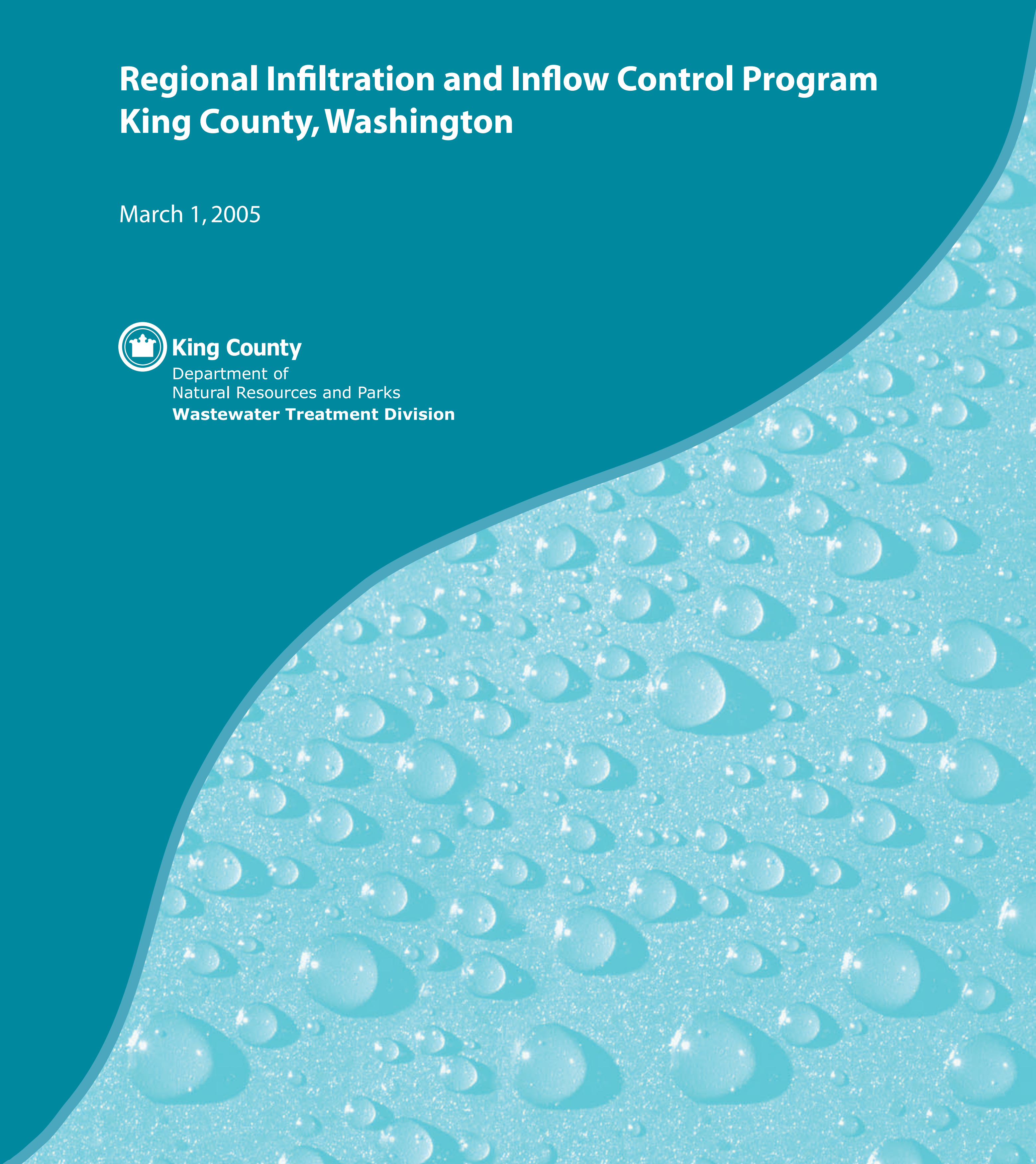
REGIONAL NEEDS ASSESSMENT REPORT

Regional Infiltration and Inflow Control Program
King County, Washington

March 1, 2005

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division



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Prepared by King County and the
Earth Tech Team, Seattle, WA

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Acknowledgements

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Acronyms and Abbreviations

CALAMAR	Calcul de lames d'eau a l'aide due radar (calculating rain with the aid of radar)
CSI	conveyance system improvement
CSO	combined sewer overflow
E&P	Engineering and Planning (MWPAAC Subcommittee)
ESA	Endangered Species Act
ETS	extended time series
ETT	Earth Tech Team
GIS	Geographic Information System
GMA	Growth Management Act (Washington state)
gpad	gallons per acre per day
I/I	infiltration/inflow
I/IP	infiltration/inflow policy
KCC	King County Code
Metro	Municipality of Metropolitan Seattle or King County Department of Metropolitan Services
mgd	million gallons per day
MOUSE	Modeling of Urban Sewers (software by DHI)
MWPAAC	Metropolitan Water Pollution Abatement Advisory Committee
NPDES	National Pollutant Discharge Elimination System
PAWS	Public Agricultural Weather System
PSRC	Puget Sound Regional Council
RCW	Revised Code of Washington
RNA	Regional Needs Assessment
RWSP	Regional Wastewater Services Plan
Sea-Tac	Seattle Tacoma
UGA	Urban Growth Area
WLRD	Water and Land Resources Division (King County)
WTD	Wastewater Treatment Division (King County)

Chapter 1

Executive Summary

The purpose of this Regional Needs Assessment (RNA) is to identify conveyance system improvement (CSI) projects and costs in order to provide a baseline for conducting benefit/cost analyses of potential Infiltration and Inflow (I/I) reduction projects. Flow monitoring and modeling data and assumptions specifically developed for the I/I Control Program were used to project CSI project needs to allow for an accurate comparison of benefits and costs between CSI projects and I/I reduction projects. As a result, the complete list of CSI projects reported here differs from what is included in the Regional Wastewater Services Plan (RWSP), as updated in 2004. The major difference is that CSI projects identified in this RNA are projected through 2050 rather than 2030 - the planning horizon for the RWSP. Additionally, the more recent and comprehensive flow metering and modeling data used differs from that used during the update of the RWSP. This resulted in some modification of CSI projects expected to be needed by 2030. While some differences exist between the CSI projects identified in this RNA and those in the RWSP, this latest list of needs should not be viewed as a departure from recommendations contained in the RWSP. Rather it should be viewed as providing a baseline for conducting benefit/cost analyses of potential I/I reduction projects using assumptions and data developed specifically for the I/I Control Program.

1.1 Regional Wastewater System

King 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 King County and thirty-four cities and sewer agencies. These cities and sewer agencies (collectively known as local agencies) provide direct sewer collection service to residences and businesses. King County owns and operates regional facilities necessary for *wastewater treatment* including treatment plants, major conveyance pipes, regulators, and pump stations. Local Agencies own and operate the facilities necessary for *collecting wastewater* from residences and businesses. Their facilities include collector sewers, laterals, side sewers, and some pump stations.

The system of pipes that collects and conveys wastewater was constructed over many decades. Older pipes, located in most parts of Seattle, are a combined sewer system that collects a combination of stormwater and sanitary sewage. The rest of the region, including some portions of north Seattle, is served by a separated sewer system. Separated systems have separate collection and conveyance pipes for wastewater and storm water. Separated wastewater systems dedicate their capacity to convey and treat wastewater. Stormwater is not supposed to enter the separated wastewater system.

The components that make up the regional wastewater system are:

- 3 secondary treatment facilities (including the Vashon Treatment Plant)
- 335 miles of regional conveyance pipes
- 42 pump stations
- 19 regulator stations
- 2 combined sewer overflow (CSO) treatment plants
- 38 permitted CSO locations.
- 5,100 miles of collection pipes and numerous pump and regulator stations (owned by the local agencies)

System Components Defined

Treatment Plants provide primary and secondary treatment of wastewater before discharging the treat effluent to Puget Sound.

Conveyance Pipes carry wastewater to the treatment plants.

Pump Stations house pumps and other equipment that lift wastewater in pipes to higher elevations so that they can continue to flow by gravity.

Regulator Stations control the flow of wastewater from two or more input pipes to the collection system.

CSO Treatment Plants operate during periods of peak flow following large storm events. They provide primary treatment and disinfection to wastewater diluted by stormwater prior to discharge to Puget Sound.

CSO Control Structures store excess wastewater diluted by stormwater to prevent overflows into surface waters.

1.2 What Drives Capacity Demand

The two factors that drive the need to expand capacity in the conveyance system are regional population growth, and I/I flows within the system.

Growth in sanitary sewerage from residences and businesses, or “base flow,” volume over time is driven by changes in population and employment in the service area, septic conversions to sewers, and changes in water use levels through conservation efforts. Based on these factors, base flow in the regional service area is projected to grow from approximately 75-million gallons-per-day (MGD) to over 120 MGD by 2050. Figure 1-1 illustrates the projected growth rate in base flow for the region. Note that the projected growth in base flow through 2010 is relatively flat. This is due to the expected immediate positive influence of water conservation efforts that are currently under way. Projected growth after 2010 assumes that the affects of water conservation will remain constant.

Of the growth factors described above, growth in residential sewered population (from either new development or septic conversions) has the biggest effect on growth in base flow.

I/I is clean stormwater runoff and ground water that enters wastewater collection pipes during periods of rain. Most inflow comes from stormwater; most infiltration comes from groundwater.

I/I significantly affects the capacity of the region’s wastewater conveyance and treatment system because it is the largest contributor to wastewater volumes that must be conveyed and treated in the wet season. About 75-percent of the region’s peak flows in the separated conveyance system comes from I/I[1]. Figure 1-2 contains a hydrograph that shows how I/I affects regional wastewater volumes that must be conveyed and treated. As can be seen, flow volumes can quadruple during rain events when the conveyance system must handle base flow plus I/I (the blue line in Figure 1-2).

[1] Regional Wastewater Services Plan, Executive’s Preferred Plan; April 1998, page 14.

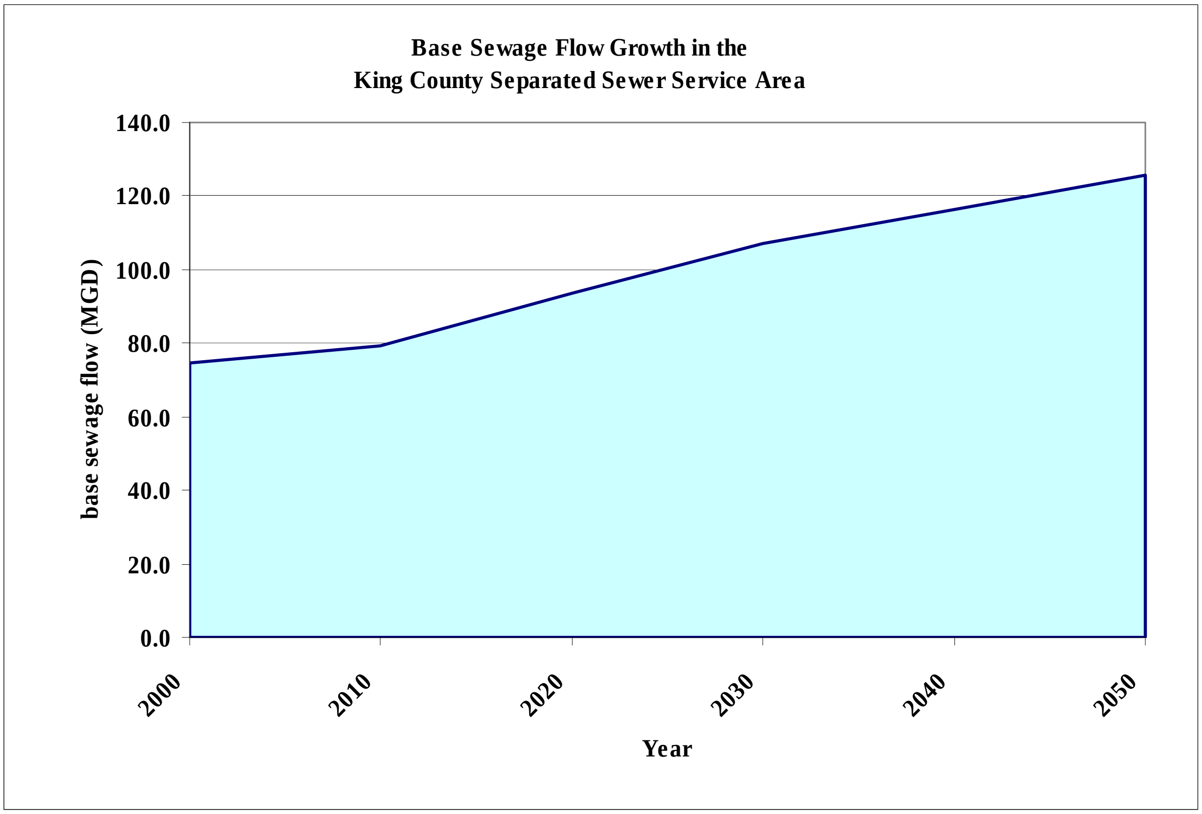

Figure 1-1. Projected Growth in Base Flow

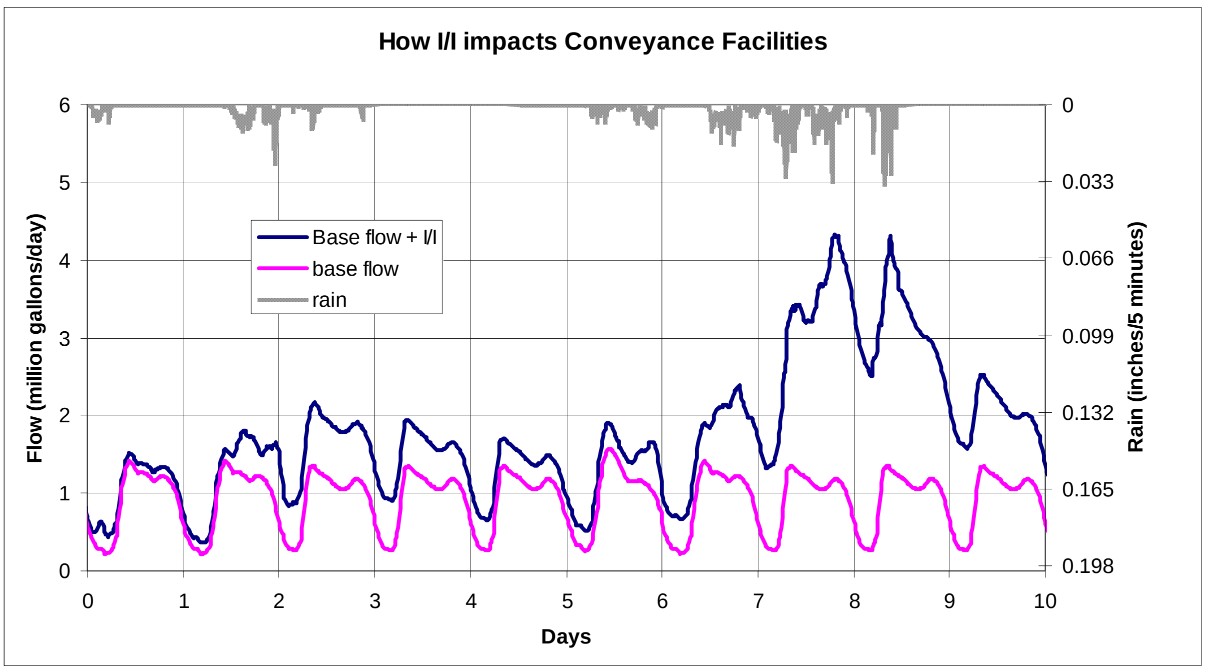

Figure 1-2. Impacts of I/I on Wastewater Flows

1.3 Current Conditions

The regional wastewater conveyance system was developed over the last 40-plus years. Most of the system has the necessary capacity to transmit wastewater flows today and in the future. However, some portions of the system are at or near capacity during periods of peak flow[2]. As the region grows over time, these portions of the system and others will not have adequate capacity to transmit peak wastewater flows to treatment plants. The lack of adequate capacity in portions of the system increases the risk of wastewater back-ups and overflows.

