).

The sum of the I/I reduction was exported from the B/C Tool into an output file. This output file was processed by the County, where the file was imported into the regional conveyance system hydraulic model and the output from the hydraulic model used to recalculate the capital facility costs using TABULA software (see Section 3.2.4.9 for a description of TABULA). Finally, the output from TABULA and the hydraulic model was re-entered in the B/C Tool, which compared the reduction in capital costs (if any) to the cost of I/I rehabilitation. The results of the comparison determined if the I/I rehabilitation project was cost effective.

Based on the TABULA and hydraulic model results, adjustments to the selected mini-basins or I/I removal technique around a particular facility sometimes occurred. When this occurred, the current settings in the B/C Tool were saved with a unique “iteration” number before any changes were made. This allowed for recall of previous iterations if the changes were less cost effective than the original settings.

For the analyses performed using the E&P Assumptions and costs and the Sensitivity Analysis (Initial) Assumptions and costs, the iteration numbering convention was as shown in Table 4-1.

Table 4-1. Iteration Numbering Convention,
E&P and Sensitivity (Initial) Costs and Assumption Analysis

E&P Costs and Assumptions	Purpose
Iteration 1.10 & 1.01	Independent analysis of single facilities
Iteration 1.11, 1.12, 1.13, 1.14…	Revised analysis of single facilities (if necessary)
Iteration 1.60	All final cost-effective facilities runs
Iteration 1.61	All runs impacted by final cost-effective facilities
Sensitivity Analysis (Initial) Costs and Assumptions	
Iteration 3.01	Independent analysis of single facilities
Iteration 3.02, 3.02, 3.03, 3.04…	Revised analysis of single facilities (if necessary)
Iteration 3.10	All final cost-effective facilities runs and all runs impacted by final cost-effective facilities

If one or multiple iterations resulted in a cost-effective I/I project, the most cost effective project was selected. When analysis continued at upstream or downstream locations, the impacts of an approved project were reflected in the related analyses. The effects of a cost-effective project might or might not be carried forward if those same savings could be rolled into another, more cost-effective upstream or downstream project.

After all likely combinations of mini-basins and associated I/I reduction were exhausted, the iteration closest to being cost effective was flagged and placed on a Select List (see Section 4.5 for a description of the Select List). Analysis of the next downstream facility then occurred. If a project downstream was determined to be cost effective, all upstream facility analyses were revisited and the effects of the downstream project were included. The iteration on the Select List was also revised.

Before the evaluation started, prospective improvements to the regional conveyance system were identified – the total of 63 different "facility improvements" of different types (Table 4-2) were identified as "needed" and sized utilizing the hydraulic model and parameters described in Chapter 3. An additional hydraulic analysis was then completed to estimate a "target" level of I/I reduction necessary to reduce, delay, or eliminate the needed facility improvement. For each needed facility improvement, approximate costs for construction, schedule, and operation/maintenance were determined.

Table 4-2. Types of Facility Improvements

- Construction of new or expansion of existing pump station and/or force main
- Modification to existing wastewater treatment plant
- Construction of new parallel line for interceptor
- Construction of new conveyance storage facility
- Upsizing of existing interceptor (for example, from 36-inch diameter to 40-inch)

Next, a list of prospective I/I rehabilitation projects was identified and evaluated to ensure that they a met a set of "minimum" criteria. Under the first minimum criterion, mini-basins with less than 3,500 gpad[3] were excluded as candidates for I/I reduction. A second criterion set a minimum I/I level of 3,500 gpad for any mini-basin, regardless of the I/I reduction technique selected or the initial level of I/I in the targeted basin. It was determined that mini-basins that fell below the minimum gpad after I/I reduction needed to have their I/I reduction flows and associated costs reduced until the 3,500-gpad level was met. These criteria for establishing a maximum value for I/I removal success were based on experience from the 10 pilot rehabilitation projects described in Section 3.2.5 and were approved by the local agencies and the County.

Out of all the mini-basins in the regional service area, a total of 450 mini-basins qualified as potential I/I rehabilitation projects for I/I reduction. For each qualifying mini-basin, the four rehabilitation strategies outlined in Table 3-7 were evaluated through the technique selection process described in Section 3.2.5.3 to determine if the level of I/I reduction estimated for the selected rehabilitation technique could achieve the targeted level of I/I reduction.

The process of selecting one of the four I/I reduction techniques may have many iterative steps prior to selecting a preferred I/I reduction project(s) alternative. The selection process utilizes the combined information developed through the hydrologic model, pilot projects and I/I rehabilitation assumptions to identify the I/I reduction technique resulting in the lowest cost per gallon of I/I removed. The lowest cost per gallon technique for I/I reduction is used unless it fails to achieve the targeted level of I/I reduction needed to delay, reduce or eliminate a planned CSI facility. Under that condition, an alternative I/I reduction technique is selected and evaluated to determine if it will reach the targeted level of I/I reduction and if the I/I reduction effort is cost effective. This process of implementing the B/C Tool to identify one or more mini-basins (I/I rehabilitation projects) is illustrated in Figure 4-2 and described in the 11-step process that follows.

[3] A 3,500-gpad threshold was established based on the results of the 10 pilot projects; in some mini-basins, rehabilitation of sewer system components did not result in I/I reduction levels of less than 3,500 gpad. For more information about I/I reduction and rehabilitation effectiveness, see Sections 8.6 and 8.7 of the *Pilot Project Report* (October 2004).

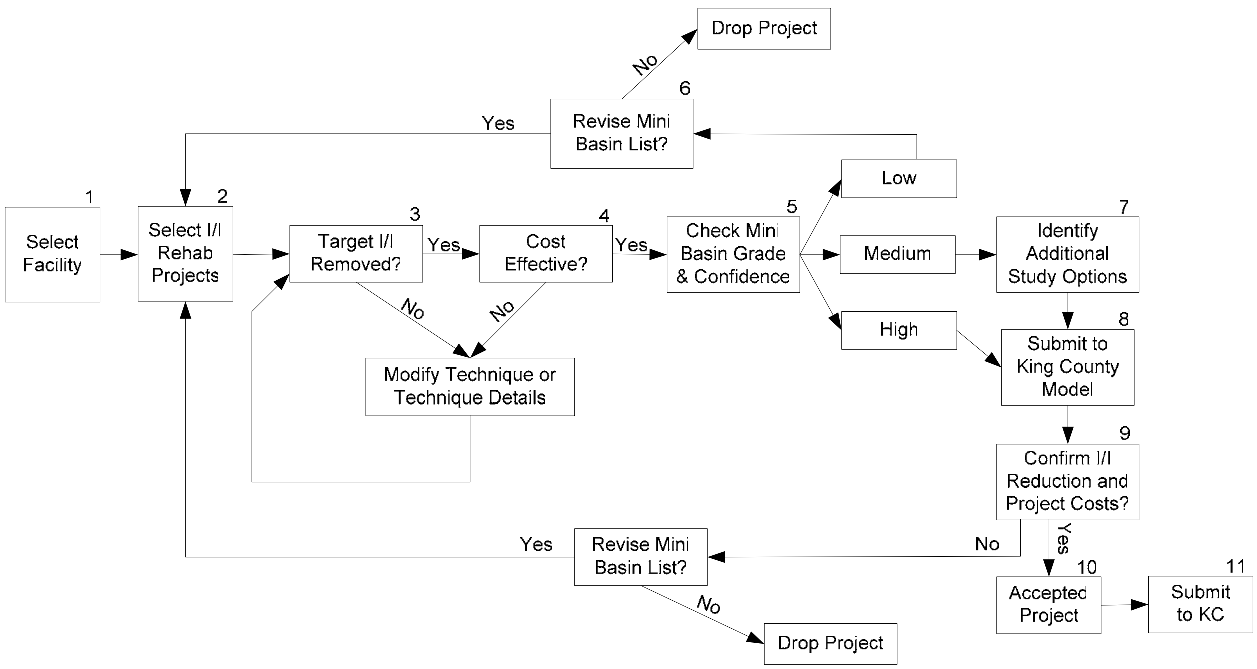

Figure 4-2. Alternatives Selection Process

Step 1 – Select Facility

Beginning at the most upstream point of each regional wastewater treatment plant basin, conveyance facility improvements (as identified in the Regional Needs Assessment) were selected and target levels of I/I reduction were identified. Preliminary downstream I/I reduction was calculated to identify if additional downstream "benefits" could be achieved.

Step 2 – Select I/I Rehabilitation Projects

The mini-basins were selected based on least cost per gallon for I/I reduction and a rehabilitation technique was chosen from those described in Section 3.2.5.3. Once a technique was selected, the I/I reduction assumptions were applied to one or more mini-basins that qualified for rehabilitation until the level of I/I removal was comparable to the target level of I/I impacting the facility. If there was inadequate I/I flow to eliminate the need for the identified conveyance facility improvement, a possibility still existed for delaying construction or reducing the size of the proposed facility.

Step 3 – Targeted I/I Removed?

The mini-basin hydrologic model was then used to simulate a long-term rainfall condition to estimate peak flows in the mini-basin before and after rehabilitation, and to determine if the targeted level of I/I was achieved. If the target level of I/I reduction was not achieved, then Step 2 needed to be repeated and other I/I removal techniques considered, or additional mini-basin rehabilitation projects added if available.

Step 4 – Cost Effective?

Once the targeted level of I/I reduction was achieved as described in Step 3, then the I/I reduction costs were calculated for the targeted mini-basins. These costs were based on the I/I reduction technique selected, the quantity of work to be done, and the unit costs for the associated I/I reduction (see Section 3.2.5.3 for a description of I/I rehabilitation assumptions and Section 3.2.5.4 for cost assumptions). A mini-basin's I/I reduction flows and costs were proportioned if they fell below the minimum gpad limit after rehabilitation. I/I removal efficiency factors were modified and then rounded up to the nearest 10 percent.

This projected cost of I/I reduction was then compared with the projected cost of a conveyance facility improvement (see Table 3-3 for conveyance facility cost assumptions) that would be needed without the I/I reduction. If the CSI facility cost was less than the cost of the proposed I/I reduction, then another I/I reduction technique or set of mini-basins might require evaluation. In some cases, the maximum extent of I/I reduction only reduced the size and cost of a proposed CSI facility and did not entirely eliminate the need for the facility improvement. In this situation, the cost of the I./I rehabilitation was compared to the CSI cost savings from the proposed I/I reduction and not the original estimated conveyance facility improvement cost.

Step 5 – Check Mini-Basin Grade and Confidence

This step took into consideration the confidence factors for each mini-basin data based on the quality of flow monitoring data for each mini-basin (as previously described in Section 3.2.4.8). The criteria for establishing the confidence in a mini-basin was used to qualify a targeted mini-basin as having low, medium or high confidence in the quality of its flow data.

Step 6 – Low Confidence/Revise Mini-Basin List

If the level of confidence for a targeted mini-basin was determined to be low, a revised list of mini-basins that did not include mini-basins with low confidence was considered for evaluation, if possible. If that was not possible, the mini-basins with low confidence were reassessed to determine if a lower value of I/I for the mini-basin could be used with an acceptable level of confidence. If this was not possible, than the I/I reduction project for the conveyance facility improvement under analysis was dropped from consideration.

Step 7 – Medium Confidence/ Identify Additional Study Options

If the level of confidence for a targeted mini-basin was determined to be medium, additional study options were recommended to confirm, if possible, the sources of I/I within the targeted mini-basin. This would also apply to any low confidence mini-basins selected for rehabilitation in Step 6 above. An example of this was a recommendation that mini-basin field investigations of possible I/I sources be completed and evaluated prior to proceeding with implementation of the I/I reduction project.

Step 8 – High Confidence/ Submit to County for Hydraulic Model Evaluation

The I/I reduction (as estimated in Steps 2 and 3) for the targeted mini-basins rating a medium or high level of confidence were submitted to the County for verification of the I/I reduction at the targeted CSI facility.

Step 9 – Confirm I/I Reduction and Projected Costs

Confirmation of I/I reduction and projected costs was accomplished through the use of the model basin hydrologic model and the County hydraulic model. The hydrologic and hydraulic models simulated a long-term rainfall (60-year) record to estimate peak flows in the County conveyance system after I/I removal and to determine if the targeted level of I/I was achieved. If the target level of I/I reduction was not achieved, then other I/I removal techniques were considered, or additional mini-basin rehabilitation projects were added, if available. If either of these two options was possible, then Steps 2 thru 9 were repeated until the I/I reduction project was accepted for submittal to the County. In those cases where it was not possible, the I/I reduction project for the targeted conveyance facility improvement was dropped from consideration

Step 10 - Accept I/I Reduction Project

Once the targeted level of I/I reduction was verified in Step 9, then the proposed I/I reduction project, the projected I/I reduction, and the estimated cost developed in Step 4 for the I/I reduction project were accepted.