1.4 Estimated Capacity Needs

Sixty-three CSI projects have been identified to meet the region's projected capacity needs through 2050. The projects identified are based on the data gathering and modeling efforts completed for the I/I Control Project as described in Chapter 3 of this RNA. These projects and their estimated costs, discussed in Chapter 4, provide the basis for conducting benefit/cost analyses of potential I/I reduction projects. The list of projects and schedule will be refined further in the coming months as the County and local agencies work together to develop a regional I/I control program. Refinements may lead to revisions in the list of projects.

1.5 Approach to Providing Capacity and Reducing Cost

The capacity needed to convey and treat peak flows in the region can be provided by expanding the capacity of the conveyance system, or by trying first to reduce flows thereby reducing the capital investments necessary to upgrade the conveyance system. The region is investigating the feasibility of the latter approach based on policy direction contained in the adopted RWSP. RWSP Policy I/IP-1 states that the County will: "reduce I/I whenever the cost of rehabilitation is less than the cost of conveying and treating the flow or when rehabilitation provides significant environmental benefits to water quantity, water quality, stream flows, wetlands, or habitat for species listed under the Endangered Species Act (ESA)." Since 2000, the County and local agencies have been working to develop an I/I control program to reduce I/I flows, and reduce the cost for providing adequate conveyance capacity for the region's wastewater through 2050.

This RNA provides the baseline for measuring the costs and benefits of implementing I/I reduction projects to reduce flow volume in lieu of making a capital investment in the conveyance system. The County and local agencies will continue to work together to estimate the costs of I/I reduction projects upstream of identified conveyance improvement projects. The costs of conveyance system improvements identified in Table 4-1 above will be compared with the estimated costs of reducing I/I levels. The goal of the benefit/cost analyses is to provide a cost effectiveness comparison on a project specific basis.

[2] Peak Flow is the highest base flow and infiltration/inflow expected to enter a wastewater system during wet-weather that a treatment plant and conveyance facility(ies) is designed to accommodate.

1.6 Next Steps

Some CSI projects identified in Table 4-1 will be designed and built within the next few years because the conveyance capacity these projects will provide is needed within the next three to five years. I/I projects take approximately that much time to design, build, and test to make sure that I/I levels have actually been reduced. Consequently, the I/I program will be focused on CSI projects needed after 2010.

In 2005, flow and benefit/cost analyses will be conducted to determine if I/I reduction projects can cost-effectively reduce or eliminate the need for adding conveyance capacity. A list of cost-effective I/I projects and their associated cost savings will be included in the Executive's proposed I/I Program Recommendation that is due to the County Council by December 31, 2005.

Chapter 2

Background

King County's regional wastewater system is a large, integrated wastewater conveyance and treatment system that serves 34 cities and sewer agencies. These cities and sewer agencies (collectively known as local agencies) provide direct sewer collection service to residences and businesses in incorporated and unincorporated areas of the County and parts of south Snohomish County and north Pierce County where natural drainage basins lead to a King County regional facility. King County owns and operates regional facilities necessary for *wastewater treatment* including treatment plants, major conveyance pipes, regulators, and pump stations. Local agencies own and operate the facilities necessary for *collecting wastewater* from residences and businesses. Their 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.

This chapter summarizes the components that make up the regional wastewater treatment system.

2.1 Service Area

King County's regional wastewater system serves approximately 1.4 million residents within a 420-square-mile service area (Figure 2-1). The perimeter of the regional service area is defined by the service areas of the local agencies in King, Pierce, and Snohomish Counties that send their wastewater to the regional treatment system. These areas are located within the limits of the Urban Growth Areas (UGAs) as defined by the Growth Management Act (GMA). The portions of Pierce County in the regional service area are limited to portions of the Cities of Auburn and Pacific. Portions of south Snohomish County served by the Alderwood Sewer District, Cross Valley Water District, City of Brier, and Olympic View Water and Sewer District are also in the regional service area.

System Components Defined

Treatment plants perform primary and secondary treatment of wastewater before discharging the clean effluent to Puget Sound.

Conveyance pipes carry all wastewater to the treatment plants.

Pump stations house pumps and other equipment that lift wastewater in pipes to higher elevations so that they can continue to flow by gravity.

Regulator stations control the flow of wastewater from two or more input pipes to a single output.

CSO treatment plants operate during periods of peak flow following large storm events. They provide primary treatment for wastewater diluted by stormwater prior to discharge to Puget Sound.

CSO control structures store excess wastewater diluted by stormwater to prevent overflows into surface waters.

Figure 2-1. Local Sewer Agencies Within King County Wastewater Service Area

2.2 Regional Wastewater System

The regional wastewater system consists of the following components:

- 3 secondary treatment facilities (including the Vashon Treatment Plant)
- 335 miles of regional conveyance pipes
- 42 pump stations
- 19 regulator stations
- 2 combined sewer overflow (CSO) treatment plants
- 38 permitted CSO locations.
- 5,100 miles of collection pipes and numerous pump and regulator stations (owned by the local agencies)

Figure 2-2 shows conveyance pipes and treatment plants within the service area boundaries for the regional wastewater treatment system.

2.2.1 Conveyance and Treatment

With the exception of Vashon Island, the West Point Treatment Plant in Seattle or the South Treatment Plant in Renton currently treat all flows in the the regional wastewater service area. As such, the service area is divided into major sub-areas: the West Service Area and the East Service Area. The West Service Area includes areas north of Lake Washington and the City of Seattle. The East Service Area includes areas east of and south of Lake Washington. An exception to this service area delineation is the North Service Swap Area; flows from this area can currently be conveyed to either treatment plant. The swap area includes the eastern part of the regional wastewater service area in Snohomish County extending down to the northern half of the Lake Sammamish locality (Figure 2-2).

Figure 2-2 illustrates the service areas for the treatment plants. Note that the North Service Swap Area and part of the West Service Area in Snohomish County will be transferred to the new Brightwater Treatment Plant when it becomes operational.

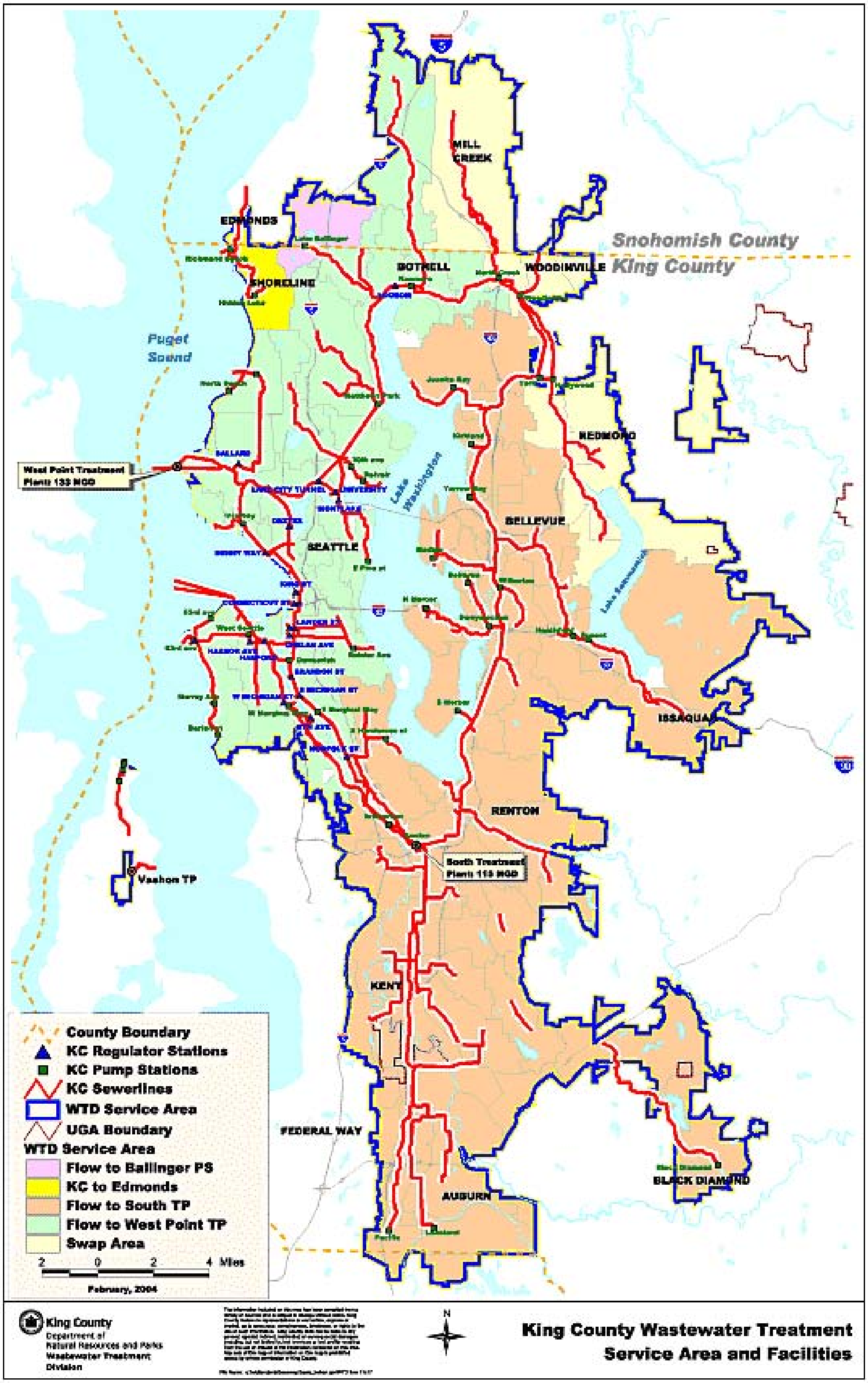

Figure 2-2. King County Wastewater Service Area

2.2.2 Combined Sewers and Separated Sewers

The systems of pipes that collect and convey wastewater were constructed over many decades. Older pipes, located in most parts of Seattle, are a combined sewer system that collects a combination of stormwater and sanitary sewage. During storms, the volume of stormwater entering combined sewer pipes can take up the capacity of pipes and of the West Point Treatment Plant, which treats wastewater from the combined sewer system.

The rest of the region, including some portions of north Seattle, is served by a separated sewer system. Separated systems have separate collection and conveyance pipes for wastewater and stormwater. Separated wastewater systems dedicate their capacity to convey and treat wastewater. Figure 2-3 illustrates the structural and functional differences of combined and separated sewer systems.

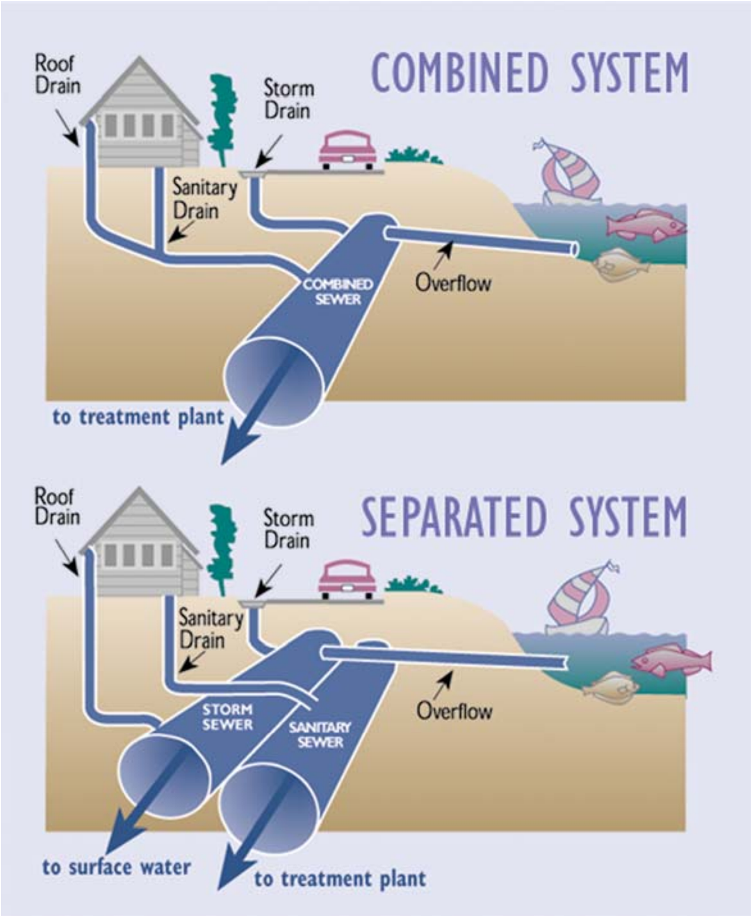

Figure 2-3. Combined and Separated Wastewater Conveyance Systems

Although the separated wastewater system is designed to handle wastewater only, other water does enter the system via inflow and infiltration (I/I). I/I is stormwater or groundwater that enters the separated system from sources such as leaky sewer pipes, roof drain connections, and manhole covers. Most inflow comes from stormwater; most infiltration comes from groundwater. I/I is a regional problem because it takes up needed capacity in collection and conveyance pipes and in treatment plants, which can lead to backups and overflows. About 75-percent of the region's peak flows in the separated conveyance system comes from I/I[1].

[1] Regional Wastewater Services Plan, Executive's Preferred Plan; April 1998, page 14.

2.3 Assessment of Needs

This Regional Needs Assessment (RNA) focuses on identifying needed improvements to the separated conveyance system that are necessary to accommodate projected regional growth and volumes of I/I through the year 2050. It identifies the current condition of the separated system, and identifies the conveyance system improvement (CSI) projects needed, including estimated costs, over the next several decades to meet capacity demands. This information provides a baseline for evaluating the cost-effectiveness of implementing I/I projects in lieu of constructing individual CSI projects.

2.4 Description of System Design Standards

King County has set a design standard for the wastewater conveyance system to ensure that an adequate level of service is provided across the region. The standard is based on policy contained in the adopted Regional Wastewater Services Plan (RWSP). The design standard is as follows: “The twenty-year design storm shall be used as the design standard for the County’s separated wastewater system” (KCC 28.86.060-CP-1:1).

Application of the standard considers both the sizing and timing of facilities:

- **Sizing.** What peak flow will a facility be designed to handle? What ultimate population will the facility serve (planning horizon)?
- **Timing.** What peak flow level should be used to decide when the facility would be replaced, upgraded, or added to? What is the expected life of a facility?

To determine an appropriate planning horizon for conveyance system improvements, population and economic growth projections developed by the Puget Sound Regional Council (PSRC) are used in combination with flow data from the regional system to calculate the ultimate population that conveyance facilities are expected to serve. This calculation is referred to as “saturation.” For the regional wastewater system, saturation is projected to occur by 2050. Thus, the design standard employed for regional conveyance system improvements is the 20-year design storm projected to occur in 2050[2].

2.5 Other Related Programs

2.5.1 Combined Sewer Overflow (CSO) Planning

As mentioned in the discussion of combined sewer systems above, a portion of the regional wastewater system within the City of Seattle still manages stormwater and wastewater together

[2] 2050 is the projected date when the regional wastewater service area will be fully built out and all portions of the service area will be connected into the wastewater treatment system.

in a combined sewer system. When flows entering the combined sewer system exceed pipe or treatment process capacity, overflows of wastewater diluted with stormwater are released into receiving waters.

The City of Seattle still owns and maintains a large portion of the combined sewer system. However, the County acquired some larger combined sewer facilities in the 1960s or developed new facilities over the years. Whenever possible, the County and the City of Seattle undertake joint projects to reduce CSO discharges. The combined efforts of the County to implement treatment and CSO control programs and the City has reduced the volume of overflows from about 30 billion gallons per year in the 1960s to approximately 1.5 billion gallons per year in 2000. The County’s goal for controlling CSOs is to limit untreated discharges at each CSO location to one event per year (on average) by the year 2030. The CSO program will meet state and federal regulations and agreements, and King County will coordinate with state and federal agencies to develop cost-effective regulations that protect water quality.

This RNA identifies conveyance system improvements needed for the separated sewer system only. CSO planning is done separately on a 5-year cycle. In 2005, the County will submit a CSO program update to the Washington State Department of Ecology that coincides with the National Pollutant Discharge Elimination System (NPDES) permit renewal for the West Point Treatment Plant.

2.5.2 Brightwater Planning

Planning for the new Brightwater Treatment Plant is well under way. A plant site is selected in unincorporated Snohomish County. The routes for the conveyance and outfall pipes to send wastewater to the plant and treated water to Puget Sound are also identified. Predesign of both the treatment plant and conveyance and outfall pipes are under way. Design of the conveyance and outfall piping for the new treatment plant is expected to be substantially complete by late 2005.

This RNA identifies conveyance system improvements for the portions of the separated sewer system to be served by the existing West Point and South Treatment plants. While the planning and design of Brightwater treatment and conveyance facilities is a separate project, the conveyance improvements identified in this assessment account for projected capacity improvements and changes in flow that will result from operating the new Brightwater Treatment Plant.

Chapter 3

Condition of the Regional Wastewater Conveyance System

The regional wastewater conveyance system has developed over the last 40-plus years. Most of the system has the necessary capacity to transmit wastewater flows today and in the future. However, some portions of the system are at or near capacity during periods of peak flow.[1] As the region grows over time, these portions of the system and others will not have adequate capacity to transmit peak wastewater flows to treatment plants. Inadequate capacity in portions of the system increases the risk of wastewater backups and overflows during periods of peak flow.

Wastewater flows, both existing and projected, come from two basic sources: *sanitary flows* from homes and businesses and *infiltration and inflow* (I/I) of clean stormwater and groundwater that enter the separated sewer system. Sanitary flow (also referred to as base flow) is the only flow component intended to enter the separated wastewater system. I/I enters the separated wastewater system through cracks and other leak points that result from general degradation and damage to pipes, manholes, and other system features over time (Figure 3-1). The most common leak point for I/I is side sewers on private property. These privately owned pipes connect into collection pipes owned and operated by the 34 local agencies that are served by the regional conveyance and treatment system. See the *I/I Alternatives/Options Report* for a more detailed discussion of possible approaches to managing I/I within the region.

3.1 Why Parts of the System Are Near or At Capacity

There are multiple reasons why portions of the conveyance system are at or near capacity. They include the age of some system components, improved information about system demands from population growth and I/I, and changes in design and performance standards. Each is discussed in more detail below.

3.1.1 Portions of the System Are Well Over 40-Years Old

The regional conveyance system includes pipes and other features that were built as early as 1900, with substantial additions being made through today. The various portions of the conveyance system were constructed to meet design standards and growth projections that were available at the time they were designed and constructed. As a result, some portions of the system have reached or are reaching their maximum designed capacities.

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[1] Peak Flow is the highest base flow and infiltration/inflow expected to enter a wastewater system during wet-weather at a given frequency that a treatment plant and conveyance facilities are designed to accommodate.

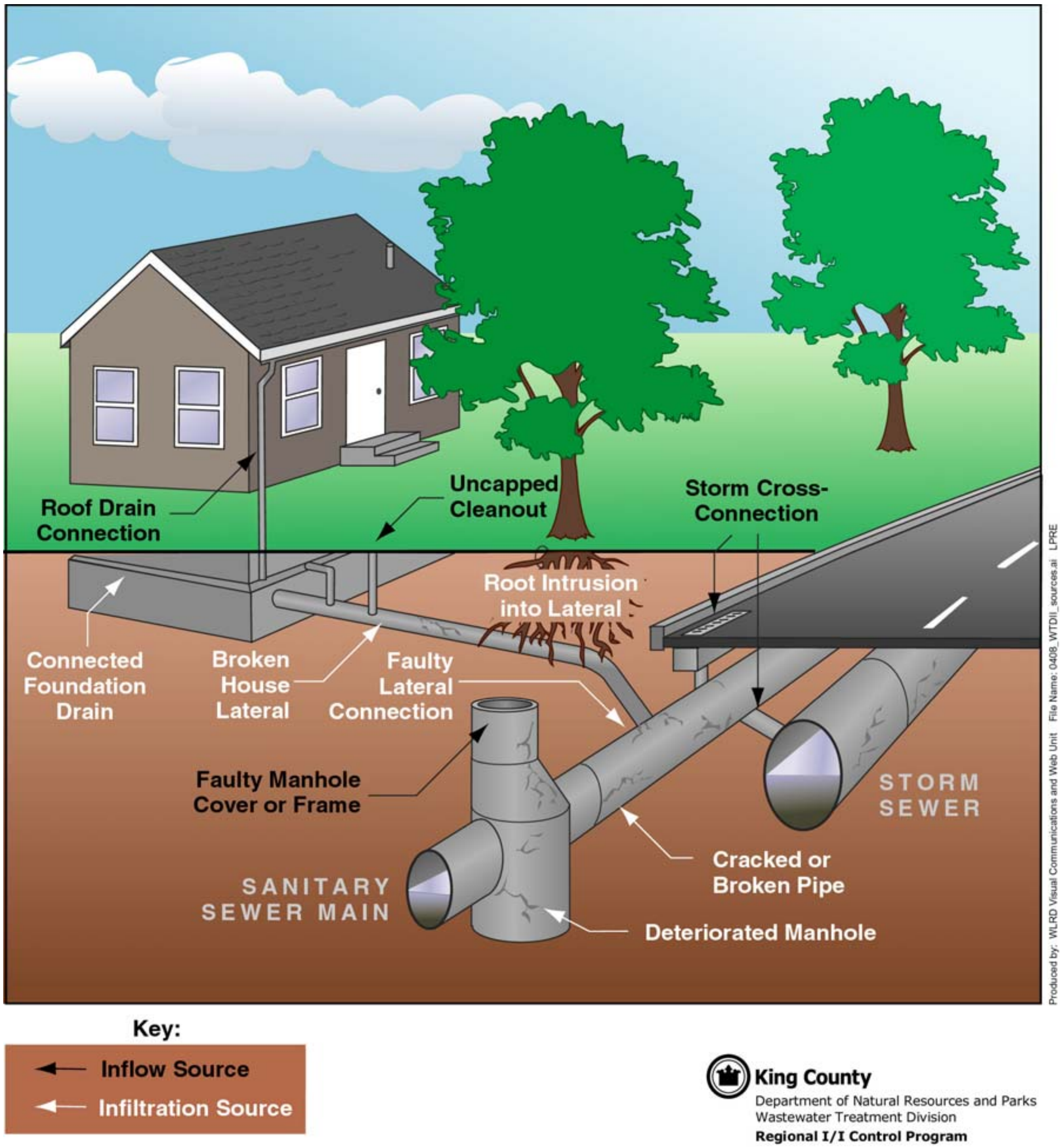

Figure 3-1. Sources of Infiltration and Inflow

3.1.2 Projections of System Capacity Have Improved

A closely related condition to the age of portions of the conveyance system is that information available about regional growth and the resulting flow projections has improved over time. Information related to population and employment growth, water consumption and conservation, rainfall, and other factors that affect wastewater flow projections has grown and become more accurate. In the past, census data, regional rainfall data, and general experience were the basis for sizing pipes and other components of the conveyance system. Today, flow monitoring data, more specific census data, improved population and economic growth forecasts, and rainfall data obtained from meters dispersed across the region and from radar tracking of rainfall allow for more accurate projections of flow. The availability of improved data coupled with modern computer-based modeling tools allow for more comprehensive and accurate projections of wastewater flows. The results of improved analyses indicate that certain portions of the conveyance system require expansion because wastewater flows are higher than what was projected earlier.

3.1.3 The System Was Built to Varying Capacity Standards Over Time

Various components of the conveyance system were built to projected capacities that could be estimated or agreed to at the time of their development. Recommended design standards for the original Metro trunk and interceptor sewers included a peak wet-weather inflow of 2,000 gallons per acre per day (gpad) and an infiltration value of 1,200 gpad for total peak I/I values of 3,200 gpad for existing systems and 1,100 gpad for newly constructed systems.[2] Based on observations and modeling analysis, the peak I/I flows in the service area are greater than the 3,200 gpad standard for existing sewers and the 1,100 gpad standard for new construction that was used for design in much of the system. Therefore, this standard is no longer considered practical.

The adoption of the RWSP in 1999 established a uniform development standard for all future development. RWSP Policy CP-1 states:

> *"To protect public health and water quality, King County shall plan, design, and construct county wastewater facilities to avoid sanitary sewer over flows.*
>
> 1. *The twenty-year design storm shall be used as the design standard for the county's separated wastewater system."*

To ensure that components of the system are adequately sized for the future and the number of facility upgrades is minimized, the Wastewater Treatment Division has chosen 2050 as its design year for all new facilities and facility upgrades. The year 2050 is the projected date when the regional wastewater service area will be fully built out and all portions of the service area will be connected into the wastewater treatment system. This means that facilities are being designed to convey and treat projected 20-year peak flows between now and 2050. To avoid over-building, facility construction is being phased whenever practical. The effect of applying the 20-year peak design standard is that certain components of the conveyance system that were previously built to a different standard now require upgrades to meet the new standard.

3.2 Condition of the System

Based on the analyses conducted, most of the regional conveyance system has capacity to accommodate the 20-year peak flow through 2050. Figure 3-2 shows the regional conveyance system and identifies those portions of the system that require upgrades or expansion. Portions of the conveyance pipes (shown in purple) require expansion and eight additional pump stations (shown in pink) are expected to be needed.

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[2] Metropolitan Seattle Sewerage and Drainage Survey, Chapter 13, 1958.

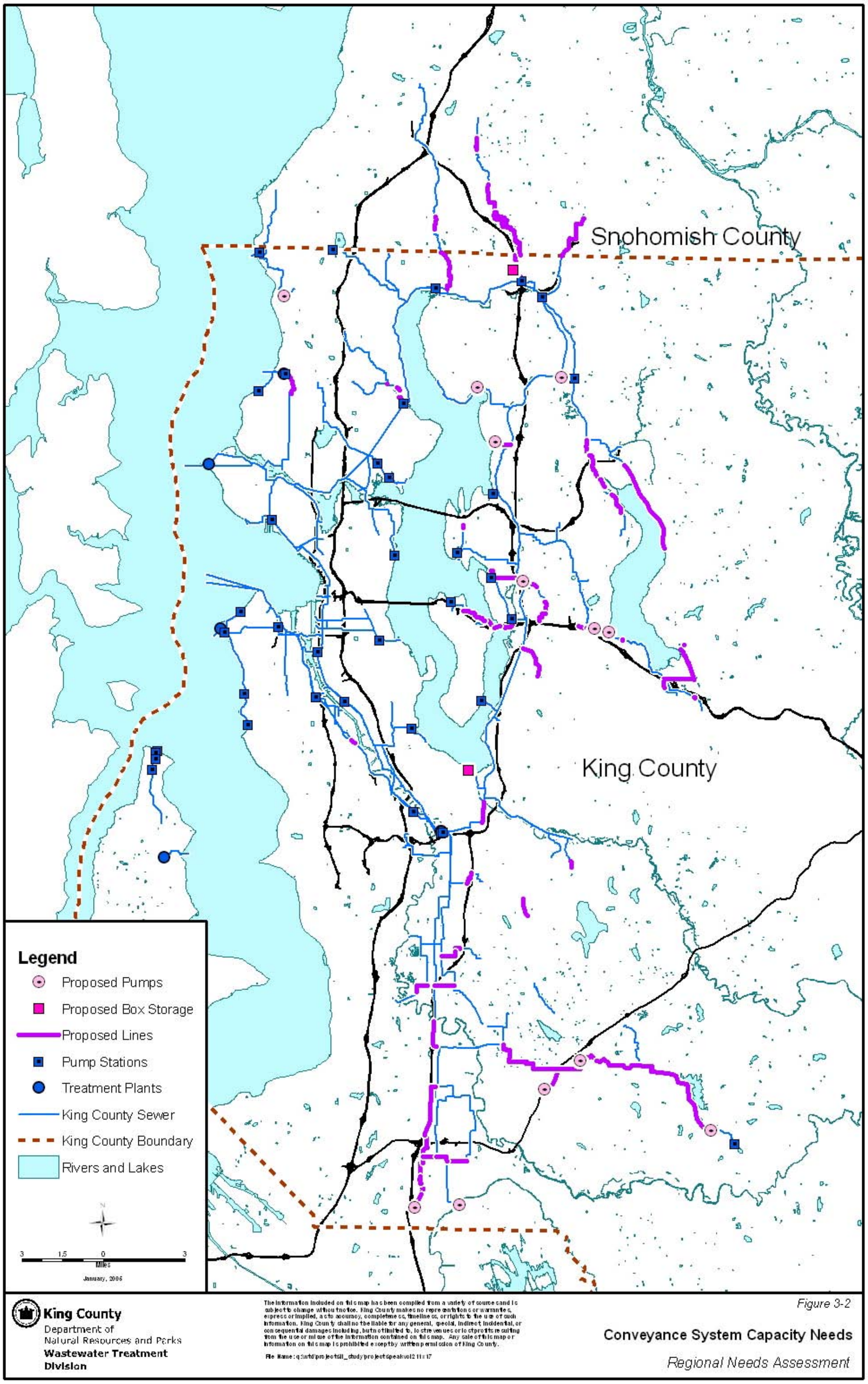


Figure 3-2. Map of Conveyance System Capacity Needs

The two factors that drive the need to expand capacity in the conveyance system are regional population growth and I/I flows within the system. Regional population and employment growth was discussed in the previous pages. The impact of I/I flows is discussed here.

I/I significantly impacts the capacity of the region's wastewater conveyance and treatment system. During storm events, I/I is by far the largest contributor to wastewater volumes that must be conveyed and treated. Figure 3-3 is a hydrograph that illustrates how I/I affects the volume of regional wastewater volumes that must be conveyed and treated. As can be seen, flow volumes can quadruple during rain events when the conveyance system must handle base flow ***plus*** I/I (the blue line in the figure).