Step 11 - Submit I/I Reduction Project to County

Once an I/I reduction project was accepted as a cost-effective project, a complete benefit/cost analysis package was prepared and submitted to the County for review and approval.

A Facility Benefit/Cost Analysis Cover Sheet was prepared for each I/I reduction project determined to be cost effective, and presented a summary of I/I flow and cost information utilized in the analysis, including:

- Listing of mini-basins used
- Upstream and downstream impacts
- Overall costs of the CSI facility improvements with and without the I/I project
- Benefit/cost ratio
- Net project cost or savings

Each I/I reduction project was evaluated using both E&P Assumptions and costs and Initial Assumptions and costs. Each of these evaluations was completed by utilizing the B/C Tool in a series of database iterations. For the E&P Assumptions, the iteration numbering nomenclature was “Iteration 1.xx”, with each new iteration assigned a new number for tracking purposes. Similarly, for the Initial Assumptions, the iteration numbering nomenclature was “Iteration

3.xx", with each new iteration assigned a new number for tracking purposes. Complete analysis packages for all projects are summarized in Section 4.5; complete packages are included in Appendices A1 through B1.

In addition, four lists were generated from the E&P Assumptions and costs analysis:

1. Cost-Effective List
2. Select List
3. Regional List
4. 30-Percent I/I Reduction List

4.3 Candidate Regional Conveyance System Improvement (CSI) Projects

To compare the benefits and costs of proposed I/I reduction projects to those of conveyance system improvement (CSI) projects, it was necessary to identify and evaluate the CSI projects that were likely candidates for elimination or reduction. This process was first presented in Section 3.2. A list of candidate CSI projects from the Regional Needs Assessment is presented in Table 3-12.

The County maintained a list of capital projects, the CSI Project List, which was originally generated for the Regional Needs Assessment. Each capital project on the list was comprised of one or more individual conveyance system facility improvements.

The CSI Project List was the starting point for the benefit/cost analysis (see Section 4.2 for a description of how the Baseline Project List was used as input into the B/C Tool). The CSI Project List included a target for I/I flow reduction that would eliminate each conveyance facility improvement, and an estimated capital cost for each.

The locations of planned CSI projects are shown in Figure 3-9. Each facility (pipeline or pump station) within the regional conveyance system receives sewage flow from upstream mini-basins. The point of connection of each mini-basin to the regional conveyance system was identified through review of GIS and as-built documentation provided by local agency sewer systems. This information provided the basis for understanding which portions of the regional conveyance system are impacted by elevated levels of I/I.

To determine if proposed I/I reduction projects in mini-basins tributary to a particular regional conveyance system improvement might be cost effective, it was necessary to achieve a flow reduction threshold at the regional conveyance system facility, or at associated upstream or downstream facilities, that triggered a significant reduction in the required conveyance facility improvement investment, such as a smaller pipe size, fewer pumps, or a flow reduction significant enough to eliminate the need for the planned conveyance system facility improvement. This was achieved through an iterative process using the B/C Tool described earlier in Section 4.2.

4.4 Confidence Factors

As is typical when flows are modeled, the quality of the results varied from basin to basin. Several factors influenced the confidence that could be placed in modeling results and the certainty with which the results could be used in the benefit/cost analysis. The most significant factors included:

- Quality and accuracy of calibrated flow and rainfall data
- Quality of the simulation match to measured flow
- Results of the mini-basin/model basin apportionment process, particularly where high or low apportionment factors were derived

These level of confidence factors were utilized when evaluating mini-basin flows as potential targets for I/I reduction. Confidence factors for each mini-basin are described in Section 3.2.4.8 and are presented in more detail in Appendices A1 through B1.

4.5 Identified Cost-Effective I/I Projects

4.5.1 CSI Project Lists

Baseline Project List

The Baseline Project List is a list of conveyance facility improvement projects as identified in the Regional Needs Assessment (see Section 3.2.4.9 and Table 3-12).

Cost-Effective List

The Cost-Effective List presents the results of the cost-effectiveness analysis and I/I reduction levels achieved if Alternative 3 were implemented. Alternative 3 is designed to identify specific I/I reduction projects that are cost effective based on their own cost savings, compared with conveying and treating their own I/I flows (see Section 3.2.6).

The Cost-Effective List contains all projects with a benefit/cost ratio greater than 1. Using the E&P-Approved Assumptions and costs analysis, nine projects were identified that would eliminate, reduce, or delay the planned facilities. These nine projects were assigned an iteration number of 1.60 and are listed in Table 4-3.

In Table 4-3, the "Capital Facility Cost Reduction" column shows the total cost savings associated with the proposed I/I work at a given facility for a specific iteration. This Capital Facility Cost Reduction number includes monies saved from the reduction/deletion of the facility listed as well as upstream and downstream facilities. The "I/I Rehab" column shows the actual cost of implementing I/I remediation work. The "B/C Ratio" (benefit/cost ratio) column shows the Capital Facility Cost Reduction number divided by the I/I Rehab cost. If the benefit/cost ratio is greater than 1, the project would save more money than it costs.

Table 4-3. Cost-Effective Project List

CSI No.	Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio	No. of Private Properties
60	1.60	South Renton Interceptor (RE*SRENTON.R18-16(9))	7.0	0.81	$7,270,000	$2,217,645	3.3	119
58	1.60	ULID 1 Contract 4 (RE*ULID 1-4.S-31(8))	5.5	1.08	$2,410,000	$999,123	2.4	101
55	1.60	Auburn 3 New Storage (Auburn3 Twin Tube Storage)	52.8	6.87	$22,990,000	$11,362,511	2.0	1,176
59	1.60	Issaquah 2 Trunk (RE*ISSAQ2.R17-40(3))	5.4	1.05	$5,770,000	$3,964,850	1.5	395
33	1.60	Bryn Mawr Storage (Bryn Mawr Tube Storage)	16.2	2.04	$8,510,000	$6,018,534	1.4	557
47	1.60	Lk Hills Trunk 3rd Barrel Upgrade (WE*LKHILLST.ENTR(3))	10.8	2.20	$14,438,000	$11,307,052	1.3	1,086
41	1.60	Eastgate Storage and Trunk (Eastgate Tube Storage)	8.7	3.55	$16,629,000	$14,459,862	1.2	1,163
35	1.60	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-05(7))	10.4	2.39	$12,058,000	$10,550,378	1.1	976
46	1.60	Garrison Creek Trunk (RE*ULID 1-5.57I(10))	5.7	2.12	$13,660,000	$12,013,489	1.1	1,275

Notes:

1. Identified projects are based on E&P-Approved Assumptions.
2. The projects at the Eastgate Tube Storage and RE*ISSAQ2.R17-40(3) are interrelated and should be considered as one project for construction.
3. Capital facility modeling for the Eastgate Trunk facilities was updated since the *Regional Needs Assessment Report* was published in March 2005. The updated project now includes the new Eastgate Storage facility.

Completion of these I/I projects would save the County approximately $31 million. It is estimated that approximately 22 million gallons per day (mgd) of I/I would be removed, which is roughly 5 percent of the total I/I in the County's system.

Select List

The Select List (Table 4-4) contains all projects on the Cost-Effective List and all remaining non-cost-effective projects, assuming that the projects on the Cost-Effective List have been completed.

The purpose of the Select List is to present all planned conveyance system improvement project identified in the Regional Needs Assessment in order of their respective I/I reduction benefit/cost ratios.

Facilities with an iteration number of 1.61 are directly impacted by a cost-effective project. Those facilities with a Capital Facility Cost Reduction and an I/I Rehab cost equal to zero were deleted by a cost-effective project. All 55 proposed facilities are shown on this list.

Table 4-4. Select Project List

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
1.60	South Renton Interceptor (RE*SRENTON.R18-16(9))	7.0	0.81	$7,270,000	$2,217,645	3.3
1.60	ULID 1 Contract 4 (RE*ULID 1-4.S-31(8))	5.5	1.08	$2,410,000	$999,123	2.4
1.60	Auburn 3 New Storage (Auburn3 Twin Tube Storage)	52.8	6.87	$22,990,000	$11,362,511	2
1.60	Issaquah 2 Trunk (RE*ISSAQ2.R17-40(3))	5.4	1.05	$5,770,000	$3,964,850	1.5
1.60	Bryn Mawr Storage (Bryn Mawr Tube Storage)	16.2	2.04	$8,510,000	$6,018,534	1.4
1.60	Lk Hills Trunk 3rd Barrel Upgrade (WE*LKHILLST.ENTR(3))	10.8	2.20	$14,438,000	$11,307,052	1.3
1.60	Eastgate Storage and Trunk (Eastgate Tube Storage)	8.7	3.55	$16,629,000	$14,459,862	1.2
1.60	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-05(7))	10.4	2.39	$12,058,000	$10,550,378	1.1
1.60	Garrison Creek Trunk (RE*ULID 1-5.57I(10))	5.7	2.12	$13,660,000	$12,013,489	1.1
1.61	Eastgate Storage and Trunk (RE*EGATE.R11-67(2))	29.8	2.31	$7,350,000	$9,788,577	0.75
1.61	Issaquah Storage (Issaquah Tube Storage)	14.0	2.51	$7,810,000	$11,790,996	0.66
1.10	Richmond Beach Storage (Richmond Beach Triple Tube)	14.3	4.09	$15,560,000	$28,975,090	0.54
1.10	Medina Storage (Medina Tube Storage)	3.8	0.78	$1,820,000	$3,486,033	0.52
1.10	Sammamish Plateau Storage (Sammamish Plat.Tunnel Stg.)	5.1	3.03	$290,000	$568,018	0.51
1.10	N. Mercer & Enatai Interceptor (Sweyoloken Microtunnel)	11.9	4.64	$10,418,000	$20,884,416	0.50
1.10	N. Mercer & Enatai Interceptor (East Channel Siphon)	9.7	4.64	$10,412,000	$20,884,416	0.50

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
1.10	N. Mercer & Enatai Interceptor (North Mercer Interceptor 1)	10.6	4.63	$10,411,000	$20,884,416	0.50
1.10	N. Mercer & Enatai Interceptor (North Mercer Interceptor 2)	10.6	4.63	$10,411,000	$20,884,416	0.50
1.61	Auburns West Valley - C ([CSI]AUBWVAL-C)	15.0	1.06	$1,840,000	$3,732,106	0.49
1.10	Issaquah Crk. Highlands Stg. (Issaquah Creek Tube Storage)	3.1	1.28	$2,760,000	$5,784,296	0.48
1.61	Heathfield/Sunset PS & FM (RE*ISSAQ1.SUNSET(1)FM)	21.0	4.90	$12,060,000	$25,927,887	0.47
1.61	Heathfield/Sunset PS & FM (SUNSET PUMP STATION)	21.0	4.05	$10,310,000	$23,451,983	0.44
1.61	Heathfield/Sunset PS & FM (RE*ISSAQ1.HEATHFIEL(1)FM)	21.0	4.06	$10,310,000	$23,549,181	0.44
1.61	Heathfield/Sunset PS & FM (Heathfield Pump Station)	21.0	4.06	$10,310,000	$23,549,181	0.44
1.61	Auburns West Valley - A ([CSI]AUBWVAL-A)	4.9	1.21	$2,100,000	$5,260,835	0.40
1.61	Auburns West Valley - B ([CSI]AUBWVAL-B)	14.1	1.31	$2,250,000	$6,747,525	0.33
1.10	Boeing Creek Storage Extension (Boeing Creek Tube Storage)	5.9	3.54	$10,230,000	$34,132,369	0.30
1.61	NW Lk Sammamish Interceptor (WE*LKHILLST.T-17A(2))	9.8	1.43	$3,592,000	$14,642,366	0.25
1.61	NW Lk Sammamish Interceptor (WE*LKHILLST.T-04(3))	12.8	1.68	$3,551,000	$14,943,805	0.24
1.61	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-27(18))	17.1	3.10	$5,655,000	$24,944,620	0.23
1.61	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-08(9))	21.4	3.26	$5,541,000	$27,143,897	0.20
1.01	Garrison Creek Trunk (RE*GARISN.R18-06(8))	3.8	1.12	$1,910,000	$10,588,316	0.18
1.61	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-32A(6))	13.1	2.15	$3,612,000	$20,533,762	0.18
1.61	Algona Pacific Trunk Stage 1 (RE*ALPAC.238(9))	3.1	0.16	$310,000	$1,996,267	0.16
1.61	Algona Pacific Trunk Stage 1 (RE*ALPAC.PS 2(1)FM)	3.1	0.16	$310,000	$1,996,267	0.16
1.61	Lakeland Trunk (RE*LAKELAND.02(3))	7.2	9.64	$200,000	$1,486,691	0.13