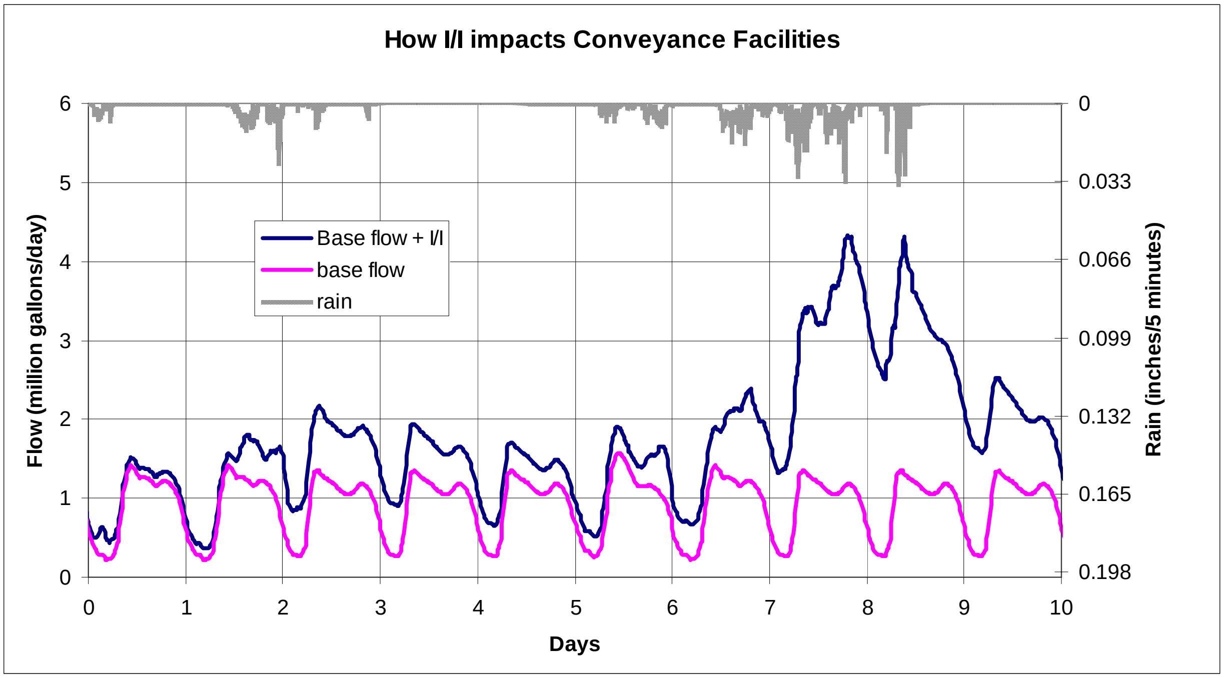


Figure 3-3. Impacts of I/I on Wastewater Flows

3.3 How the System Condition Was Assessed

To determine the condition of the conveyance system and measure its long-term capacity to direct existing and projected wastewater flows to the treatment plants, the Wastewater Treatment Division in cooperation with local agencies undertook a conveyance system flow modeling effort as part of the I/I program.

Modeling of sewage and I/I flows for the I/I control program serves as the basis for establishing the baseline of conveyance facility needs for comparison to various I/I reduction scenarios. It establishes the I/I reduction efficiencies and characterized the regional and agency I/I levels for design flow conditions. Flow modeling provides a consistent method of estimating the peak flows generated by residents and businesses served by local agencies and, in turn, the effects of peak flows on the County conveyance system. Flow modeling also provides a means to assess the current condition of the system by calibrating to a limited set of measured data and to see how future sewered growth and existing I/I volumes will affect the King County system.

3.4 Overview of I/I Program Modeling

The general strategy for modeling I/I and sewage flows was to collect rainfall and flow data for the model and calibrate the continuous *hydrologic* portion of the model to the rainfall response for 147 “model basins” in the service area. (Model basins and their flow data are discussed in Section 3.5 of this report) Once good calibration was achieved, a long-term (60-year) rainfall data set was used to “run” each model basin to model long-term flow. The modeled long-term flows were analyzed statistically to determine the 20-year peak flow produced within each particular model basin. These peak flows from the model basins were then applied (input) to a hydraulic model of the County conveyance system. The *hydraulic* model was then run to analyze how the system performs under the 20-year existing peak flow conditions.

Once the existing 20-year peak flows for the current conditions were established (assumed to be year 2000), future flow conditions were projected. The projections involved applying assumptions related to sewered growth, existing I/I rates and I/I rates from areas to be sewered in the future, and analyzing their impacts on the County conveyance system. The results of this analysis identify needed capital improvements to the regional conveyance system. These needed capital improvements are discussed in Chapter 4.

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 the 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% chance, of being exceeded in any given year.

3.5 Model Selection, Data Collection, and Modeling Assumptions

The following sections detail the model selection process, the acquisition and application of data, the model calibration process, the establishment of 20-year peak flows, the assumptions related to sewered population and area growth and their application, and the eventual assessment of the needs for conveyance improvements and upgrades.

3.5.1 Model Selection

The County acquired new hydraulic modeling software, MOUSE™ (Modeling of Urban Sewers) and a personal computer (PC) based model with a graphic interface to GIS. County management and staff decided to move away from an in-house model to a commercially available modeling package because it allows modeling results to be easily shared and analyzed by the County and local agencies. Selection of the MOUSE™ modeling software was the result of a detailed competitive selection process where three software packages were evaluated for technical capability and cost. The model selection process is detailed in *Appendix A1*.

3.5.2 Data Collection

The I/I modeling required the following data:

- Flow data
  - Including varying groundwater conditions
- Rainfall and evaporation data
  - Including large rain storms to trigger I/I response
  - Including several storms to ensure simulation of different rainfall conditions
- Sewer basin data
  - Sewered area
  - Dry weather flow patterns
- Conveyance system specifications

Flow Data

To quantify both base and I/I flows, “model basins” and “mini basins” were identified and mapped by the County and local agencies.:

- *Model basins* represent the sewered area flowing to a specific flow meter location. Each Model basin consists of approximately 1,000 sewered acres and 100,000 lineal feet of pipe. There are 147 model basins. Some of the model basins straddle agency boundaries due to agreements between agencies to “pass through” flows to King County.

- *Mini basins* are a further sub-division of model basins that geographically isolate variation in I/I flow rates within the model basins. There are 775 mini basins. They average 150 acres with 22,000 lineal feet of pipe.[3]

To measure and project base flow and I/I, flow meters were installed throughout the regional service area to measure flows during dry-weather and wet-weather periods. Flows during dry-weather periods are typically base flows only. Wet-weather periods typically consist of ***both*** base flows and I/I. Metering flows during both dry and wet-weather periods makes it possible to develop separate measurements for base flow and I/I. The data gathered from flow meters were used to calibrate the hydrologic component of the conveyance system model and to establish non-storm flow patterns to characterize the base sewage flow from specific portions of the service area.

Over 800 flow meters were installed and monitored by the County during the 2000–2001 wet season. Due to a drought, the monitoring effort was repeated during the 2001–2002 wet season to obtain accurate wet-weather flow data. (The wet season was defined as November 1 through January 15.) The locations of flow meters were carefully chosen so that the service area could be consistently delineated to support the use of the computer model, provide clarity and accuracy, and allow interpretation and application for other uses. Three types of meters were placed throughout the service area:

- **Long-term meters—**75 long-term 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 would allow for monitoring and assessment of system operation to further calibrate and validate the system model.
- **Modeling meters—**94 meters were placed at the outlets of model basins in order to provide flow information for calibration of the hydrologic model. Modeling meters collected data only during the wet weather season. Some of the long-term meters also functioned as modeling meters for about 160 basins.
- **Mini-basin meters—**638 meters, in addition to the above meters, 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.

The locations of the flow meters are shown in Figure 3-4. The flow meters measure both the depth and velocity of wastewater flows in pipes. Conducting flow monitoring at the mini basin level helps to assure that wet-weather performance was measured equitably, both system-wide and within each local agency's sewer collection service area. Flow monitoring in all of the mini basins was conducted simultaneously so that monitoring results were comparable.

[3] There is an average of five model basins per local agency, with a maximum of 17 model basins in Bellevue. The average number of mini basins within a model basin is five. The maximum number of mini basins per model basin is 13, and the minimum number is one (the model basin and the mini-basin are the same). The average number of mini-basins per agency is 23; the maximum is 117, once again in Bellevue. Five local agencies have just one mini basin.

The flow monitoring data gathered provides an accurate picture of current flows in local agency collection systems and the County's regional conveyance system. Projecting future flows required calibration of the hydrologic portion of the model to the measured flows.

Rainfall and Evaporation Data

Rainfall data throughout the regional wastewater service area were collected for the 2000-2001 and 2001-2002 wet seasons. Data were gathered from 64 rain gauges. The rain gauge data were used in combination with CALAMAR (Calcul de lames d'eau a l'aide due radar [*calculating rain with the aid of radar*]) radar images to define varying rainfall intensities throughout the service area.

Rainfall data were used to calibrate the hydrologic model and establish storm flow patterns to characterize I/I patterns that cause peak flows during storm events. A continuous time series of rainfall data was a required input for the hydrologic modeling performed. Local rainfall data coupled with radar-based rainfall intensity data were used for the model calibration. For prediction of the 20-year peak I/I flow, a 60-year rainfall record was used as a reasonable approximation of future rainfall frequency and intensity.

The 60-year rainfall record is an extended time series (ETS) based on Seattle-Tacoma (Sea-Tac) International Airport precipitation records. The ETS records represent the longest continuous record of rainfall data for the area. For modeling purposes, it was assumed that the past ETS records are representative of future rainfall patterns that are likely to occur in the service area. Such a record is valuable because of the strong influence that antecedent conditions have on I/I flow entering a pipe. The most effective way to simulate antecedent conditions is to utilize a model simulation that uses an actual series of measured rainfall. One of the primary features of the ETS rain data is that it contains scaled rainfall data sets based on zones of mean annual precipitation (MAP zones). This allows the model to account for locations within the service area that have greater rainfall amounts than Sea-Tac but no long-term rainfall record. For more information on the ETS and its application for this project, see *Appendix A2*.

Evaporation data needed for the continuous hydrologic modeling process were obtained from Washington State University's public agricultural weather system (PAWS) Puyallup weather station. This data source provides commonly used data for hydrologic modeling in the Puget Sound region. Evaporation data used for the long term ETS model runs were supplied with the rainfall files and were generated based on long-term Puyallup weather station data.

Sewer Basin Data

Population and sewered area information is a combination of available data and analyses of parcel data, aerial photos, zoning, and land-use information that identifies the sewered portion of the wastewater service area. The resulting product was GIS-based information about the service area previously unavailable at the level that it now exists. Along with its value for model calibration, the results of the analyses let us clearly apply growth assumptions to future I/I and base flow scenarios.

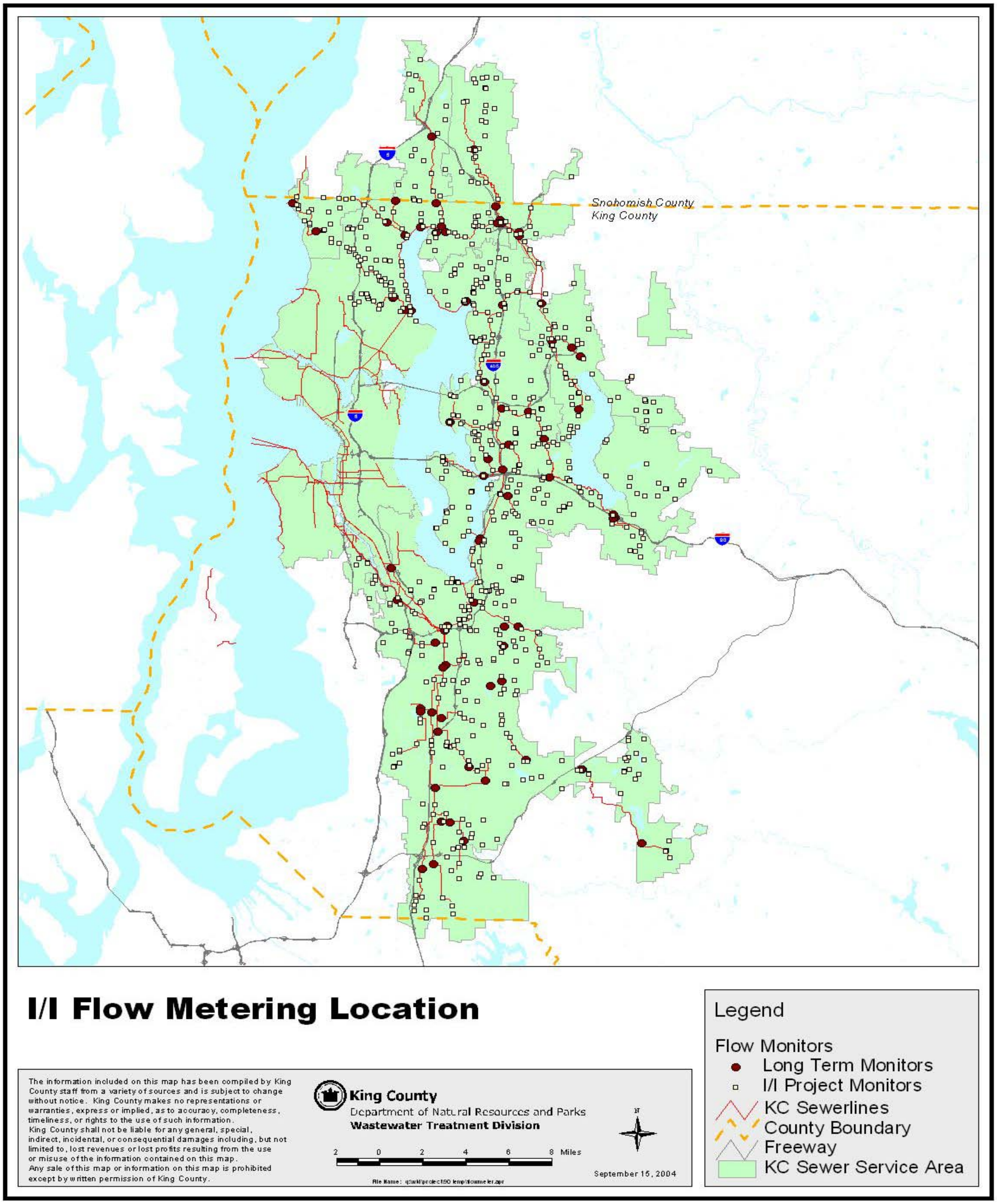


Figure 3-4. Flow Meter Locations

Population and sewered area information is a necessary input for both hydrologic and hydraulic modeling. The information includes specific population data and geographic information about the size of the sewered area. Combined, these two factors contribute to the base sewage flow and I/I generated in the 147 model basins.

The sewered area information was key and needed a certain level of accuracy due to the characterization of I/I flows in King County Code Section 28.84.050 (K) (3), which states, in part, that “an additional charge will be made for quantities of water other than sewage and industrial waste hereafter entering those sewers constructed after January 1, 1961.”The value of the peak I/I flow can be very sensitive to how the sewered area is defined. Large open spaces, like parks, are not sewered and do not contribute to I/I flows in the sewer system. It was important to identify and isolate these areas in order to calculate accurate I/I flow and base flows. For more information characterizing these areas, see *Appendix A3.*

Conveyance System Specifications

Conveyance system specifications include specific physical details (such as pipe sizes, elevations, pump station capacities, and connection points) about the conveyance system. Most of the necessary data were available from the County’s GIS database. Other details were provided by local agencies. The specifications are a key input into the hydraulic model, which measures and projects how different components of the conveyance system perform when subject to sewage flows and I/I following storm events.

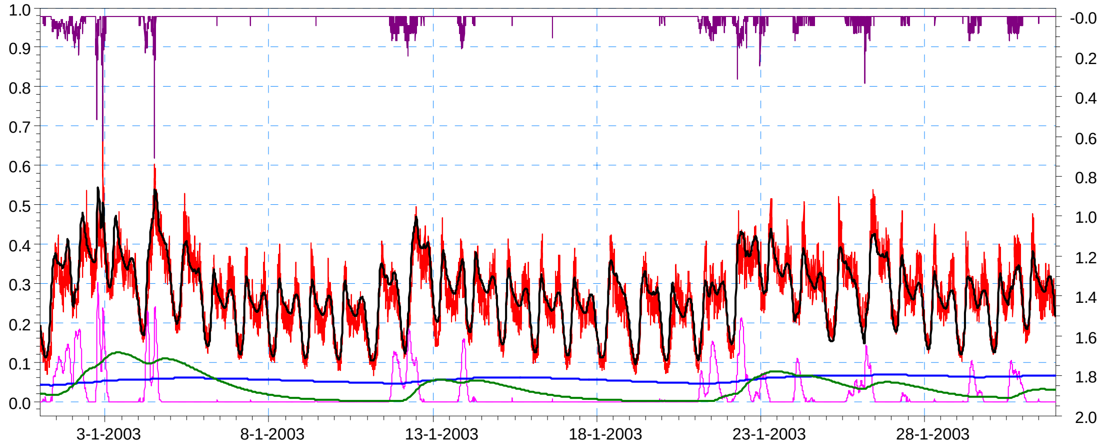
3.5.3 The Model Calibration Process

Calibration of the model is necessary to test the accuracy of its outputs. Calibration was accomplished by comparing model results to actual measured flow data. Both the hydrologic and hydraulic components of the model were calibrated to the two wet seasons of flow data collected in 2000–2002, and to the dry-weather sewage flow pattern.

Calibration involved adjusting wet-weather flow parameters in the model until the model output matched actual measured wet-weather flows. The dry-weather flow calibration process involved taking measured sewer flow data from dry-weather periods and identifying diurnal patterns[4] based on measured flows on weekdays and weekends. The establishment of dry-weather diurnal patterns throughout the week allowed the model to distinguish between rainfall-induced peak flows and flows generated by periods of high water consumption in different parts of the service area. As an example, non-storm peak diurnal flows from the Sammamish Plateau on weekends are higher than storm-induced peaks on weekdays.

Figure 3-5 below is a graphical example of how the calibrated model output matches the measured flow data for a variety of storms in the 2001–2002 monitoring period.

[4] Diurnal patterns are the regular rise and fall in daily consumptive use of water and production of wastewater. Varying land uses within sewer basins have a large impact on diurnal patterns and volume. (i.e., different mixes of residential, commercial, and industrial land uses).



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

Figure 3-5. Comparison of Modeled Flow Data to Measured Flow Data

Once the models were calibrated, long-term simulations were run using the data inputs described above. The output from the long-term simulations was analyzed to determine the probability of a given peak flow being exceeded during a given year. This probability was then used to calculate the return period of peak flow. More detail on the calibration, dry weather calibration, and estimation of peak flows is contained in *Appendix A4.*

3.5.4 Model Verification Through use of the Hydraulic System Model

The next key element for modeling was inputting the flows into a hydraulic model of the County system of conveyance facilities (pipes, pumps, and storage) so that the current state of the system could be evaluated. This involved using the calibrated outputs from the hydrologic model along with base sewage flow data. The modeled flows were inputted into the hydraulic model in the appropriate physical locations. This was necessary because the model basins vary from a single connection point to the conveyance system to as many as nine connection points per model basin. Using flows from the calibration time period allowed us to spot check the original model basin calibrations by comparing combined model basin flows to actual flow measurements in the system. Comparing these flows allows the County to make adjustments to both base sewage flows and I/I model parameters to better characterize the base sewage and I/I contributions to the system.

Once good agreement was reached in the modeled versus measured flows, 20-year peak flow demands on the system were established by making long-term model runs of the hydraulic model to establish the current performance of the County conveyance system relative to the peak flow demands that currently impact the system.

3.6 Projecting Peak Flows into the Future

Ongoing wastewater flow and rainfall monitoring efforts and use of a computer-based conveyance system model provide the basis for establishing the current conditions of the wastewater conveyance system, described above, and for projecting future flows. These projected flows are the basis for identifying the needed conveyance system improvements described in Chapter 4.

The projected peak flow rates are a combination of base sewage increases due to growth, existing I/I rates, and I/I rates from newly sewered areas and I/I from degradation of existing and new sewers. The planning assumptions are applied by decade to each model basin and then compared to the capacity of the specific conveyance elements affected by the growth. Once the model assesses that elements of the system are under capacity relative to the demand, the time of the excedence is noted and a capacity alternative is formulated to provide the needed capacity under the saturation condition (2050) 20-year return period peak flows. The capacity alternatives are typically pump station replacement or upgrade, parallel or replacement of gravity sewer lines, or storage facilities to temporarily store excess I/I flows until peak flows subside and there is enough capacity to safely convey the flows downstream. The chosen capacity upgrades may be one or some combination of pumps, pipes, or storage and is assumed to be the lowest cost alternative. These assumed conveyance costs form the baseline for comparison to I/I reduction costs and benefits.

3.6.1 Base Sewage Flow Growth

Growth in sanitary or base flow volume over time depends on changes in population and employment in the service area, septic conversions to sewers, and changes in water use levels through conservation efforts. Based on these factors, base flow in the regional service area is expected to grow at a steady rate through 2050.[5] Currently, base flow in the regional wastewater system is approximately 75-million gallons per day (mgd). Through urban growth and septic conversions, base flow is projected to grow to over 120 mgd by 2050. Figure 3-6 illustrates the projected growth rate in base flow for the region. Note that the projected growth in base flow through 2010 is relatively flat. This is due to the expected positive influence of current water conservation efforts. Water conservation levels are expected to remain constant after 2020.

Of the growth factors described above, growth in residential sewered population (either from new development or septic conversions) has the biggest effect on growth in base flow. Figure 3-7 highlights the differences in the projected residential, commercial, and industrial growth rates within the regional service area.

[5] The year 2050 is the established planning horizon for the wastewater treatment system.

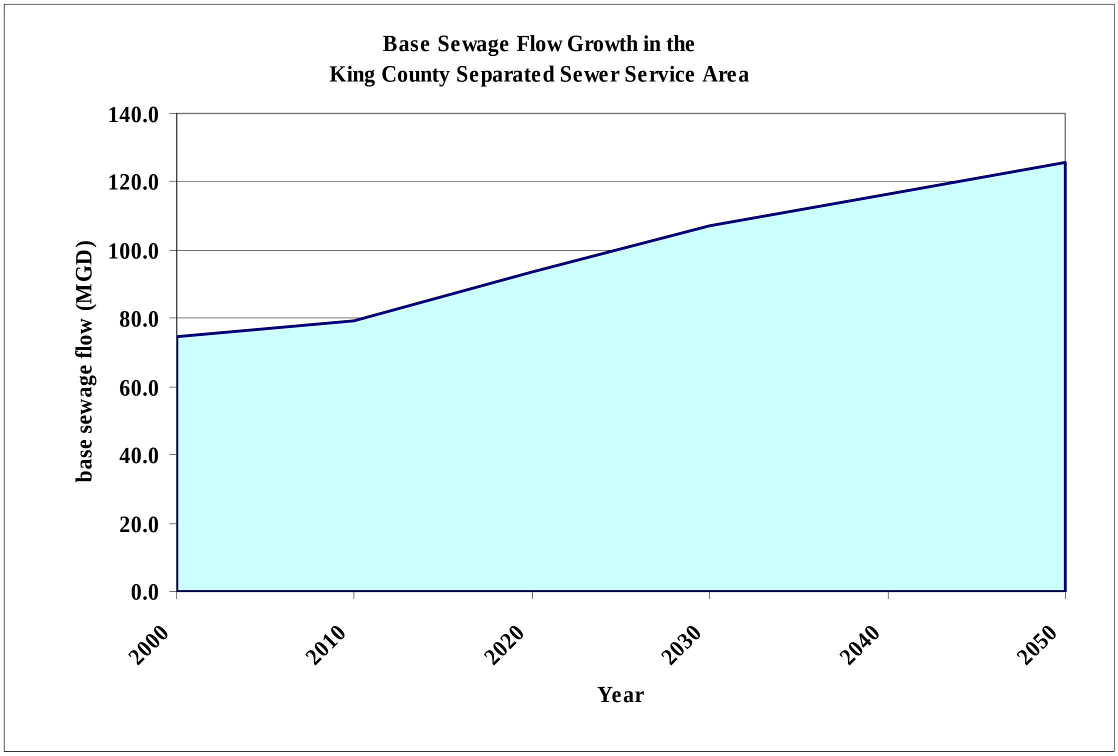


Figure 3-6. Projected Growth in Base Flow

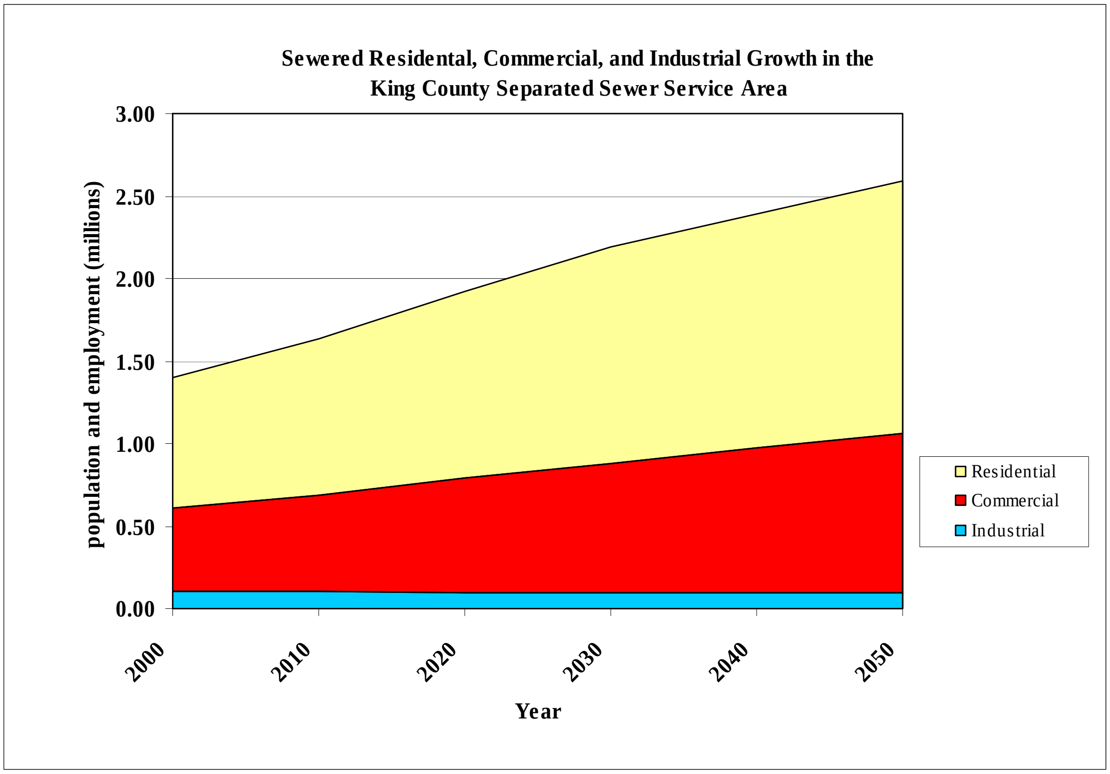


Figure 3-7. Residential, Commercial, and Industrial Growth Rates

3.6.2 I/I Growth

Growth in I/I comes from two major components: degradation of existing sewers and I/I from new sewered areas. I/I in the currently sewered areas is established based on modeling of the current conditions. Assumptions for I/I anticipated from areas sewered in the future are based on modeling results from areas sewered since 1990. The sewered area analysis described earlier in the report allows us to identify how some conveyance facilities are affected more than others in the service area by how much capacity for sewered growth exists in the area served by the facility.

Degradation or the increase of I/I into the sewer system is expected to occur over time at a rate based on historical observation.

3.7 Planning Assumptions

Planning assumptions are needed to estimate the size, timing, and costs of new conveyance system components. The events that drive the timing, sizing, and costs of facilities occur in the future and require assumptions to arrive at answers.

Following completion of I/I reduction pilot projects in early 2004, local agencies (via MWPAAC's Engineering and Planning Subcommittee) and the County used a collaborative process to discuss and agree upon a set of assumptions. Table 3-1 summarizes several of the more significant planning assumptions. See *Appendix A5* for a detailed description of all planning assumptions.

Table 3-1. 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 SeaTac 60-year rainfall record, adjusted per annual average rainfall over each part of the service area
Degradation	7% per decade starting from year 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%

Sensitivity Factor	I/I Modeling Assumption
Inflation rate	3%
Operation and maintenance analysis	Update the following from RWSP: • •New pipes: 15 cents per lineal foot annually • New pump stations: $4,104 per mgd + $60,384 • New storage facilities: $34,091 per MG + $4,546 • Treatment plants: $15,000–$30,000 per mgd of average annual flow reduction (plant specific); covers energy and disinfection costs

Chapter 4

Conveyance Needs

This chapter identifies the Conveyance System Improvement (CSI) projects and costs that provide a baseline for conducting benefit-cost analyses of potential Infiltration and Inflow (I/I) reduction projects. Flow monitoring and modeling data developed for the I/I control program were used to project CSI project needs to allow for an accurate comparison of benefits and costs between CSI projects and I/I reduction projects. As a result, the complete list of CSI projects reported here differs from what is included in the Regional Wastewater Services Plan (RWSP), as updated in 2004.

4.1 List of CSI Projects

Table 4-1 summarizes the list of 63 CSI projects that would meet the region's projected capacity needs through 2050. The projects identified are based on the data gathering and modeling efforts of base flow and I/I generation that was done for the I/I control program, as described in Chapter 3 of this report. The projects, estimated project costs, and estimated online date for each project are based on projected 20-year peak flow volumes, and were developed to provide a basis for conducting benefit-cost analyses of potential I/I reduction projects.

Table 4-1. Conveyance System Improvement Projects and Estimated Project Costs

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/Wiburton Odor Contol	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

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
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
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
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

Project #	Project List	Project Type	Year Online[1]	Estimated Project Cost[2]
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
		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.