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
1.61	Lakeland Hills PS Upgrade (Lakeland Hills Pump Station)	2.3	9.55	$200,000	$1,486,691	0.13
1.61	Stuck River Diversion 2 ([CSI]STUCK2)	7.5	9.64	$200,000	$1,486,691	0.13
1.01	Rainier Vista Trunk (WE*RVISTA.W314-34(2))	8.5	5.1	$640,000	$5,957,016	0.11
1.10	Thornton Creek Interceptor - 3 ([CSI]THRCRK-3)	52.4	5.00	$280,000	$3,752,431	0.075
1.10	North Soos Creek Interceptor (RE*NSOOS.382(7))	3.8	0.55	$220,000	$3,732,106	0.059
1.10	Thornton Creek Interceptor - 2 ([CSI]THRCRK-2)	62.6	20.40	$5,910,000	$101,155,463	0.058
1.01	Swamp Creek Parallel ([CSI]SwCr1B)	10.4	3.15	$750,000	$14,189,182	0.053
1.10	Coal Creek Trunk Replacement ([CSI]COAL)	10.7	3.81	$440,000	$12,867,565	0.034
1.10	Mill Creek Relief Sewer ([CSI]MILLCRRELIEF(1))	10.4	2.96	$540,000	$19,716,595	0.027
1.01	Bellevue Influent Trunk (RE*BELLINF.RO7-06(6))	8.9	4.51	$190,000	$11,594,139	0.016
1.10	Thornton Creek Interceptor - 1 ([CSI]THRCRK-1)	22.7	7.80	$570,000	$43,282,181	0.013
1.61	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-09(1))	17.1	0.00	$1,620,000	$0	0.000
1.10	North Creek 1-A ([CSI]NC3-A(1))	19.4	0.00	$0	$0	0.000
1.01	Sammamish Plateau Diversion ([CSI]Sammamish Diversion)	1.0	0.00	$0	$0	0.000
1.61	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-19(7))	5.3	0.00	$0	$0	0.000
1.61	Algona Pacific Trunk Stage 2 (RE*ALPAC.256(7))	3.1	0.00	$0	$0	0.000
1.10	North Creek Trunk (WW*NCREEK_76-1.44(8))	3.5	0.60	$0	$6,664,476	0.000
1.61	Stuck River Diversion 1 ([CSI]STUCK1)	4.9	0.00	$0	$0	0.000
1.61	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-25(8))	4.0	0.00	$0	$0	0.000

Notes:

1. An original analysis of 59 of the 63 facilities was completed because the following four facilities were removed from the final Select List; they were already under construction or too far along in the development process to be modified: (a)

Wilburton Pump Station; (b) RE*KIRKLAND.R04-01(3); (c) Kirkland Pump Station; and (d) RE*KIRKLAND.KIRKLAND (1) FM.

2. Capital facility modeling for the Eastgate Trunk facilities was updated since the *Regional Needs Assessment Report* was published in March 2005. The updated project now includes the new Eastgate Storage facility.

Regional List

The Regional List (Table 4-5) contains all projects on the Cost-Effective List and other selected non-cost-effective projects. The purpose of the Regional List was to present the analysis of the cost effectiveness and I/I reduction levels achieved if Alternative 2 were implemented. Alternative 2 identifies those I/I reduction projects that could be implemented if the cost savings realized from the cost-effective projects were reinvested to fund additional I/I reduction projects as needed until the savings from cost-effective reduction projects are used up and the overall cost of I/I reduction equals the cost of regional conveyance and treatment of equivalent I/I flows (see Section 3.2.6).

The selection of non-cost-effective I/I projects for this list was made using several criteria, including project location, deletion of related facilities, and the benefit/cost ratio. The non-cost-effective I/I reductions projects selected for this list were not necessarily the closest to being cost effective or ones that might eliminate the most I/I. Projects were selected based on their ability to eliminate or reduce planned conveyance facility improvements that would also have ongoing operations and maintenance costs. This is typically the situation for pump stations or storage facilities.

Table 4-5. Regional Project List

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
1.60	South Renton Interceptor (RE*SRENTON.R18-16(9))	7.0	0.81	$7,270,000	$2,217,645	3.3
1.60	ULID 1 Contract 4 (RE*ULID 1-4.S-31(8))	5.5	1.08	$2,410,000	$999,123	2.4
1.60	Auburn 3 New Storage (Auburn3 Twin Tube Storage)	52.8	6.87	$22,990,000	$11,362,511	2
1.60	Issaquah 2 Trunk (RE*ISSAQ2.R17-40(3))	5.4	1.05	$5,770,000	$3,964,850	1.5
1.60	Bryn Mawr Storage (Bryn Mawr Tube Storage)	16.2	2.04	$8,510,000	$6,018,534	1.4
1.60	Lk Hills Trunk 3rd Barrel Upgrade (WE*LKHILLST.ENTR(3))	10.8	2.20	$14,438,000	$11,307,052	1.3
1.60	Eastgate Storage and Trunk (Eastgate Tube Storage)	8.7	3.55	$16,629,000	$14,459,862	1.2
1.60	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-05(7))	10.4	2.39	$12,058,000	$10,550,378	1.1
1.60	Garrison Creek Trunk (RE*ULID 1-5.57I(10))	5.7	2.12	$13,660,000	$12,013,489	1.1
1.1	Richmond Beach Storage (Richmond Beach Triple Tube)	14.3	4.09	$15,560,000	$28,975,090	0.54
1.1	Medina Storage (Medina Tube Storage)	3.8	0.78	$1,820,000	$3,486,033	0.52
1.1	N. Mercer & Enatai Interceptor (East Channel Siphon)	9.7	4.64	$10,412,000	$20,884,416	0.50
1.1	Issaquah Crk. Highlands Stg. (Issaquah Creek Tube Storage)	3.1	1.28	$2,760,000	$5,784,296	0.48

Note:

Capital facility modeling for the Eastgate Trunk facilities was updated since the *Regional Needs Assessment Report* was published in March 2005. The updated project now includes the new Eastgate Storage facility.

30-Percent I/I Reduction List

The purpose of the 30-percent reduction simulation was to present the analysis of the cost effectiveness of implementing Alternative 1. Alternative 1 is designed to reduce I/I levels by 30 percent system-wide, as identified in the RWSP (see Section 3.2.6).

The analysis evaluated the cost of removing 135 million gallons per day (mgd) of I/I from the County system. This amount is 30 percent of the County’s estimated 450 mgd of I/I. To achieve 30-percent reduction in I/I, it was estimated to cost approximately $398 million for I/I reduction while saving only $116 million in conveyance system improvement costs.

The mini-basins where I/I removal was most cost effective (least cost-per-gallon) were included in the analysis until the 135-mgd target was reached. All the utilized mini-basins had at least 3,500 gallons per acre per day (gpad) of I/I after rehabilitation, and no "No Confidence" mini-basins were included (see Section 3.2.4.8 for a description of confidence levels).

4.6 Sensitivity Analysis of Selected Projects (Alternative 3: Project-Specific)

As described in Section 3.2.5.3, Initial Assumptions about I/I reduction were prepared and submitted to the E&P Subcommittee for consideration. These Initial Assumptions were modified by a consensus of the E&P Subcommittee with the primary differences between the two sets of assumptions being: (a) the I/I reduction factors, (b) the limit for the minimum gallons per acre per day (gpad) remaining after I/I reduction, and (c) the unit costs used for I/I rehabilitation techniques. The Initial Assumptions were less conservative than the E&P Assumptions, and were based on the observed results from the pilot projects (see Section 3.2.5 for a description of the pilot projects). To put an upper limit on the potential savings available to the County through I/I reduction, these Initial Assumptions were used to complete a Sensitivity Analysis at the request of the E&P Subcommittee.

The Sensitivity Analysis used assumptions that represented the higher end of the expected performance range to determine the impact on the benefit/cost analysis results. The Initial Assumptions included lower costs, higher effectiveness, and less work effort to achieve assumed I/I reduction rates.

The efficiency of the I/I remediation techniques was generally given a higher efficiency factor in the Initial Assumptions compared with the E&P-Approved Assumptions (see Table 4-6 for the efficiency assumptions). The percent I/I reduction by Techniques 1 and 2 was 5 percent higher, and the percent reduction for Technique 4 was 15 percent higher. The reduction for Technique 3 was the same for both sets of assumptions. The I/I reduction assumptions used in the Sensitivity Analysis are shown in Tables 4-6 and 4-7.

Table 4-6. Efficiency Assumptions by Technique

	Technique	E&P Efficiency Assumptions	Initial Efficiency Assumptions
1	Direct disconnects (DD)	10%	15%
2	Replace everything and DD	80%	80%
3	Replace public sewers and DD	40%	45%
4	Private property with some laterals and DD	60%	60%

The gpad limit necessary to perform remediation on mini-basins also varied between the Initial and E&P-Approved Assumptions for cost. The gpad threshold was modified from 3,500 gpad (E&P-Approved Assumptions) to 1,500 gpad (Initial Assumptions). This created a larger pool of mini-basins for use in the Initial Assumptions analysis than for the E&P-Approved Assumptions analysis.

The cost to perform I/I remediation under the Initial Assumptions was less than the cost for the E&P-Approved Assumptions.

Table 4-7. Sensitivity Analysis Unit Cost by I/I Reduction Technique, Initial Assumptions

Technique	Description	Assumed Unit Costs
1	Direct disconnects (DD)	$1,000 each
2	Replace everything and DD	Sewer mains: $90/linear foot Manholes: $2,800 each Laterals: $3,900 each Side sewers: $2,800 each Direct disconnects: $1,000 each
3	Replace public sewers and DD	Sewer mains: $90/linear foot Manholes: $2,800 each Laterals: $3,900 each Direct disconnects: $1,000 each
4	Private property and some laterals and DD	Laterals: $3,900 each Side sewers: $2,800 each Direct disconnects: $1,000 each

Specific cost-effective projects were ranked on a priority basis, as summarized and presented in Table 4-8. Total I/I removed was estimated at approximately 59 mgd (13 percent). Total cost of the I/I reduction projects was calculated at approximately $107 million. The impact on County facilities resulted in an estimated cost savings of $217 million by eliminating the need for 28 conveyance facility improvement projects and reducing the size or capacity of 12 facilities. The result would be an overall cost savings of approximately $110 million.

Table 4-8. Alternative 3: Cost-Effective/Project-Specific I/I Removal Summary, Initial Assumptions

Total I/I Removed	Total I/I Rehabilitation Costs	Total Capital Facility Savings (Benefit)	Total County Savings	% I/I Removed	Number of Facilities Eliminated	Number of Facilities Downsized
58.7 mgd	$106,852,000	$216,529,000	$109,700,000	13.0	28	12

The Sensitivity Analysis, which used the Initial Assumptions for cost, yielded another iteration of the Select List (see Table 4-9). The Select List contains all projects on the Cost-Effective List and all remaining non-cost-effective projects, assuming that the projects on the Cost-Effective List have been completed.

Those facilities with an iteration number of 3.10 and a benefit/cost ratio less than 1 are directly impacted by a cost-effective project. Those facilities with a Capital Facility Cost Reduction and an I/I Rehab cost equal to zero were replaced on the list with a cost-effective project. All 55 proposed facilities are shown on this list.