4.2 Comparison of Projects and Estimated Costs to the Updated RWSP

The updated RWSP contains a list of CSI projects and a cost estimate of approximately $638 million (2003 dollars). The RWSP identified CSI needs through 2030. The list of CSI projects and estimated costs for the same time-period contained in this RNA are approximately $648 million. The approximate 2-percent difference in the cost estimates is attributable to the fact that more detailed flow monitoring and modeling data developed for the I/I control program were used to project CSI project needs. Again, this was done to allow for an accurate comparison of benefits and costs between CSI projects and I/I reduction projects. When the RWSP was updated in early 2004, flow monitoring and modeling data were not available for the entire service area or at the level of detail available today. The projected cost estimate for all 63 CSI projects through 2050 is approximately $779 million (2003 dollars).

The flow monitoring and modeling data developed for the I/I control program indicate that I/I levels in certain areas of the region are greater than the assumptions used to update the RWSP. Based on a comparison of these modeled flows to the capacity of the conveyance system, 10 additional projects[1] not previously identified in the updated RWSP were included in the list of CSI projects included in Table 4-1. Two projects[2] that were included in the updated RWSP were not listed in Table 4-1 because modeled flows in a portion of the system were less than those assumed for the RWSP update. Additionally, the flow monitoring and modeling data allowed for

[1] Project Nos. 28, 29, 31, 33, 35, 42, 44, 45, 47, and 50 in Table 4-1.
[2] Effluent Transfer System (ETS) Storage project and Tukwila Freeway Crossing project.

projecting flows and capacity needs from 2031 through 2050.[3] Therefore, additional projects anticipated to be needed between 2031 and 2050 are included in this RNA. Their estimated cost is approximately $131 million.

The CSI projects and estimated costs listed in Table 4-1 assume that the rate of growth in base flow will grow as population and employment grow in the region and that I/I will continue unchecked into the future. In other words, the cost estimate for expanding the capacity of the regional conveyance system assumes no action will be taken to reduce capacity demand by reducing flow volumes. This assumption is necessary to provide a baseline for conducting benefit/cost analyses of potential I/I reduction projects.

Projects 1 through 23 in Table 4-1 are either complete or in the predesign, design, or construction phase and will not be included in I/I benefit-cost analyses. Figure 4-1 identifies the location of the CSI projects by project number as listed in Table 4-1.

4.3 Correlation to I/I Flows

Figure 4-2 shows the location of needed CSI projects in relation to metered I/I levels in mini-basins[4] throughout the service area. As can be seen, a number of the improvement projects are near mini basins with relatively high I/I flows. As was discussed earlier, I/I significantly affects the capacity of the region's wastewater conveyance and treatment system. During storm events, I/I is by far the largest contributor to wastewater volumes that must be conveyed and treated. If I/I flows could be reduced in targeted mini basins, it may be possible to reduce the need for conveyance system improvements because the capacity needed to convey and treat wastewater from these mini basins would also be reduced.

[3] The year 2050 is the projected date when the regional wastewater service area will be fully built out and all portions of the service area will be connected into the wastewater treatment system.

[4] Mini basins are geographically isolated areas that show variation in I/I flow rates. There are 775 mini basins that average 150 acres in size and contain approximately 22,000 lineal feet of pipe. See Chapter 3 of this report for a more detailed discussion of mini basins.

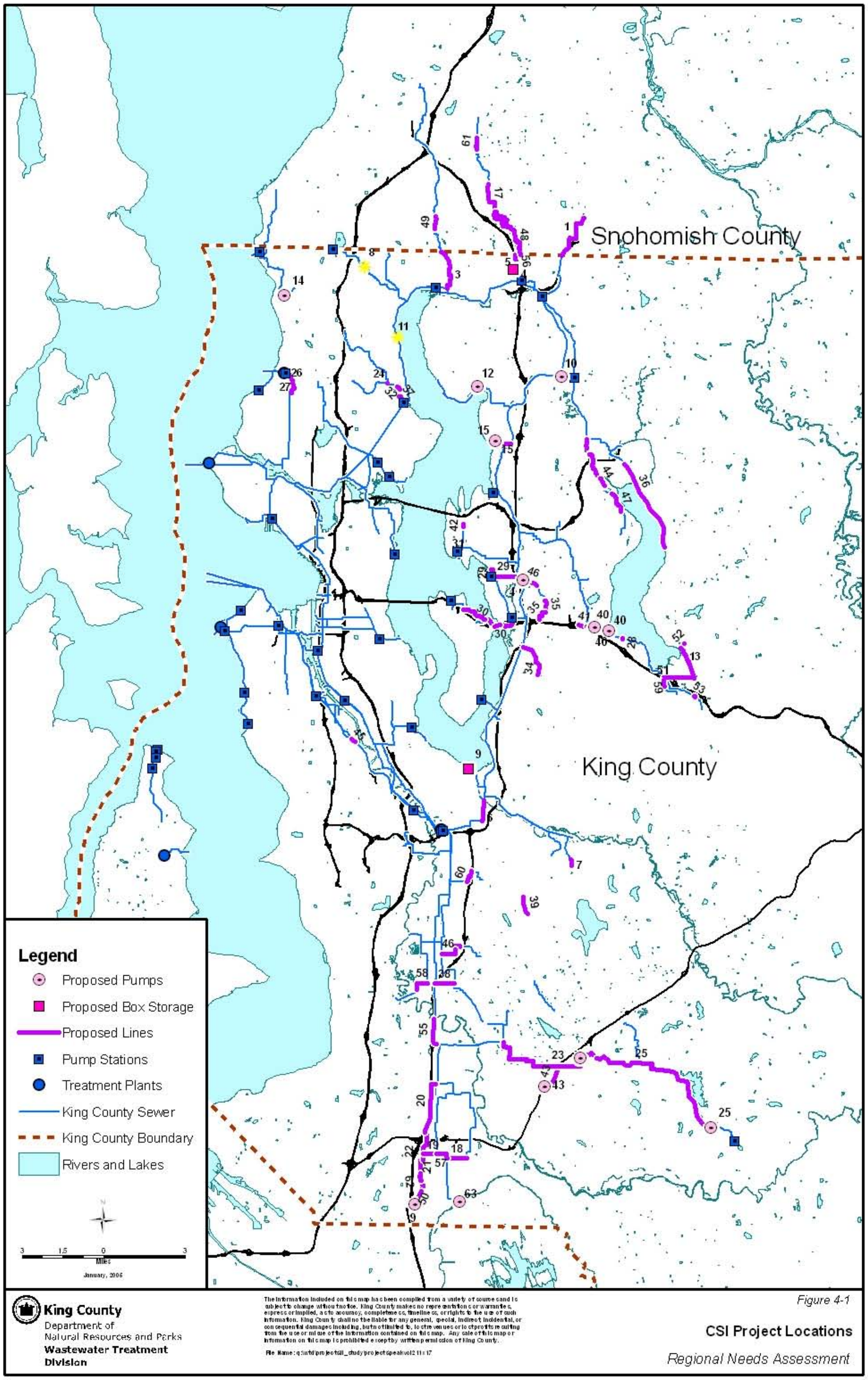


Figure 4-1. Conveyance System Improvement Project Locations

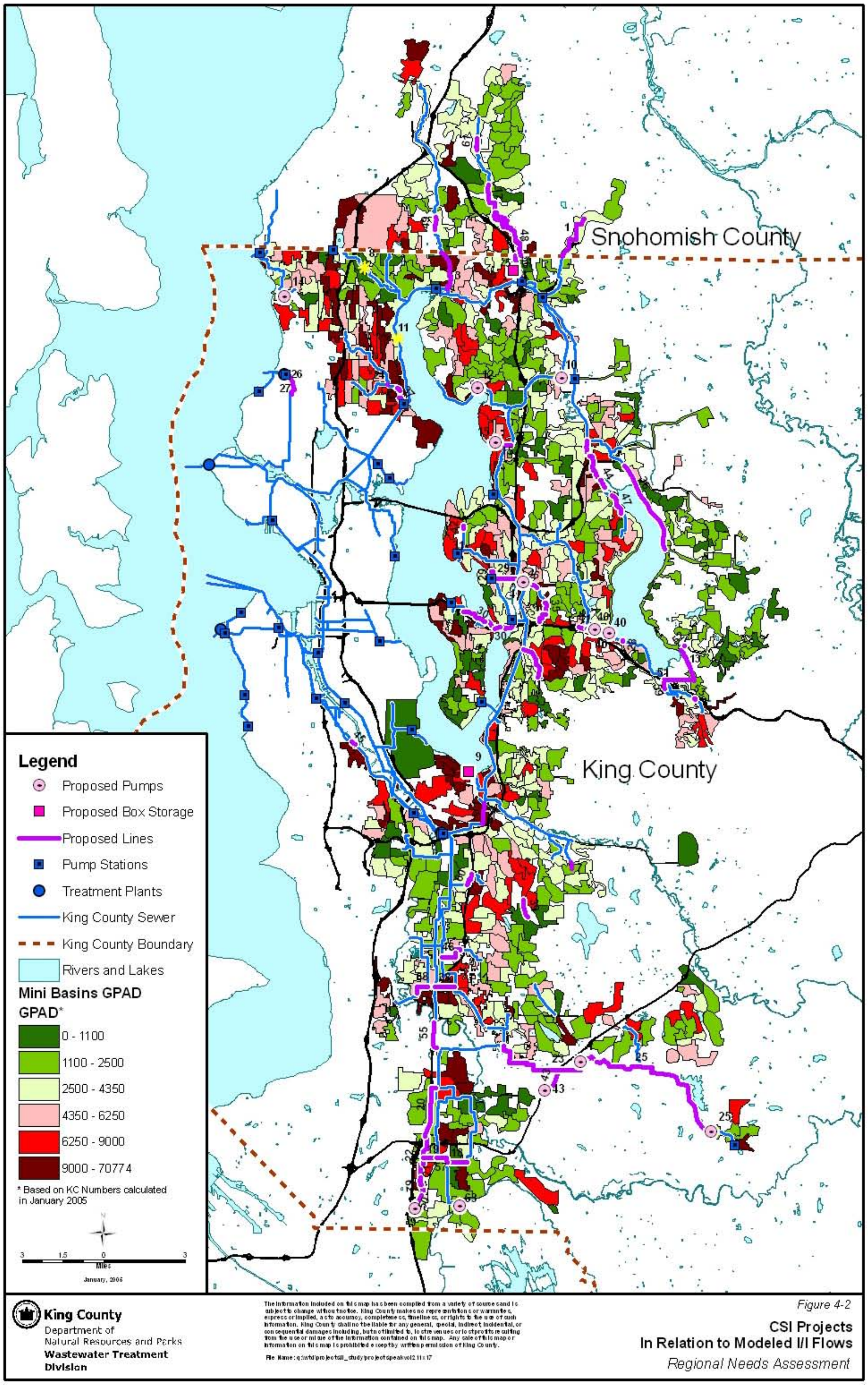


Figure 4-2. Conveyance System Improvement Projects in Relation to I/I Levels

4.4 Approach to Providing Capacity and Reducing Cost

The capacity needed to convey and treat peak flows in the region can be provided by expanding the capacity of the conveyance system, or by trying to first reduce flows and thereby reduce the capital investments necessary to upgrade the conveyance system. The region is investigating the feasibility of the latter approach based on policy direction contained in the adopted RWSP. Policy I/IP-1 states that the County will "reduce I/I whenever the cost of rehabilitation is less than the cost of conveying and treating the flow or when rehabilitation provides significant environmental benefits to water quantity, water quality, stream flows, wetlands, or habitat for species listed under the ESA. [5]" Since 2000, the County and local agencies have been working to develop an I/I control program that will reduce I/I flows and reduce the cost of providing adequate capacity for the region's wastewater through 2050.

This RNA provides the baseline for measuring the costs and benefits of implementing I/I reduction projects to reduce flow volume in lieu of making a capital investment in the conveyance system. The County and local agencies will continue to work together to estimate the costs of I/I reduction projects upstream of identified conveyance improvement projects. The costs of conveyance system improvements identified in Table 4-1 will be compared with the estimated costs of reducing I/I levels to arrive at the cost-effectiveness comparison on a project specific basis.

4.5 Next Steps

The CSI projects identified in Table 4-1 that have been completed or are in the predesign, design, or construction phases will need to be designed and built within the next few years and will not be included in the I/I benefit-cost analysis. For the remaining conveyance system improvement projects, flow and benefit-cost analyses will be conducted in 2005 to determine if I/I reduction projects can cost-effectively reduce or eliminate the need for adding conveyance capacity. A list of cost-effective I/I projects and their associated cost savings will be included in the Executive's proposed I/I Program Recommendation that is due to the County Council by December 31, 2005.

[5] Endangered Species Act (ESA).

List of Appendices

Appendix A1

Model Selection Process

Appendix A1

Model Selection Process

Conveyance system modeling was conducted to simulate peak design flows in the separated wastewater conveyance system and to determine system capacities. The model was also used to simulate I/I flows in the system. King County acquired new hydraulic modeling software, MOUSE™ (Modeling of Urban Sewers), a personal computer (PC) based model with a graphic interface to GIS. Descriptions of the process used to select the model, model capabilities, operation and calibration of the model, and quality procedures to ensure accuracy of the model are provided below.

When modeling software is used, conveyance system alternatives can be investigated. These alternatives include storage facilities or flow swaps with adjacent agencies and operational changes over a wide range of flow conditions. Other conditions that cannot be easily measured can be considered with the aid of a computer model, such as the impact of disconnecting downspouts in a local basin or lining trunk sewers in a basin.

A1.1 Model Selection

A model selection team identified potential software vendors, prepared a Request for Proposal (RFP) for model selection, reviewed proposals, and compared features of models to facilitate selection of the best system for the I/I project needs. The model selection effort began in early January 2000. King County staff was involved in a similar City of Seattle effort before 1999, which provided County staff with additional knowledge about potential vendors. An RFP for selection of a computer package was prepared and published in April 2000 based on data collected from the City's and County's evaluation processes and from the County's early-2000 survey of vendors and users.

A1.2 Alternatives Considered

Vendors for SewerCAT, InfoWorks, and MOUSE™ software responded to the RFP. The initial review of proposals eliminated SewerCAT and clarified some issues:

- Although the SewerCAT vendor is a local company offering the advantage of convenient communication, the proposed work would require extensive customization of software. In contrast, the InfoWorks and MOUSE™ packages would not need major customization. Favorable consideration was given to off-the-shelf products where little or no customization was required.
- SewerCAT would not require paying a license fee. Lack of a licensing agreement could result in limited support and no upgrades in the future.
- While working with SewerCAT would favor the model development schedule by making use of the County's existing model data and providing continuity in the future, the need for full-scale development of a user interface would negatively impact the schedule.
- SewerCAT lacked many of the features offered by other packages. SewerCAT did not include hydrologic and infiltration modules. Features that were stronger in other packages included dry weather flow development; ESRI's ArcView™ GIS basin information import, export, and management; and graphic user interface (GUI).

The review team believed that, in addition to concern about schedule impacts, the Reid Crowther team (SewerCAT developer) could experience difficulty in providing the necessary resources to customize its package. Based on these considerations, Wallingford Software's InfoWorks and DHI's MOUSE™ were short-listed for further consideration.

A1.3 Model Evaluation and Selection

In terms of technical capability, both InfoWorks and MOUSE™ offered powerful tools for calibrating and simulating rainfall-dependent I/I (RDII) and hydraulic systems. After reviewing the proposals, the selection team members requested that vendors provide a live demonstration using the County's sewage basin data. Two primary features were evaluated during the demonstrations: (1) the model's ability to calibrate I/I flows to flow monitoring data; and (2) computation speed. The basin runoff model was calibrated using meter data and compared with an additional storm event. A 2-month simulation was conducted for comparison of computation speed during the demonstration.