Table 4-9. Select Project List, Sensitivity Analysis

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
3.10	ULID 1 Contract 4 (RE*ULID 1-4.S-31(8))	5.5	1.23	$2,410,000	$503,115	4.8
3.10	South Renton Interceptor (RE*SRENTON.R18-16(9))	7.0	0.81	$7,270,000	$2,217,645	3.3
3.10	Garrison Creek Trunk (RE*ULID 1-5.57I(10))	5.7	2.31	$13,660,000	$4,381,782	3.1
3.10	Bryn Mawr Storage (Bryn Mawr Tube Storage)	16.2	2.55	$9,560,000	$3,434,053	2.8
3.10	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-27(18))	17.1	8.16	$44,329,000	$18,257,229	2.4
3.10	Heathfield/Sunset PS & FM (RE*ISSAQ1.SUNSET(1)FM)	21.0	4.64	$16,232,000	$7,145,990	2.3
3.10	Auburn 3 New Storage (Auburn3 Twin Tube Storage)	52.8	14.17	$44,520,000	$19,857,837	2.2
3.10	Eastgate Storage and Trunk (Eastgate Tube Storage)	8.7	4.82	$19,719,000	$9,529,936	2.1
3.10	Coal Creek Trunk Replacement ([CSI]COAL)	10.7	5.62	$15,300,000	$8,974,170	1.7
3.10	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-05(7))	10.4	5.81	$19,218,000	$12,962,235	1.5
3.10	N. Mercer & Enatai Interceptor (Sweyoloken Microtunnel)	11.9	8.43	$24,311,000	$20,545,818	1.2
3.01	Richmond Beach Storage (Richmond Beach Triple Tube)	14.3	5.11	$15,710,000	$16,532,597	0.95
3.01	Medina Storage (Medina Tube Storage)	3.8	0.99	$1,820,000	$1,989,060	0.92
3.01	North Soos Creek Interceptor (RE*NSOOS.382(7))	3.8	2.04	$5,960,000	$8,208,872	0.73

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
3.01	North Creek Trunk (WW*NCREEK_76-1.44(8))	3.5	1.30	$4,230,000	$6,638,779	0.64
3.01	North Creek 1-A ([CSI]NC3-A(1))	19.4	7.2	$13,210,000	$22,140,575	0.59
3.10	Algona Pacific Trunk Stage 1 (RE*ALPAC.238(9))	3.1	0.56	$2,230,000	$3,772,193	0.59
3.10	Algona Pacific Trunk Stage 1 (RE*ALPAC.PS 2(1)FM)	3.1	0.56	$2,230,000	$3,772,193	0.59
3.01	Rainier Vista Trunk (WE*RVISTA.W314-34(2))	8.5	2.45	$640,000	$1,276,215	0.50
3.01	Boeing Creek Storage Extension (Boeing Creek Tube Storage)	5.9	4.43	$7,750,000	$19,475,235	0.40
3.10	Auburns West Valley - C ([CSI]AUBWVAL-C)	15.0	1.62	$2,740,000	$7,228,588	0.38
3.10	Auburns West Valley - B ([CSI]AUBWVAL-B)	14.1	1.61	$2,560,000	$7,217,290	0.35
3.10	Stuck River Diversion 2 ([CSI]STUCK2)	7.5	0.39	$1,000,000	$3,066,005	0.33
3.10	Issaquah Storage (Issaquah Tube Storage)	14.0	1.77	$1,230,000	$4,276,479	0.29
3.10	NW Lk Sammamish Interceptor (WE*LKHILLST.T-17A(2))	9.8	0.78	$750,000	$3,176,645	0.24
3.10	Stuck River Diversion 1 ([CSI]STUCK1)	4.9	0.18	$240,000	$1,079,285	0.22
3.01	Thornton Creek Interceptor - 3 ([CSI]THRCRK-3)	52.4	13.40	$3,370,000	$16,801,705	0.20
3.10	Heathfield/Sunset PS & FM (SUNSET PUMP STATION)	21.0	6.01	$4,467,000	$22,616,195	0.20
3.10	Heathfield/Sunset PS & FM (RE*ISSAQ1.HEATHFIEL(1)FM)	21.0	6.01	$4,459,000	$22,616,195	0.20
3.10	Heathfield/Sunset PS & FM (Heathfield Pump Station)	21.0	6.01	$4,095,000	$22,616,195	0.18
3.10	Eastgate Storage and Trunk (RE*EGATE.R11-67(2))	29.8	7.54	$4,458,000	$28,023,512	0.16
3.01	Thornton Creek Interceptor - 2 ([CSI]THRCRK-2)	62.6	24.49	$6,850,000	$51,855,959	0.13
3.01	Swamp Creek Parallel ([CSI]SwCr1B)	10.4	4.46	$480,000	$7,038,803	0.068
3.01	Mill Creek Relief Sewer ([CSI]MILLCRRELIEF(1))	10.4	4.93	$960,000	$17,123,465	0.056

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
3.01	Bellevue Influent Trunk (RE*BELLINF.RO7-06(6))	8.8	6.05	$300,000	$7,318,570	0.041
3.01	Thornton Creek Interceptor - 1 ([CSI]THRCRK-1)	22.7	10.13	$570,000	$27,449,025	0.021
3.10	N. Mercer & Enatai Interceptor (North Mercer Interceptor 1)	10.6	0.00	$0	$0	0
3.10	Lk Hills Trunk 3rd Barrel Upgrade (WE*LKHILLST.ENTR(3))	10.8	0.00	$0	$0	0
3.10	Issaquah Crk. Highlands Stg. (Issaquah Creek Tube Storage)	3.1	0.00	$0	$0	0
3.10	Issaquah 2 Trunk (RE*ISSAQ2.R17-40(3))	5.4	0.00	$0	$0	0
3.02	Sammamish Plateau Diversion ([CSI]Sammamish Diversion)	1.0	0.27	$0	$2,578,173	0
3.10	Lakeland Hills PS Upgrade (Lakeland Hills Pump Station)	2.3	0.00	$0	$0	0
3.10	Garrison Creek Trunk (RE*GARISN.R18-06(8))	3.8	0.00	$0	$0	0
3.10	N. Mercer & Enatai Interceptor (East Channel Siphon)	9.7	0.00	$0	$0	0
3.10	Algona Pacific Trunk Stage 2 (RE*ALPAC.256(7))	3.1	0.00	$0	$0	0
3.10	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-25(8))	4.0	0.00	$0	$0	0
3.10	Lakeland Trunk (RE*LAKELAND.02(3))	7.2	0.00	$0	$0	0
3.10	Sammamish Plateau Storage (Sammamish Plat. Tunnel Stg.)	5.1	0.00	$0	$0	0
3.10	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-32A(6))	13.1	0.00	$0	$0	0
3.10	Wilburton PS / Factoria Trunk (RE*FACTOR.RO6-19(7))	5.3	0.00	$0	$0	0
3.10	NW Lk Sammamish Interceptor (WE*LKHILLST.T-04(3))	12.8	0.00	$0	$0	0
3.10	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-09(1))	17.1	0.00	$1,620,000	$0	0
3.10	NW Lk Sammamish Interceptor (WE*NWLKSAM.R19D-08(9))	21.4	0.00	$0	$0	0
3.10	N. Mercer & Enatai Interceptor (North Mercer Interceptor 2)	10.6	0.00	$0	$0	0

Itn.	Project (Facility)	I/I Available (mgd)	I/I Reduction (mgd)	Benefit: Capital Facility Cost Reduction	Cost: I/I Rehab	B/C Ratio
3.10	Auburns West Valley - C ([CSI]AUBWVAL-A)	4.9	0.00	$0	$0	0

Notes:

1. An original analysis of 59 of the 63 facilities was completed because the following four facilities were removed from the final Select List: (a) Wilburton Pump Station, (b) RE*KIRKLAND.R04-01(3), (c) Kirkland Pump Station, and (d) RE*KIRKLAND.KIRKLAND(1)FM. These projects were already under construction or too far along in the design process to modify.
2. Capital facility modeling for the Eastgate Trunk facilities was updated since the *Regional Needs Assessment Report* was published in March 2005. The updated project now includes the new Eastgate Storage facility.

Descriptions of each cost-effective I/I reduction project (project-specific) are presented in Chapter 5. Figures 5-1 through 5-9 illustrate the locations of mini-basins included in cost-effective projects and the general locations of proposed CSI facilities delayed, reduced, or eliminated by the proposed I/I reduction.

Chapter 5
Summary

This chapter provides a more detailed description of the nine I/I reduction projects that were identified by the benefit/cost analysis as cost effective. It lists specific conveyance facility improvement projects that could be eliminated, reduced, or delayed by implementing I/I reduction projects in accordance with the evaluation and selection process described in Chapter 4. Information about the locations of proposed I/I reduction projects, quantities of I/I removed, net cost savings, and projected benefit/cost ratio is also provided to expand the level of understanding for each project. See Appendices A1 through B1 for more detailed project information.

Considerations when reviewing the nine cost-effective I/I reduction projects include:

- The estimated cost of implementing the nine cost-effective I/I reduction projects is approximately $73-million, based on the Engineering and Planning (E&P) Assumptions described in Chapters 3 and 4 of this report.
- The anticipated I/I reduction achievable is estimated at 22-million gallons per day (mgd), or approximately 18 percent of the I/I present in the impacted mini-basins and approximately 5 percent of the I/I present in the entire regional service area.
- As a result of reducing I/I flows, it is estimated that the capital costs for the nine identified impacted regional conveyance facility improvement projects could be reduced from approximately $268-million to $164-million, resulting in regional conveyance facility improvement savings of nearly $104-million.
- The net overall savings realized from implementing the nine identified cost-effective I/I reduction projects is estimated at approximately $31-million.
- This report is a planning-level document prepared to support decision-making about how to proceed with I/I reduction efforts in the regional wastewater service area.

The nine I/I reduction projects identified as cost effective may require the rehabilitation of laterals and side sewers in as many as 7000 private properties. Three key elements of the I/I control program that have contributed to the selection of this I/I rehabilitation technique include:

- Mini-Basin Hydrologic Modeling
- Pilot Project Results
- I/I Rehabilitation Assumptions

The hydrologic modeling of the mini-basins is one of the most important elements involved in the identification of I/I components, sources, and quantities generated from the mini-basins targeted for I/I reduction. As detailed in Section 3.2.4 of this analysis, the hydrologic modeling process begins with the calibration of the mini-basin hydrologic models to actual field measured flows and culminated in the separation of the total I/I flows into individual I/I flow components. These components are identified as fast response, rapid infiltration, slow infiltration and base infiltration. Each of these identified flow components has a specific flow characteristic in response to a rainfall event that can be linked to a likely source of inflow and infiltration. These likely sources are presented in Table 3-1 and are supported by the results and findings from the ten I/I reduction pilot projects completed under the I/I Program.

One of the goals of the ten I/I reduction pilot projects was to establish the ability to locate the sources of I/I within the pilot project mini-basins and evaluate the effectiveness of several I/I reduction techniques. A discussion of the facts and findings from the ten I/I reduction pilot projects is presented in Section 3.2.5 of this analysis. This effort included an analysis of the flow monitoring and hydrologic modeling of the pilot project mini-basins, both before and after the I/I rehabilitation was completed. The results of the analysis provided a preliminary "field check" of the modeled flow components, likely I/I sources, and I/I reduction effectiveness for the pilot project mini-basins. The pilot projects also provided the basis for adjusting design-based construction cost estimates with actual final construction costs. Ultimately, the information developed and lessons learned from the pilot project provided the basis for the development of the I/I Rehabilitation Assumptions as presented in Section 3.2.5.3 of this analysis.

The Benefit/Cost Analysis Tool, as described in Section 4.2 of this analysis, utilized the information developed through the hydrologic model, pilot projects and I/I rehabilitation assumptions to identify the I/I reduction technique resulting in the lowest cost per gallon of I/I removed. The lowest cost per gallon technique for I/I reduction is used unless it fails to achieve the targeted level of I/I reduction to delay, reduce or eliminate a planned CSI facility. Under that condition an alternative I/I reduction technique is selected and evaluated to determine if it will reach the targeted level of I/I reduction and if the I/I reduction effort is cost effective.

This analysis process was completed for each of the 63 planned CSI projects and resulted in the identification of the nine cost effective I/I reduction projects, with the each utilizing I/I reduction techniques applied to private property laterals, side sewers and/or direct disconnects.

5.1 Nine Cost-Effective Projects

The proposed I/I reduction projects described herein were segregated by the wastewater treatment plant they discharge to, then listed in descending numerical order by their benefit/cost ratios.

One of the nine cost-effective I/I reduction projects is located in a basin tributary to the West Point Wastewater Treatment Plant, while eight projects are located in basins tributary to the South Wastewater Treatment Plant. Initially, finding only one cost-effective I/I reduction project in the West Point WWTP basin was unexpected given the age and materials that comprise the existing local agency conveyance systems. Upon further review it was determined that most of the needed regional conveyance and treatment facilities in the basin were already under construction or were too far along in the design process for consideration. Figure 5-1 illustrates the location of the proposed I/I reduction projects within the King County service area.

5.1.1 West Point Wastewater Treatment Plant Service Area - I/I Reduction Project

1. WE*LKHILLST.ENTR(3) (Redmond, Bellevue)

This proposed I/I reduction project could eliminate the need for the Lake Hills Trunk Third Barrel Upgrade. The I/I reduction project includes side sewer and lateral rehabilitation in two mini-basins in the City of Bellevue and one mini-basin in the City of Redmond. The estimated cost for the I/I reduction is $11,307,000 and is projected to remove 2.2 mgd of I/I from the local agency collection system, which is approximately 20 percent of the total I/I present in these mini-basins. Figure 5-2 illustrates the location of the proposed I/I reduction project and the regional conveyance facilities impacted by the estimated reduction of I/I.

Eliminating the need for the Lake Hills Trunk Third Barrel Upgrade could save an estimated $13,610,000 and would reduce the capacity needs of one upstream and five downstream conveyance facilities, saving an additional $828,000. The dates by which the capacities of the upstream and downstream conveyance facilities are estimated to be exceeded in a 20-year flow event could also be delayed. The estimated net savings for this I/I reduction project would be $3,131,000. This savings would yield a benefit/cost ratio of 1.3 to 1.

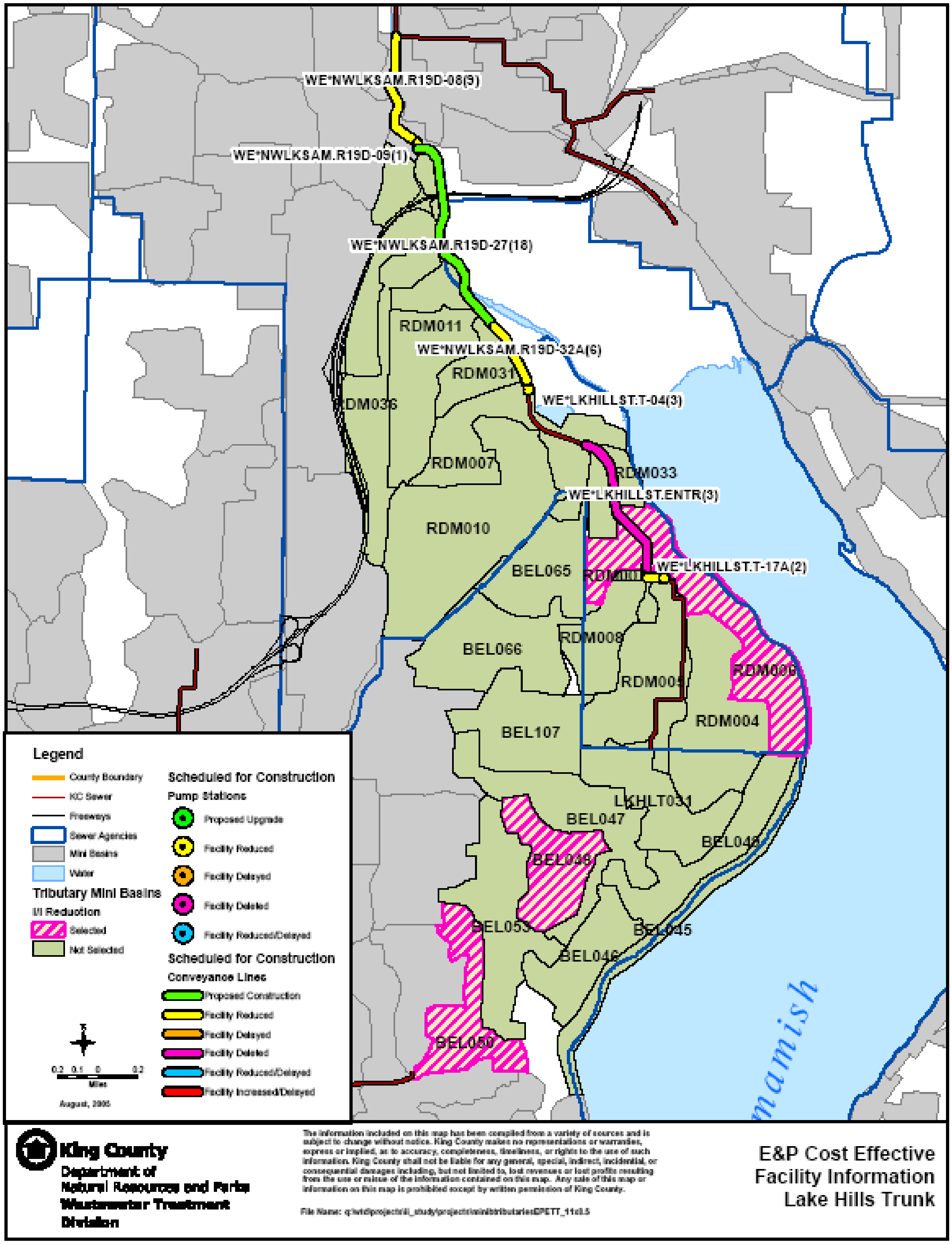

Figure 5-1. Lake Hills Trunk Third Barrel Upgrade

5.1.2 South Wastewater Treatment Plant Service Area - I/I Reduction Projects

2. RE*SRENTON.R18-16(9) (Soos Creek, Renton)

This proposed I/I reduction project could eliminate the need for the South Renton Interceptor Upgrade. The I/I reduction project includes side sewer and lateral rehabilitation in one mini-basin in Soos Creek and one mini-basin in the City of Renton. The estimated cost for the I/I reduction is $2,218,000 and is projected to remove 0.81 mgd of I/I from the local agency collection system, which is approximately 11.6 percent of the total I/I present in these mini-basins. Figure 5-3 illustrates the location of the proposed I/I reduction project and the regional conveyance facilities impacted by the estimated reduction of I/I.

Eliminating the need for the South Renton Interceptor Upgrade could save an estimated $7,270,000. The estimated net savings for this I/I reduction project would be $5,052,000. This savings would yield a benefit/cost ratio of 3.28 to 1.

3. RE*ULID 1-4.S-31(8) (Kent)

This proposed I/I reduction project could eliminate the need for the Utility Local Improvement District (ULID) 1 Contract 4. The I/I reduction project includes side sewer and lateral rehabilitation in two mini-basins in the City of Kent. The estimated cost for the I/I reduction is $999,000 and is projected to remove 1.08 mgd of I/I from the local agency collection system, which is approximately 19.6 percent of the total I/I present in these mini-basins. Figure 5-4 shows the location of the proposed I/I reduction project and the regional conveyance facilities impacted by the estimated reduction of I/I.

Eliminating the need for the ULID 1 Contract 4 pipeline could save an estimated $2,410,000. The estimated net savings for this I/I reduction project would be $1,411,000. This savings would yield a benefit/cost ratio of 2.41 to 1.

4. AUBURN 3 STORAGE (Auburn, Pacific)

This proposed I/I reduction project could reduce the size of the Auburn Twin Tube Storage Facility. The I/I reduction project includes side sewer and lateral rehabilitation in five mini-basins in the City of Auburn and one mini-basin in the City of Pacific. The estimated cost for the I/I reduction is $11,363,000 and is projected to remove 6.87 mgd of I/I from the local agency collection system, which is approximately 13 percent of the total I/I present in these mini-basins. Figure 5-5 shows the location of the proposed I/I reduction project and the regional facilities impacted by the estimated reduction of I/I.

Reducing the size of the Auburn Twin Tube Storage Facility could save an estimated $17,200,000, eliminate one upstream conveyance facility, and reduce the projected capacity needs and cost of six additional upstream conveyance facilities, saving an additional $5,790,000. The dates by which the capacities of nine upstream conveyance facilities are estimated to be exceeded in a 20-year flow event could be delayed. The estimated net savings for this I/I reduction project would be $11,627,000. This savings would yield a benefit/cost ratio of 2.02 to 1.

5. RE*ISSAQ2.R17-40(3) (Issaquah)

This proposed I/I reduction project could eliminate the need for the Issaquah2 Trunk. The I/I reduction project includes side sewer and lateral rehabilitation in two mini-basins in the City of Issaquah. The estimated cost for the I/I reduction is $3,965,000 and is projected to remove 1.05 mgd of I/I from the local agency collection system, which is approximately 19.4 percent of the total I/I present in these mini-basins. Figure 5-6 illustrates the location of the proposed I/I reduction project and regional conveyance facilities impacted by the estimated reduction of I/I.

Eliminating the need for the Issaquah2 Trunk could save an estimated $2,430,000 (see Project 7, EASTGATE STORAGE AND TRUNK (Bellevue), below) and eliminate one downstream conveyance facility, saving an additional $3,340,000. The estimated net savings for this I/I reduction project would be $1,805,000. This savings would yield a benefit/cost ratio of 1.46 to 1.

6. BRYN MAWR STORAGE (Bryn Mawr)

This proposed I/I reduction project could reduce the size of the Bryn Mawr Tube Storage Facility. The I/I reduction project includes side sewer and lateral rehabilitation in two mini-basins in Bryn Mawr. The estimated cost for the I/I reduction is $6,019,000 and is projected to remove 2.04 mgd of I/I from the local agency collection system, which is approximately 12.6 percent of the total I/I present in these mini-basins. Figure 5-7 illustrates the location of the proposed I/I reduction project and the regional facilities impacted by the estimated reduction of I/I.

Reducing the size of the Bryn Mawr Tube Storage Facility could save an estimated $8,510,000. The dates by which the capacity of the conveyance facility is estimated to be exceeded by a 20-year flow event could also be delayed. The estimated net savings for this I/I reduction project would be $2,491,000. This savings would yield a benefit/cost ratio of 1.41 to 1.

7. EASTGATE STORAGE AND TRUNK (Bellevue)

This proposed I/I reduction project could eliminate the need for the Eastgate Tube Storage Facility improvement. The I/I reduction project includes side sewer and lateral rehabilitation in five mini-basins in the City of Bellevue. The estimated cost for the I/I reduction is $14,460,000 and is projected to remove 3.55 mgd of I/I, which is approximately 40.8 percent of the total I/I present in these mini-basins. Figure 5-8 illustrates the location of the proposed I/I reduction project and the regional facilities impacted by the estimated reduction of I/I.

Eliminating the need for the Eastgate Tube Storage Facility improvement could save an estimated $21,120,000 (see Project 5, RE*ISSAQ2.R17-40(3) (Issaquah), above) and would also eliminate or impact the capacities of four upstream conveyance facilities, saving an additional $1,339,000. The dates by which the capacities of seven upstream conveyance facilities are estimated to be exceeded in a 20-year flow event could also be delayed.

Eliminating the Eastgate Tube Storage Facility would require upsizing the upstream Issaquah Tube Storage Facility at an additional estimated cost of $5,830,000. The estimated net savings for this I/I reduction project would be $2,169,000. This savings would yield a benefit/cost ratio of 1.15 to 1.

8. RE*FACTOR.RO6-05(7) (Bellevue)

This proposed I/I reduction project could reduce the capacity requirement for the Factoria Trunk and Wilburton Pump Station Upgrade. The I/I reduction project includes side sewer and lateral rehabilitation in six mini-basins in the City of Bellevue. The estimated cost of the I/I reduction is $10,550,000 and is projected to remove 2.39 mgd of I/I, which is approximately 23 percent of the total I/I present in these mini-basins. Figure 5-9 illustrates the location of the proposed I/I reduction project and the regional conveyance facilities impacted by the estimated reduction of I/I.

Reducing the capacity requirement for the Factoria Trunk and Wilburton Pump Station Upgrade could save an estimated $346,000 and would also eliminate two upstream conveyance facilities, saving an additional $11,712,000. The date by which the capacity of this conveyance facility is estimated to be exceeded in a 20-year flow event could also be delayed. The estimated net savings for this I/I reduction project would be $1,508,000. This savings would yield a benefit/cost ratio of 1.14 to 1.

9. RE*ULID 1-5.57I(10) (Kent)

This proposed I/I reduction project could eliminate the need for the Garrison Creek Trunk improvement. The I/I reduction project includes side sewer and lateral rehabilitation in two mini-basins in the City of Kent and one Utility Local Improvement District (ULID) mini-basin. The estimated cost for the I/I reduction project is $12,013,000 and is projected to remove 2.12 mgd of I/I from the local agency collection system, which is approximately 37.2 percent of the total I/I present in these mini-basins. Figure 5-10 illustrates the location of the I/I reduction project and the regional conveyance facilities impacted by the estimated reduction of I/I.

Eliminating the Garrison Creek Trunk improvement would save an estimated $12,059,000 and would also eliminate one upstream conveyance facility, saving an additional $1,601,000. The estimated net savings for this I/I reduction project would be $1,647,000. This savings would yield a benefit/cost ratio of 1.14 to 1.