Information gathered on each package during the City of Seattle's model selection process was also considered.

A1.3.1 Hydrologic Model Needs and Features

Both models had comparable in hydrologic features. InfoWorks provided more flexibility in setting up basins and more options for pervious infiltration setup. MOUSE™ offered fewer options in the hydrologic routine and pervious surface infiltration. MOUSE™ offered more for plotting components of runoff flows. MOUSE™ was stronger in terms of schedule and cost of customizations. InfoWorks could not accommodate gaps in rainfall data, while MOUSE™ could. InfoWorks could plot gaps of metered flow in plotting comparison, whereas MOUSE™ could not.

A1.3.2 Hydraulic Model Speed and Control

InfoWorks was slightly weaker in the hydraulic model speed and control. In its proposal, InfoWorks claimed to be more stable. It was difficult to verify the comparison between claimed features and actual operation of the model. MOUSE™ was stronger in setting up Manning's "n" for depth-dependent friction in circular conduits. MOUSE™ was also stronger in terms of handling flow in an internal pipe as a boundary condition.

MOUSE™ could bypass the dry period hydrodynamic simulation, but InfoWorks could only increase time steps during a dry period. This feature in MOUSE™ significantly reduced the computation time when performing long simulations. InfoWorks could allow the user to modify control elements during the simulation, while MOUSE™ could only allow the user to see the results at the end of the simulation.

A1.3.3 Data, Run, and Result Management

InfoWorks was slightly stronger in data, run, and result management. InfoWorks offered rigorous data management and tracking tools. MOUSE™ had less sophisticated data management tools with no tracking. MOUSE™ was stronger in statistical tools.

InfoWorks used a client-server setup, which is better than MOUSE™. However, this was not required as the project used a local model setup.

A1.3.4 Customization

Experience and proposal information regarding customization was more favorable for MOUSE™. DHI offered a good customization schedule, as well as providing the necessary resources. AGT's response was not clear on the schedule and resources.

InfoWorks was not as strong as MOUSE™ in several respects related to the company and product as listed below:

- In terms of the setup of technical support, MOUSE™ is directly supported by DHI, who is both the developer and the vendor. With InfoWorks, however, AGT (the vendor with some technical support) is the primary contact and then Wallingford Software (the developer with some technical support). This setup could be frustrating especially when the support time required is critical. An AGT customer expressed some frustration in this regard.

- MOUSE™ had more sewage modeling users than InfoWorks. MOUSE™ had an established user group. The user group for InfoWorks was limited to only the users of HydroWorks and there were few of these (Seattle Public Utilities was the only user identified).
- InfoWorks lacked extensive testing and, at the time of evaluation, RDII components of the model were new and not yet well tested. MOUSE™ provided a more complete history of testing, especially the RDII Module (formerly MOUSE™ NAM that had been around for some time). This was an important consideration.
- The documentation of InfoWorks was very limited with respect to the RDII routines. With all the rigorous effort during selection process, it was not clear how the RDII model in InfoWorks was set up and how equations and parameters were defined. On the other hand, MOUSE™ offered good documentation about their RDII model and how each component was defined.

While both models were ranked high in all aspects of technical capabilities, MOUSE™ was more highly rated for the company and product information.

A1.3.5 Demonstration

MOUSE™ ranked higher for the demonstration. The selection team compared the two products with respect to convenience of calibration, output handling and graphing, capability of plotting I/I components, graphic comparison between modeled and meter data, computation speed of the hydraulic engine, calibration results of the hydrologic basin, choices of I/I model, and documentation of the parameters for I/I calibration.

The calibration using MOUSE™ of the hydrologic basin was better because it demonstrated a more reliable calibration and can be extended to periods beyond the calibration period. On the other hand, InfoWorks appeared to be calibrated reasonably well in comparison to meter data for the period given, but it failed to match the flow during period beyond the calibration period. The calibration results from MOUSE™ showed more credibility in predicting storms based on rainfall data once a good calibration was achieved.

MOUSE™ has better capabilities in output and plotting I/I components, which is very useful in doing calibrations. Even though the system units in InfoWorks were changed to English units, the simulation results exported from InfoWorks were still in metric.

In terms of computation speed, MOUSE™ was faster in simulating the 7-node sample network. It took 73 seconds for MOUSE™ to finish a 2-month simulation and 114 seconds for InfoWorks to finish the same run. However, according to the network setup in MOUSE™, there were 35 computational segments. The default number of segments was about 75 for the sample network. The demonstration appeared to be set up with fewer segments in order to gain more computation speed. There were approximately 195 segments in InfoWorks. Considering the setup of the computational segments, it appeared that InfoWorks was about twice as fast as MOUSE™ in terms of hydraulic computation per computational segment. This was consistent with Seattle Public Utility's model comparison. However, the number of segments required reflects the stability of the computation. The default settings for the number of segments in each model (195 for InfoWorks, 75 for MOUSE™) should be a reflection of the stability of the hydraulic computation scheme. Therefore, it was concluded that for model steps of equivalent stability, the two models were close in speed.

The two packages were ranked on technical components, company and product, cost, and the demonstration. The final ranking was based on comparison of items listed in the original proposal in addition to the information collected during the demonstration.

Appendix A2

Application of the Extended Time Series (ETS) Precipitation and Evaporation

April 2003

Appendix A2

Application of the Extended Time Series (ETS) Precipitation and Evaporation

King County Regional Infiltration/Inflow Control Program

April 23, 2003

A2.1 Issue

Mean annual precipitation and infrequent rainfall event volume is not uniform within the KCRIICP study area. Program stakeholders have expressed concern about the appropriateness of using the 60-year rainfall record from Sea-Tac to determine design I/I flows from each model basin. This concern is based on available documentation that indicates a variation in rainfall from Sea-Tac in terms of both annual average and specific duration storm events. An alternative long-term precipitation time series is desired to avoid the application of the Sea-Tac rainfall record to the entire service area.

A2.2 Proposed Solution

As a result of similar issues facing WSDOT and Pierce County, a method has been developed by MGS Engineering to modify the Sea-Tac rainfall record for use in areas of Washington with different mean annual precipitation that have similar storm characteristics.

The full ETS time series developed for Puget Sound are 158 years in length. This long-term record was achieved by combining records from distant precipitation stations. For application within the KCRIICP, only the first 60 years of the ETS that are based on the Sea-Tac rainfall record will be used. The 60-year record is adequate since desired design flows are based on a 20-year return period, which can be estimated by interpolating between modeled peaks. The full 158-year records were originally developed for surface water applications where flows with 100-year return periods are often the analysis objective.

The ETS time series consists of sets of rainfall time series related to zones of mean annual precipitation (MAP). ETS's for Puget Sound have been developed for the Washington State Department of Transportation (WSDOT) and for Pierce County By MGS Engineering Consultants (http://www.mgsengr.com).

MAP zones that provide the basis for determining which ETS to use are produced and published by Oregon State University's Spatial Climate Analysis Service for the entire United States using the PRISM Model (http://www.ocs.orst.edu/prism/prism_new.html).

A2.3 Alternatives Considered

1. Use of a scaled version of the Sea-Tac rainfall record based on the relationship from specific time duration (i.e. 24 hour, one week, one month etc.) to a specific rain gauge near the model basin.
2. Extended Time Series (ETS) for mean annual precipitation values corresponding to the mean annual precipitation in the study area. ETS applicable to the King County study area are available for the following zones of mean annual precipitation: 36, 38, 40, 42, 44, 46, 48, 50, 52, 56 and 60 inches.

A2.4 Discussion

ETS was developed using a series of statistical scaling functions rather than a single scaling factor. The scaling functions provide for scaling of rainfall amounts at the 2-hour, 6-hour, 24-hour, 72-hour, 10-day, 30-day, 90-day, and annual durations. The ETS that are applicable to the King County study area were developed by scaling the Sea-Tac rainfall record to match the storm statistics of the time series records at over 50 precipitation gauges located in the lowlands of western Washington. Therefore, the storm characteristics contained in the ETS are based on a very large sample set of storms and stations rather than the record from a single station.

Results obtained from continuous rainfall-runoff modeling, as is being used for the KCRIICP, is sensitive to rainfall within individual events as well as the antecedent rainfall preceding each event. The amount of infiltration flow present during a given storm may be dependent on the rainfall that occurred over the preceding 6 months or year. A limitation of scaling the Sea-Tac rainfall record using only one or two characteristics is that the result may be valid for specific durations, but will incorrectly estimate intensity and rainfall volume at other durations. Therefore, to maintain the integrity of model results when using a scaled precipitation time series it is important to preserve the rainfall characteristics for a wide range of durations, as was incorporated into the development of the ETS.

Other factors supporting the credibility of using ETS in KCRIICP include:

1. ETS provides a method for using long-term continuous modeling to develop design flow estimates while also considering the variation of rainfall throughout the study area.
2. ETS is an analytically sound procedure based on available rainfall data collected throughout the study area.
3. DOE has approved ETS for continuous Stormwater Modeling in the Puget Sound region.
4. Use of the ETS is an application of the most current available published information and would be more defendable that the use of a project-specific approach.

Appendix A3

Model Basin Delineation Summary

MODEL BASIN DELINEATION SUMMARY

INTRODUCTION

Hydrologic modeling is a key technical component of the King County Regional Infiltration/Inflow Control Program. Modeling will be used to predict I/I flow from each of approximately 150 local agency modeling basins. Hydrologic models simulate the transformation of rainfall into runoff and groundwater and simulate the portion of water that enters the sewer pipes. Measured flow and rainfall data collected during the 2000-2001 and 2001-2002 wet seasons will be used to calibrate each model basin.

A fundamental input needed for the hydrologic model is the amount of sewered area within each model basin. In order to evaluate future flows, the expected additional sewered area resulting from future development must also be defined. In essence, the area contributing flow to the King County wastewater conveyance system and classification of the service area as sewered or unsewered area are “basic building blocks” needed for developing the hydrologic models.

MODEL BASINS

The model basins were delineated to quantify flow contributed by local sewer systems to various portions of the King County conveyance system. In general, the model basins were also delineated to quantify flow from each local sewer agency, although some model basins contain portions of multiple sewer agencies. The boundary of each model basin is dependent upon the placement of the modeling flow meters installed during the 2000-2001 and 2001-2002 monitoring periods.

A number of data sources, including Sewer Comprehensive Plans and available mapping of local sewers, were used to determine the area tributary to each modeling flow meter. Because the model basins will also be used for future flow estimation, the boundaries of the basins were placed to encompass the future basin limit for eventual build-out conditions, not just the currently sewered area. The actual boundary for each model basin was defined geographically using the King County GIS parcel coverage as a basis.

SERVICE AREA CLASSIFICATION

The primary purpose for classifying the service area was to distinguish between sewered and unsewered areas. Unsewered areas were divided into two major categories, Potentially Sewerable and Not Sewerable, to provide flexibility for modeling flows from projected future development and alternative growth scenarios. Various sources of information, including Sewer Comprehensive Plans, local sewer maps, aerial photography (2000) and parcel data were used to determine the proper boundaries and classifications.

A general description of the three major service area classifications is provided below. More detailed descriptions of the individual service area classifications are provided in Table 1.

1. Currently Sewered Area – this includes area served by sewers during the flow-monitoring period. Sewered means that the area is served by a sanitary sewer collection system. Sewered areas can be entire parcels or portions of large parcels.

2. Potentially Sewerable Areas – this includes privately held land (developed or undeveloped) that could potentially be sewered in the future. Includes vacant parcels and areas currently served by On Site Sewage disposal systems (OSS) and portions of parcels where part of the parcel is considered sewered but other portions are not sewered.

3. Not Sewerable Areas – this includes publicly owned parklands, sensitive areas (such as steep slopes), freeway rights-of-way, and lakes where development is not expected to occur.

As with delineation of the model basins, parcel boundaries were used primarily as the basis for delineating sewered and unsewered areas. Distinguishing between Potentially Sewerable areas and Not Sewerable areas was somewhat subjective. For properties served by sewer the entire parcel was considered sewered, unless the size of the parcel was greater than 1.5 acres (approx. 60,000 sq ft). The development present on large parcels (greater than 1.5 acres) was reviewed. If the property contained open space that would not contribute to sewer inflow and infiltration then that portion of the property was designated unsewered.

For developed areas containing many small parcels, a threshold of 1.5 acres was also used to differentiate between classifying areas as sewered or unsewered. For example, if an area of small parcels (each less than 1.5 acres) was generally developed and sewered, then all the parcels were classified as sewered. However, if a group of small parcels totaling at least 1.5 acres appeared undeveloped or unsewered, then the appropriate Potentially Sewerable or Not Sewerable classification was used.

A 5 foot buffer will be placed around sewers the do not have any service connections (“orphan sewers”), to include the possible infiltration from the pipes in the sewered area. These buffer areas will be added to the sewered area at the end of the delineation process.

TABLE 1

SEWER SERVICE AREA CLASSIFICATIONS

Code	Type	Description
Sewered		
S	Sewered	Areas adjacent to sewer lines, or with sewer lines running through them that contain at least one building and are served by the Sanitary Sewer System. These may be entire parcels or portions of parcels. Also includes roads that have sewer lines in them. Sewerlines that are traversing properties that are not sewered (without connections) will be buffered 5 feet on either side of the sewer, and this buffer will be considered sewered.
Potentially Sewerable		
U	Undeveloped	Undeveloped but potentially sewerable. (see note † below). Parcels that are listed as vacant or showing no improvement value in the King County Assessors Data and appear to be vacant in the 2000 aerial photo. The U classification only applies to entire parcels or groups of parcels that are undeveloped and not sewered.
D	Developed	Not sewered area that is developed and may be sewered in the future. (see note † below)Typically these are older residential areas that are served by individual On Site Sewage disposal systems (OSS, or septic tank and drainfield systems) The D classification only applies to entire parcels or groups of parcels that are developed and not sewered.
Y	Potentially sewerable area that is not sewered.	Y can be used to designate areas as potentially sewerable, without breaking down parcels or groups of parcels as U (undeveloped) or D (developed). Y is also used in undeveloped areas where development may be less dense than underlying zoning due to site constraints. If a parcel (or group of parcels) is partially sewered, Y is applied to the remainder of the parcel is vacant and potentially sewerable.
AGY	Agricultural	Parcels or portions of parcels currently in agricultural use. Includes parcels that are in State of Washington Current use Taxation programs. These programs discourage development through tax penalties, however the land is still potentially developable.