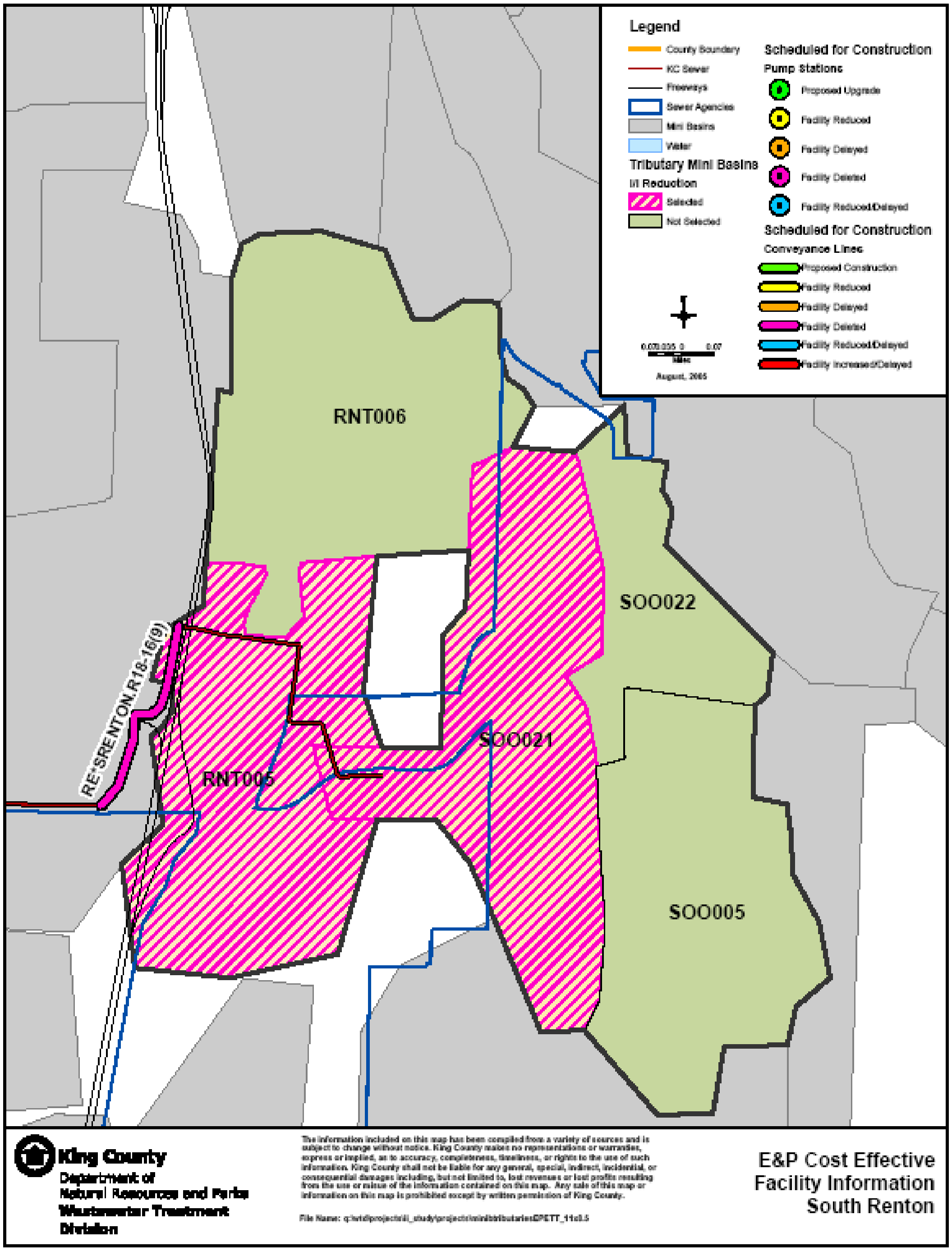

Figure 5-2. South Renton Interceptor Upgrade

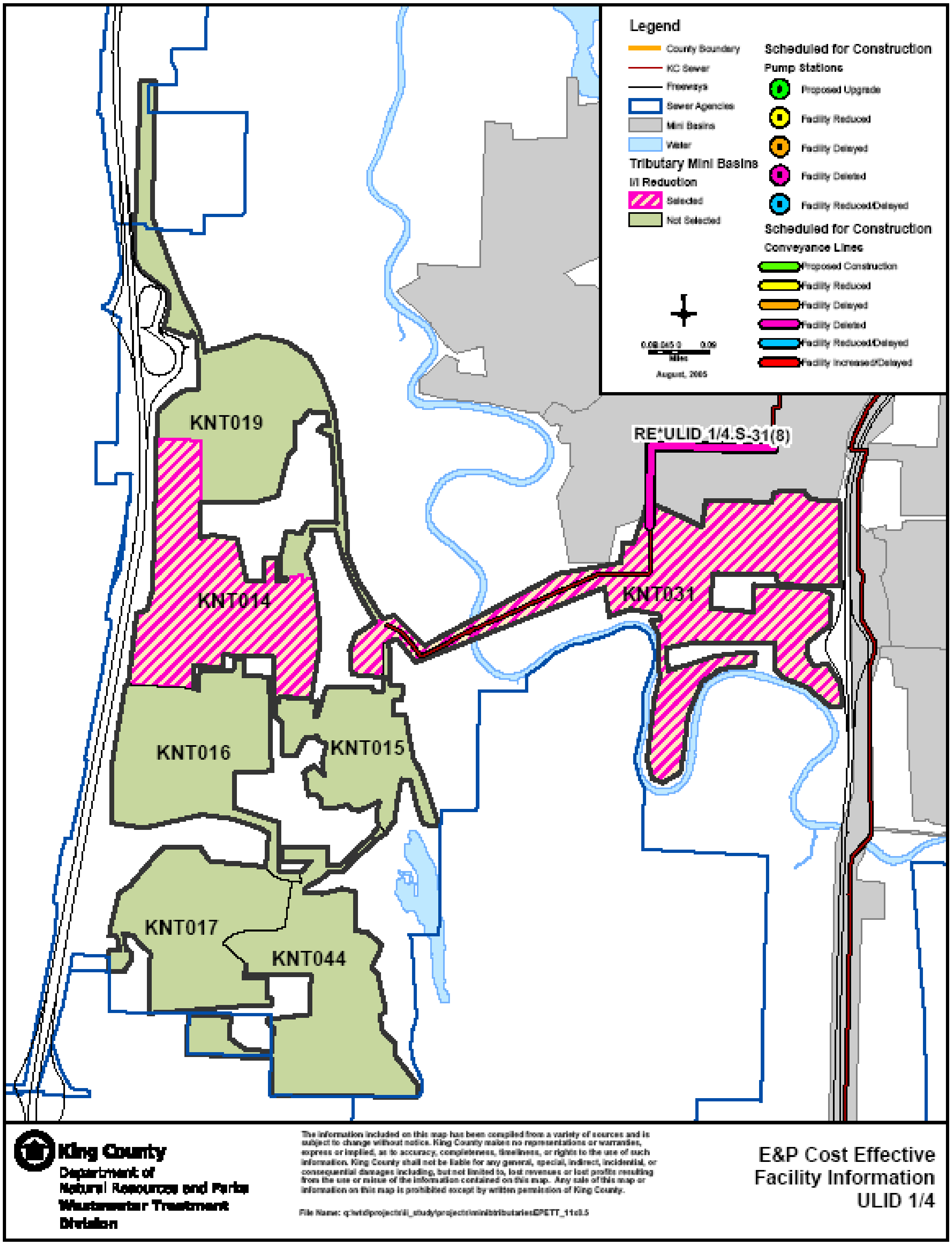

Figure 5-3. ULID 1 Contract 4

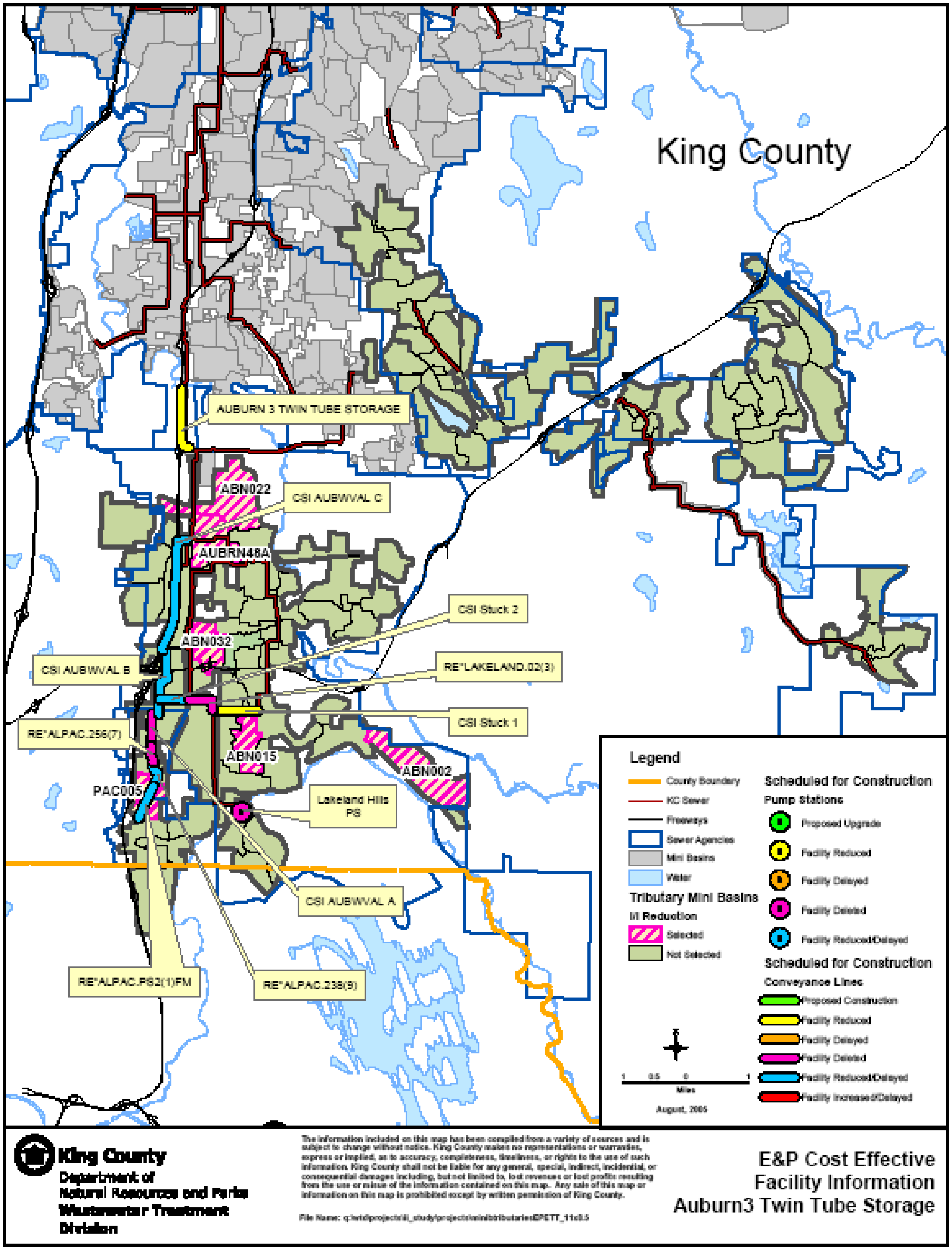

Figure 5-4. Auburn Twin Tube Storage Facility

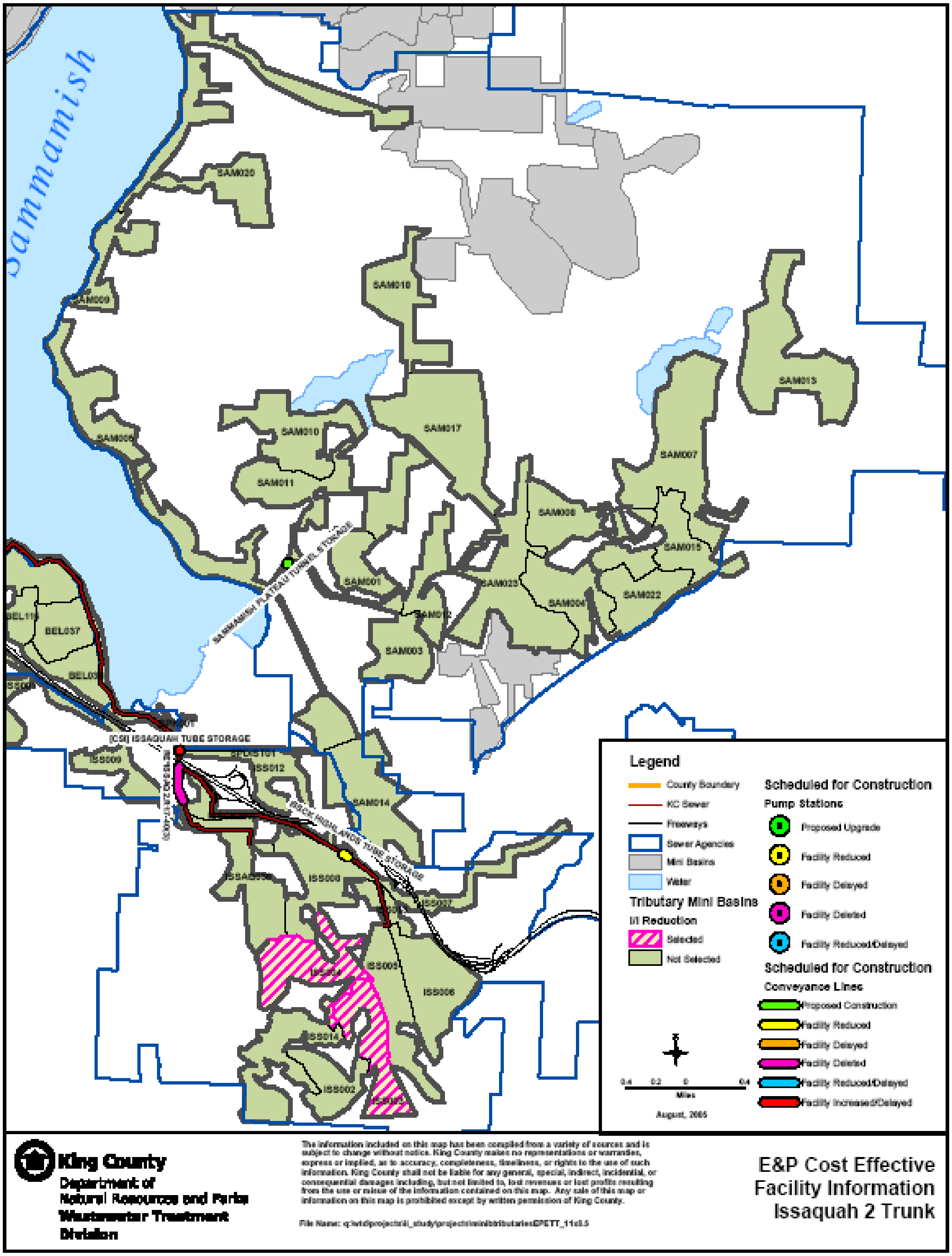

Figure 5-5. Issaquah 2 Trunk

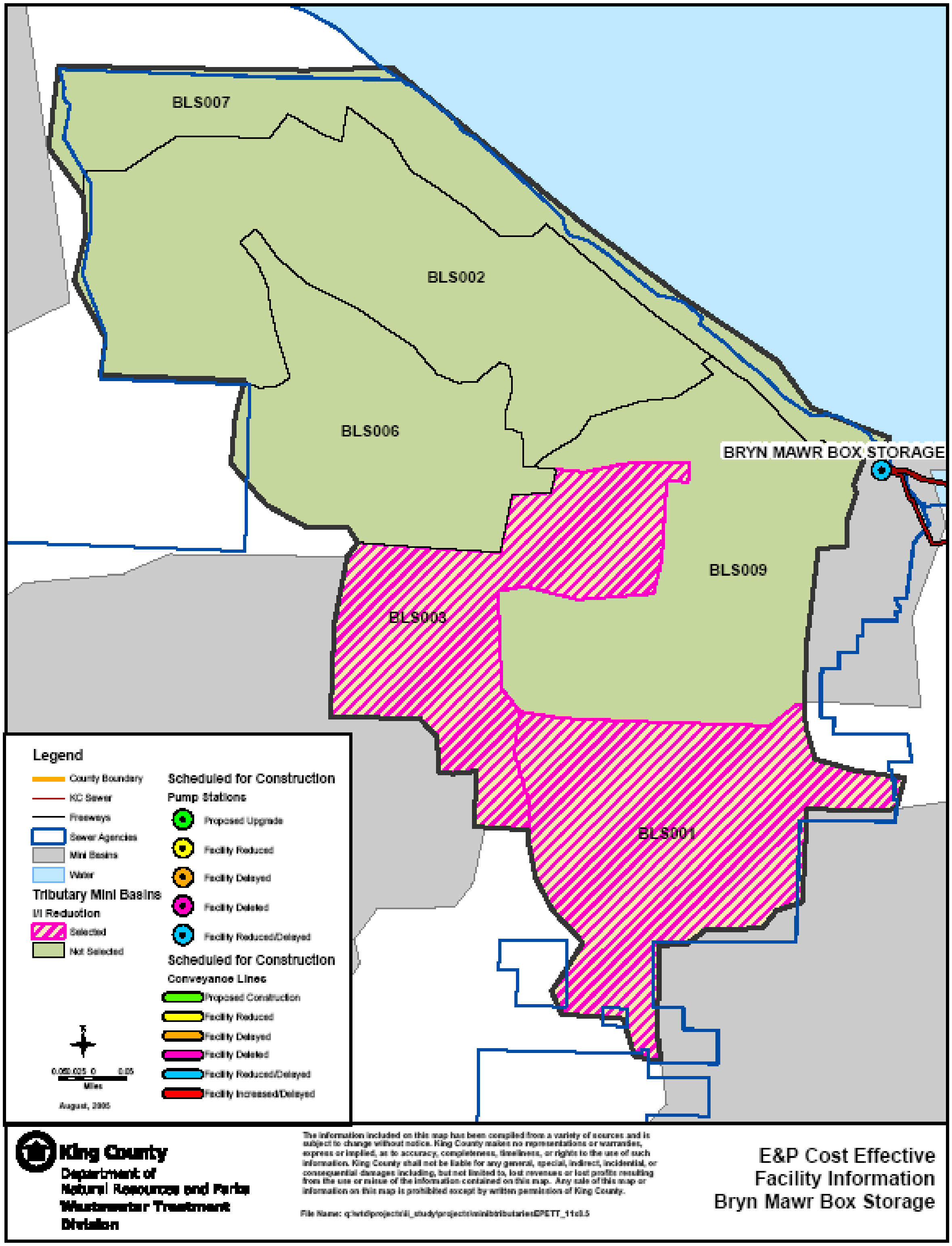

Figure 5-6. Bryn Mawr Tube Storage Facility

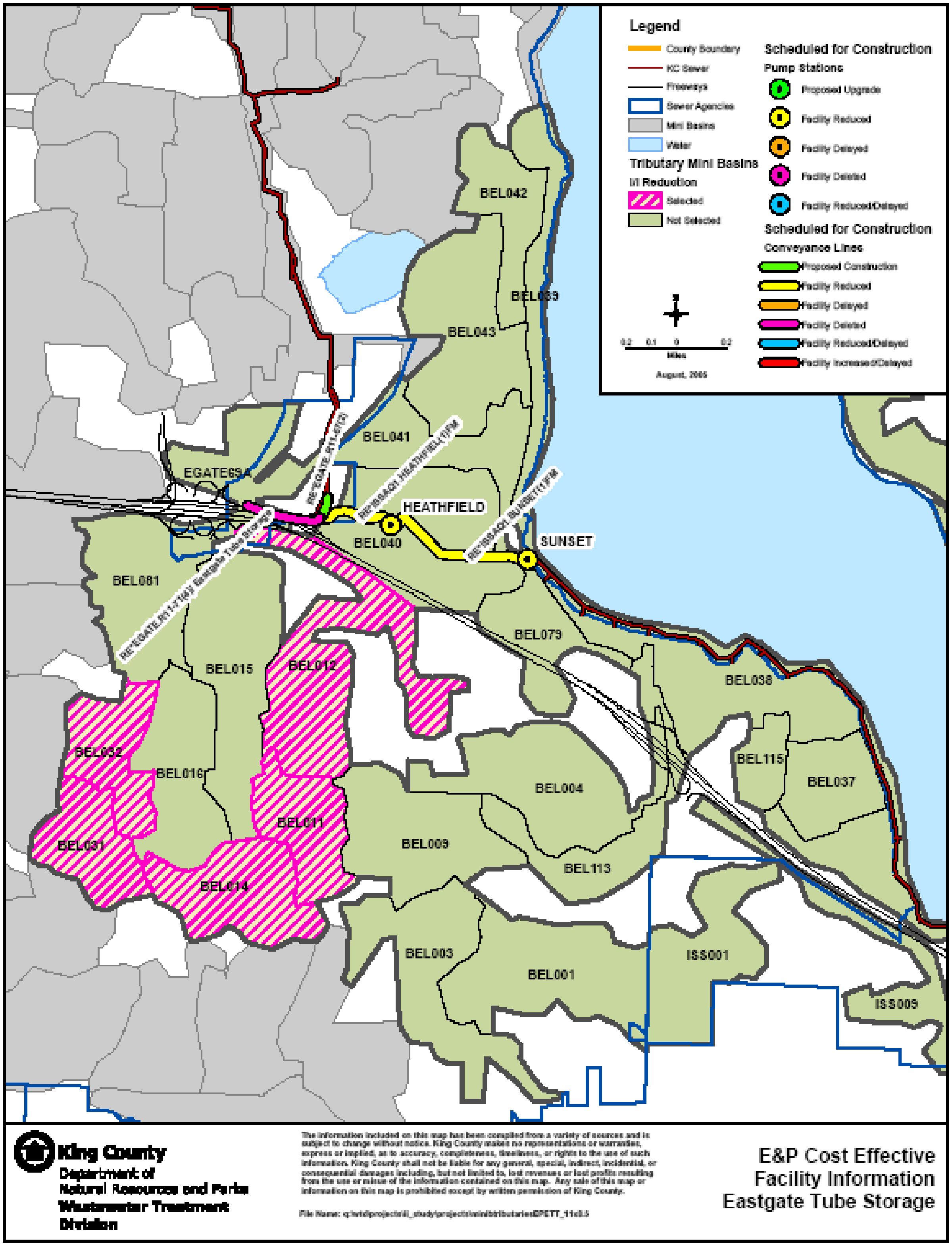

Figure 5-7. Eastgate Tube Storage Facility

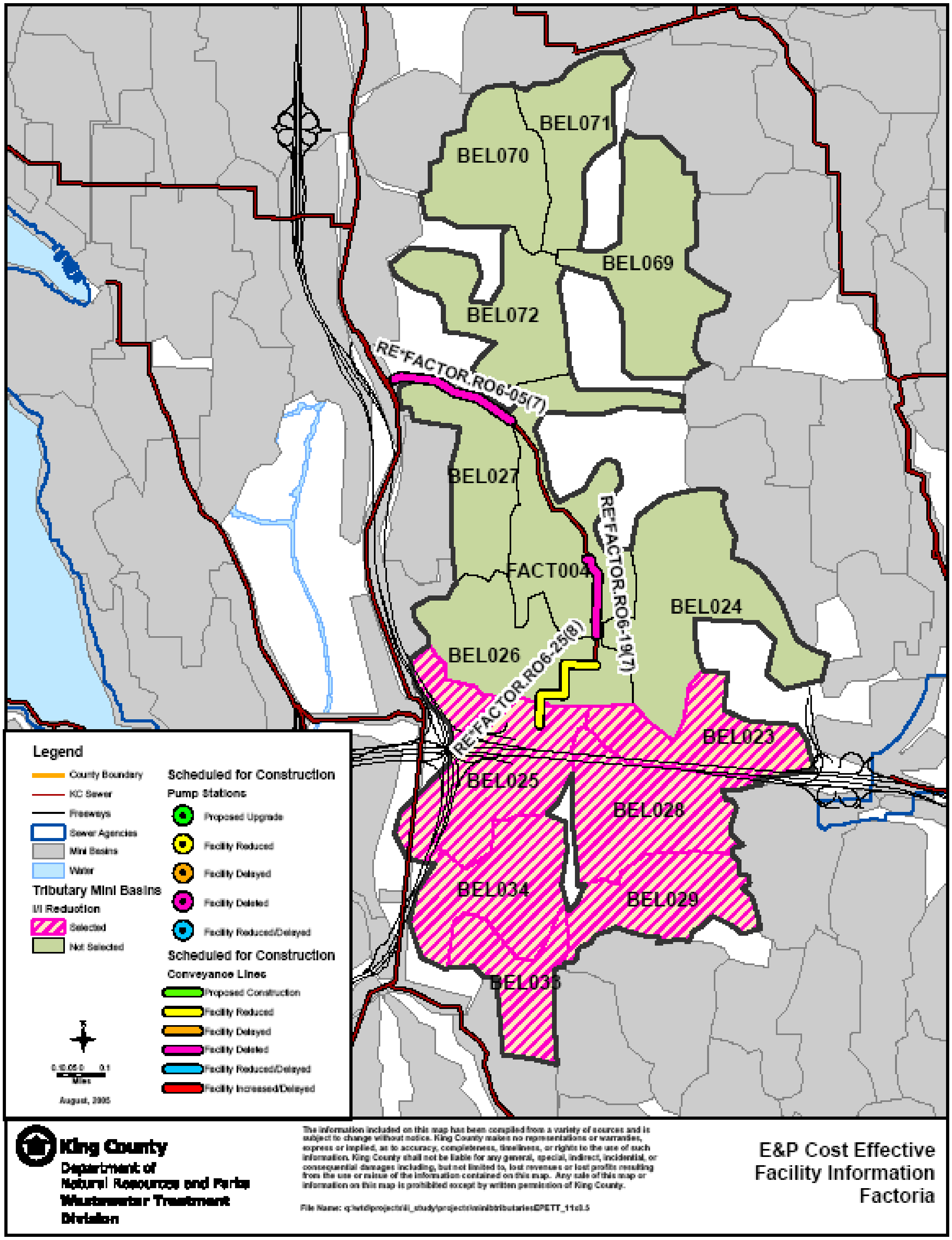

Figure 5-8. Factoria Trunk and Wilburton Pump Station

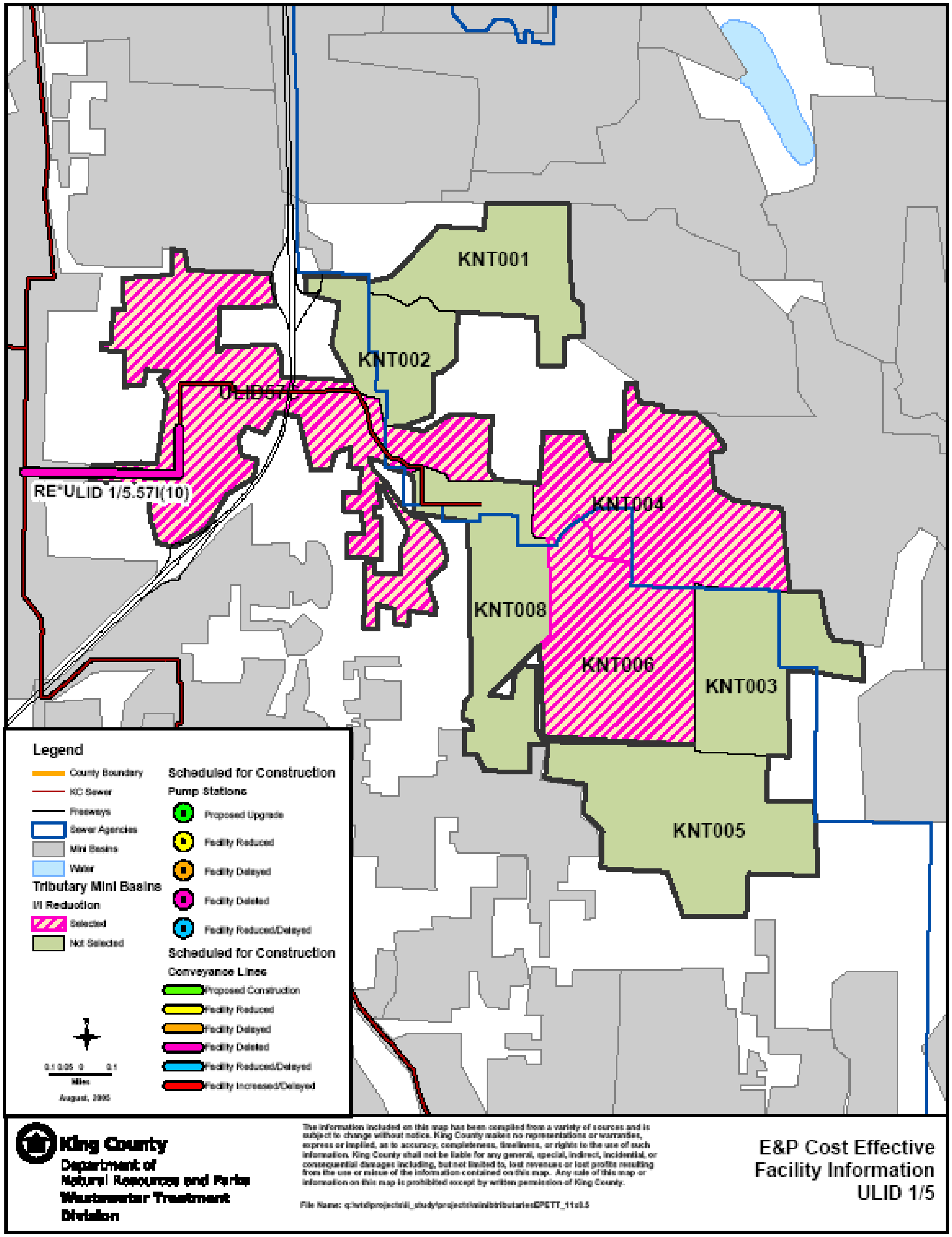

Figure 5-9. ULID 1-5 Garrison Creek Trunk

Glossary

base infiltration	Infiltration that remains at relatively steady levels over weeks and months.
base flow	Wastewater flow (not including inflow and infiltration) originating from residential, commercial, and industrial sources.
basin	A geographic area that contributes flow to a specific location, usually a flow meter or a facility. The two primary types of basins used in the assessment are model basins and mini-basins.
benefit/cost ratio	The cost of the regional conveyance system improvement (CSI) project divided by the cost of the proposed I/I reduction project.
CALAMAR	A technology that uses radar images from the National Weather Service NEXRAD radar and rain gauge data for calculating rainfall intensities.
combined sewers	A conveyance system designed to carry both wastewater and stormwater.
control basin	A drainage basin similar to a pilot basin where no work was performed; it was used to compare the impact of change in the pilot basin as a result of rehabilitation.
conveyance system	A system consisting of trunks, interceptors, force mains, pump stations and other facilities that moves wastewater from one place to another.
cured-in-place material	A material that is used to rehabilitate existing pipe by forming a lining within it. During the pilot projects, a resin-saturated fabric was used to rehabilitate some components of the sewer system.
direct disconnect	Direct disconnects occur when "illicit" connections to the sewer system (that is, pipes carrying something other than sewage) are disconnected and routed to alternative disposal systems such as a ditch or storm sewer.
drainage basin	Area that is drained by a river and its tributaries.
dry weather flow	The non-storm related wastewater flow between May and October. Composed of the base flow and infiltration/inflow (I/I).
Earth Tech Team	A collection of firms led by Earth Tech that are providing consulting services to King County on the Regional I/I Control Program. The firms include KCM Tetra Tech, HDR Engineering, Cosmopolitan Engineering Group, Rosewater Engineering, ADS Environmental Services, Financial Consulting Solutions Group, Shannon and Wilson, and Triangle Associates.

fast response to rainfall	The water that quickly enters a wastewater conveyance system in response to rainfall. Typically this may be from pipe connections from storm sewers or combined sewers, catch basins, downspouts, and/or other surface runoff.
flow meter	A gauge that shows the rate of flow or volume of a fluid. In wastewater treatment, flow meters measure how many million gallons of wastewater move through the system per day.
geographic information system (GIS)	A system of computer software, hardware, data, and personnel that helps manipulate, analyze, and present information tied to a spatial (usually a geographic) location.
groundwater	Water that infiltrates into the earth and is stored in the soil and rock within the zone of saturation below the earth's surface. Groundwater is created by rain, which soaks into the ground and flows down until it is collected at a point where the ground is not permeable. Groundwater then usually flows laterally toward a river, lake, or ocean. It is often used for supplying wells and springs.
host pipe	The existing sewer main or side sewer pipe inside which a liner is installed or within which a pipe bursting head is dragged.
hydraulic model	A model of the actual pipes that convey the wastewater flows and I/I generated by the hydrologic model. The hydraulic model outputs flow depths and velocities within specific pipe segments and allows evaluation of how the system performs under existing and future demands.
hydrograph	Graphs of flow versus time. Hydrographs were outputs of the hydrologic model and were used as inputs for the hydraulic model.
hydrologic model	A model used to numerically simulate the physical process of how rainfall ends up as inflow and infiltration.
I/I reduction technique	A means of decreasing I/I by replacing or rehabilitating selected components of the sewer system (for example, replacing public sewers and direct disconnects).
I/I rehabilitation method	The technology used to repair sewer system components (for example, dig and replace, pipe bursting, slip lining).
impervious surface	Any impenetrable material that prevents infiltration of water into the soil. Examples include rooftops, roads, parking lots, sidewalks, patios, bedrock outcrops, and compacted soil.
infiltration	Groundwater that seeps into sewers through holes, breaks, joint failures, defective connections, and other openings.
inflow	Stormwater that rapidly flows into sewers via roof and foundation drains, catch basins, downspouts, manhole covers, and other sources.
lateral	The portion of the sewer service pipe on public right-of-way. Where the sewer service pipe is on private property, it is called a side sewer. See also “side sewer”.

local agencies	Water and sewer districts that receive wholesale wastewater services from King County.
manhole	A vertical shaft covered by a lid at ground level that provides access for maintenance of an underground pipe.
Metropolitan Water Pollution Abatement Advisory Committee (MWPAAC)	This committee was created by state law and consists of representatives from the cities and sewer districts that operate sewer systems in King County. Most of these cities and sewer districts deliver their sewage to the County's system for treatment and disposal. MWPAAC advises the King County Council and Executive on matters related to water pollution abatement.
mini-basins	Drainage basins that were defined to provide manageable target areas for sewer system evaluation and rehabilitation. Mini-basins contained an average of 22,000 linear feet of sewer lines.
model basin	A geographic area defined to facilitate modeling of I/I and sewage flows. Model basins represented the entire sewered area flowing to a specific flow meter location, and consisted of an average of 1,000 sewered acres and 100,000 linear feet of pipe. Each model basin encompassed an average of 5 to 7 mini-basins.
model calibration	The process of adjusting model parameters so the model output matches the measured sewer flow for the same time period.
MOUSE	A software package (Modeling of Urban Sewers) from the Danish Hydraulic Institute. It is used to create hydrologic and hydraulic models.
open cut	A method of installing pipe near the surface, also called "trenching." The open-cut method consists of digging a trench and stockpiling excavated materials, installing pipe in the trench, backfilling the trench, and restoring the surface.
peak flow	The highest base flow and infiltration/inflow expected to enter a wastewater system during wet weather at a given frequency. The wastewater treatment plant is designed to accommodate peak flow.
pilot basin	That portion of a mini-basin where rehabilitation work was actually performed for the pilot projects.
pilot projects	Demonstration sewer rehabilitation projects that were conducted to gain a better understanding of the benefits and costs associated with I/I reduction projects.
pipe bursting	A rehabilitation method that involves replacing an existing pipe by pulling in a new pipe and simultaneously bursting the old pipe into fragments with a steel bursting head.
pump station	For wastewater purposes, a structure that houses pumps and other equipment for lifting wastewater in pipes to higher elevations so that it can continue to flow by gravity.

rapid infiltration	Infiltration into a wastewater conveyance system that is characterized by a rapid increase in flow during and/or shortly after a rainfall event, with gradual reduction in flow over a relatively short period after the event. This response is not as fast as inflow and is sustained longer than inflow.
Regional Wastewater Services Plan (RWSP)	A capital improvement program adopted by the King County Council in December 1999 to provide wastewater services to the County's service area through 2030.
return period	Average interval of the time or number of years between events of a given magnitude or larger (for example, peak flow).
sanitary sewer	A pipeline that carries household, industrial, and commercial wastewater.
separated sewer	A wastewater pipe designed to accept and transport household, industrial, and commercial wastewater and to exclude stormwater sources.
sewerable areas	Areas that are part of the future service area that will be served by a sanitary sewer system.
sewered areas	Areas served by a sanitary sewer collection system. These areas contribute to the I/I flows in the sewer system.
side sewer	The portion of the sewer service pipe on private property. Where the sewer service pipe is on public right-of-way, it is called a lateral. Also see "lateral."
slow infiltration	Infiltration into a wastewater conveyance system that is characterized by a slow increase in flow during a rainfall event. This increased flow may take several days or weeks to decline after a storm.
stormwater	The portion of precipitation that does not percolate into the ground or evaporate. Stormwater flows across the ground surface in channels or ditches, or flows within pipes.
TABULA	A planning level software tool developed by the County; the tool extends unit cost and applies construction cost indices.
travel time	The amount of time it takes flows to travel through the conveyance system.
trenchless construction	A technique that requires little or no trenching to construct the improvements.
unsewered areas	Areas that are not served by a sanitary sewer collection system (for example, large open spaces like parks). These areas do not contribute to the I/I flows in the sewer system.
wastewater	The water and wastes from homes and businesses that enter pipes and are transported to treatment plants for treatment and disposal.
wet weather flow	The flow between November 1 and April 30. Composed of the base flow and infiltration/inflow (I/I).

Appendices

Available on CD upon request

Appendix A1 – Select List Cost-Effectiveness Analysis Package per MWPAAC E&P Planning Assumptions

Appendix A2 – Regional Cost Effectiveness Analysis Package per MWPAAC E&P Planning Assumptions

Appendix A3 – 30-Percent I/I Removal Cost Effectiveness Package per MWPAAC E&P Planning Assumptions

Appendix B1 – Sensitivity Analysis Select List-Cost Effectiveness Analysis Packages per Initial Planning Assumptions