Not Sewerable		
A	Airfield	Portions of Airports that are not sewered. The portions of airports connected to the sanitary sewer system such as control towers and buildings associated with maintenance or administration are considered sewered.
AGZ AGZ (cont.)	Agricultural Agricultural	Fields under cultivation or which may potentially be cultivated. This Not Sewerable agricultural designation only applies to areas that are in King County Agricultural Production Districts (APD). It does not include Current use Taxation Parcels that are currently in agricultural use outside of APD. (see AGY in Sewerable). Farmhouses and buildings related to the processing of farm products, which may be connected to the sanitary sewer system are considered sewered
C	Cemetery	Portions of cemeteries that are not sewered. Developed portions of cemeteries, such as administration buildings, that are connected to the sanitary sewer system are considered sewered
FY	Freeway	Transportation corridors and associated right of way of major freeways and highways
G	Golf Course	Portions of golf courses that are not sewered. Clubhouses, restaurants, and other buildings that are connected to the sanitary sewer system are considered sewered
P	Private Park	Open space that is not likely subject to further development that is not publicly owned. This includes common areas associated with plats, multifamily complexes, and other commercial developments. These areas often have other constraints to development that might otherwise prevent them from being developed. In the case of multifamily and commercial development, the portions of the parcels connected to the sanitary sewer system are considered sewered.
PP	Public Park	Public parks and public open space identified by King County Assessor's information. Includes publicly owned parcels that are not developed such as water tower areas. Developed portions associated with restrooms and other buildings connected to the sanitary sewer system are considered sewered.

PR	Park & Ride	Publicly owned Park & Ride lots on separate parcels.
R	Recreational	Visually discernable recreational facilities including baseball diamonds, football fields, running tracks, tennis courts, etc. associated with public schools
RUR	Rural Areas	Areas on the Rural side of the Urban Growth Boundary (UGB). There are some minor exceptions to this rule due to permitted uses and sewer service provided prior to the establishment of the UGB.
RD	Retention / Detention Ponds	Retention / Detention Ponds. Stormwater control facilities identified by air photo and/or King County Assessors Data.
SB	Stream Buffer	Undeveloped areas adjacent to stream corridors. Varies with stream classification.
SS SS (cont.)	Steep Slopes Steep Slopes	Undeveloped areas having an average slope of 40 % or greater over 10-ft. of elevation, as determined using the steep slope coverage generated by WTD GIS. The WTD GIS staff used USGS maps at 20 ft contours along with Digital Elevation Model (DEM) coverages to create the steep slopes coverage. The 40% slope over 10 feet of elevation is the King County Sensitive Areas Standard for steep slopes. Some of these steep slope sensitive areas are included in other unsewerable areas such as parks and public parks and they have note be noted. Areas that are developed (D) or sewered (S) and lie within the SS coverage are assigned their respective code, D or S.
W	Water Body	Freshwater lakes, estuaries, lakes, and the lower portions of rivers wide enough to have been included in the County's Water Body coverage. Edge of the water body is considered to be the King county Shorelines coverage. This coverage may not follow parcel lines or the image of the waters edge in the aerial photo.
WF	Wetland/Floodpl ains	Undeveloped parcels in wetlands and floodplains as designated in King County GIS coverages used for this project.
Z	Parcels that are not sewerable but are not covered by the preceding definitions	Includes limited access publicly and privately owned parcels (SPU, Railroad Right of Way, etc.)

†Not sewered areas that are potentially sewerable can be coded as U, D, or Y. U and D polygons indicate whether there is any current development on the property. However, in some cases Y was used to reduce the effort required to delineate the differences between developed and undeveloped areas that are not sewered.

Appendix A4

Model Calibration

Appendix A4

Model Calibration

A4.1 Model Calibration

Calibration is used for nearly every kind of scientific modeling. Physically based models generally have some parameters that can be directly measured and others that cannot. During calibration, the values of non-measurable parameters are adjusted to satisfy the input/output relationship of the modeled system. This is accomplished by running the model using incremental iterations of values for one or more of the unknown parameters. Model calibration entailed adjusting the model parameters that control the magnitude and shape of simulated I/I flows. The outputs from successive model iterations were compared with measured values for the output parameters (such as flow, for a hydrologic model). When the modeled output closely and consistently matches the measured output, the model is considered calibrated.

The procedure for selecting parameter values to calibrate each flow components is complex. It requires a detailed understanding of the relationship between parameter values defined in MOUSE and the resulting simulated flow response. The Danish Hydraulic Institute developed MOUSE, or Modeling of Urban Sewers, for continuous simulation of rainfall-dependent I/I and for quantifying the I/I entering the sewer system basins. The calibration procedure typically begins by first defining the less variable components of flow, such as dry weather flow. Therefore, the initial steps of calibration involve comparing and calibrating model simulations to records collected during periods of dry weather. After dry weather calibration is completed, the effort focuses on matching simulation results to recorded wet weather flows. In general, the procedure involves targeting particular periods of the observed flow record to first match hydrograph volume, then matching peak flow and shape.

A4.1.1 Calibration Flow Time Series

MOUSE model “runs” (a run is defined as a single iteration of model calculations, representing a single parameter combination) is compared to the collected flow data. The flow data is collected at several monitoring sites and generally can be directly compared with modeling results for various basins. Sometimes, the calibration process for a basin is based upon the addition or subtraction of data between two or more different meters.

Subtraction and addition is completed by comparing upstream and downstream measured flow hydrographs. Flow travel time lags are corrected for as well as any other effects that might inhibit the subtraction. The final subtracted data is averaged over a 60-minute moving interval. Note that when calibration relies on addition or subtraction of data, the data is considered valid only for time periods when valid data was collected at all required meters.

A4.1.2 Dry Weather Calibration

The first step in the calibration process for each model basin is to match simulated flows with flows measured during dry weather. The dry weather flows measured at the beginning of each monitoring period are used to define and calibrate dry weather flow input into the model. Dry weather flows are represented in MOUSE using three components (see Figure A4-1 for additional detail):

1. The daily diurnal pattern above the daily minimum flow
2. The portion of the daily minimum flow estimated to be wastewater (the remaining flow below the daily minimum flow was assumed to be base infiltration)

The portion of the daily minimum flow estimated to be dry weather infiltration (base infiltration)

To calibrate each basin to existing conditions, the amount of dry weather flow is derived from the available measured flow data. King County had monitoring data available from dry periods, so it was not necessary to use population to determine the wastewater contribution in each basin (population can provide an estimate of the wastewater contribution in the absence of flow data collected over dry periods).

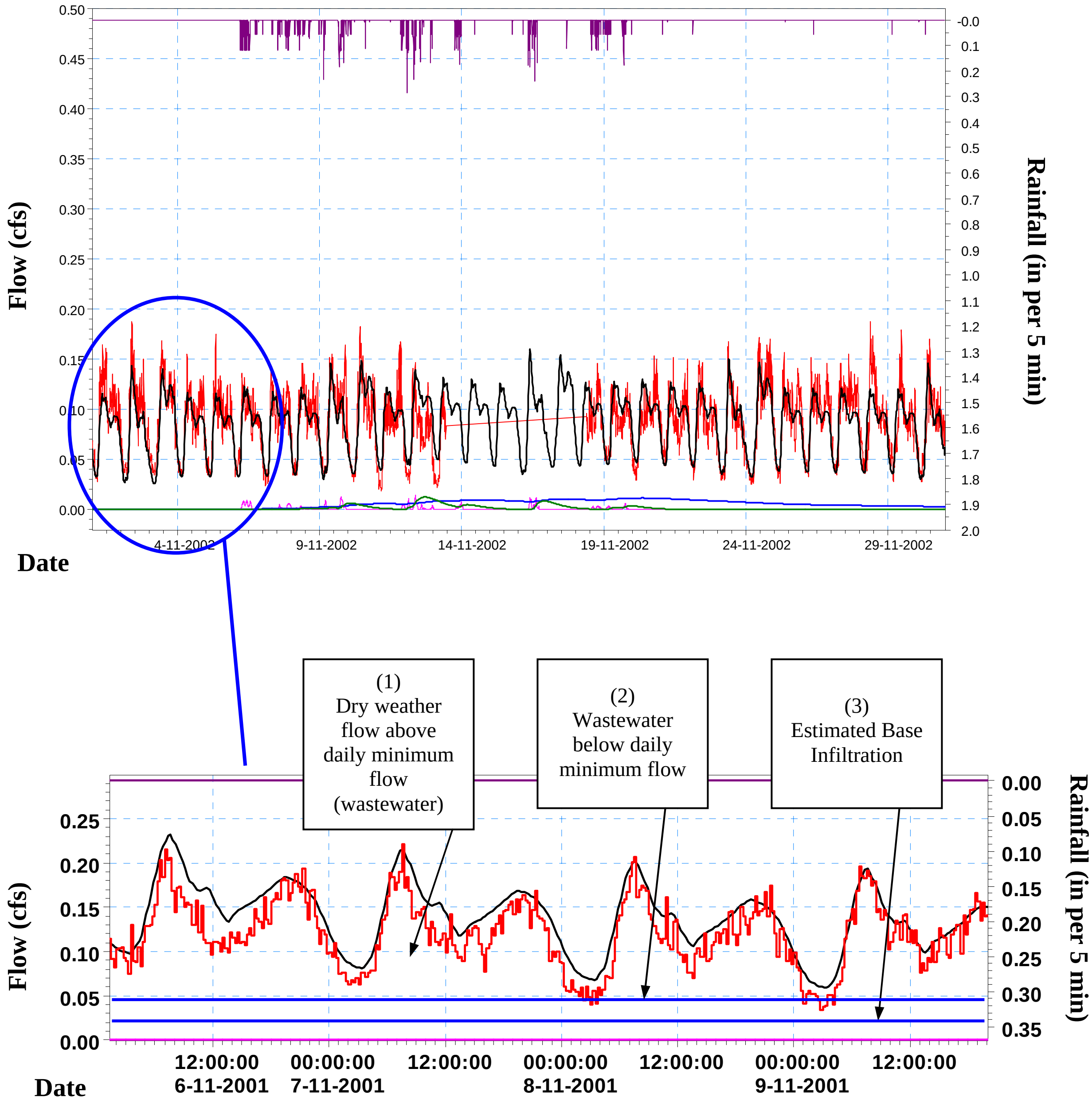


Figure A4-1. Dry Weather Flow Calibration

A4.1.3 Wet Weather Calibration

MOUSE represents wet weather I/I as three distinct responses: fast response, rapid infiltration, and slow infiltration. During the calibration process, each wet weather flow component is “tuned” (partially calibrated) individually in order (from the slow infiltration response to the fast response). Then an overall final tuning is done.

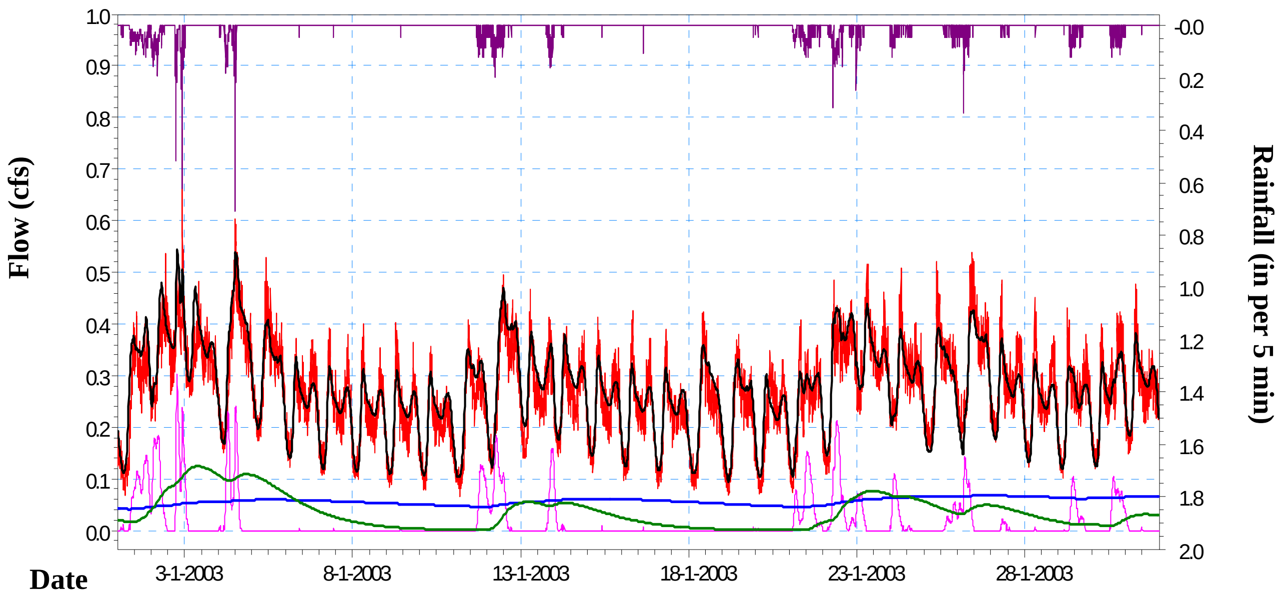
Tuning for the slow infiltration response is done by matching the diurnal dry weather flow pattern to the flow data before and after storm events as well as at the end of the monitoring season. If the slow infiltration response component is adjusted correctly, the dry weather flow pattern matches the flow data at the higher flow around the storm events. This approach is a way of separating out the component into flows that are primarily dependent on the addition of the slow infiltration component.

Tuning for the rapid infiltration component is done by matching storm event volumes and shapes with special attention to matching the flow recession of the storm events. The rapid infiltration component is primarily responsible for the recession limb of the storm event. Measured flow responses to all storms are used for calibration; however, it is typically not possible to match simulated flows to measured flow responses for all storms. In these cases, more emphasis is placed on matching flow responses to large, rather than small storms.

The last component to be tuned is the fast response component. The fast response component is tuned to match storm peaks. With regard to shape and peak, this effort involves fine-tuning the rapid infiltration response. Large storms are matched at the cost of smaller storms when there are inconsistencies.

After all components are tuned, calibration is finalized by adjusting all components together until the best model-to-flow data “fit” is achieved. Reduced emphasis is placed on periods with unreliable or inconsistent diurnal wastewater flow patterns (such as holidays). Figure A4-2 presents a plot of simulated flow (black) versus measured flow (red). Rainfall (purple) is included on the reverse second Y-axis for reference. Also included for reference are the wet weather I/I components: fast response (magenta), rapid infiltration (green), and slow infiltration (blue).

The calibration process is based on the monitored flow data. The confidence in final model parameter combinations decreases when large amounts of data are missing or not collected.



Legend: Measured Flow, Measured Rainfall, Total Simulated Flow, Fast Response Component, Slow Infiltration, Rapid Infiltration

Date Format (dd-mm-yyyy)

Figure A4-2. Model Calibration Example

A4.2 Estimated 20-Year Peak Flows

King County has adopted a 20-year flow capacity standard for conveyance facilities that transport wastewater from local agencies to County treatment plants. This means 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 King County capacity standards, the difference in the 20-year flow established for pre-rehabilitation versus post-rehabilitation is used to estimate rehabilitation effectiveness.

To estimate the benefits of I/I reduction, it is also necessary to estimate reduction in the 20-year flow achieved through system rehabilitation. It is unlikely that an event as infrequent as the 20-year flow will be measured during a short monitoring period; therefore, alternative methods were developed to estimate the 20-year flow. Many traditional methods, such as the “design storm approach,” equate rainfall probability to flow probability. These methods become unreliable when flow of a given magnitude can result from a range of rainfall events. As antecedent conditions become more significant in determining flow response, it becomes increasingly difficult to correlate flow to a single rainfall event. The design storm approach lacks the ability to account for varying geographic coverage, antecedent conditions, or impacts from successive rainfall events, all of which are common in this region. An additional consideration is the sensitivity of flows resulting from rainfall received over successive days, weeks, or even months.

The method used to estimate the 20-year 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 describing each basin were adjusted to represent the processes that transform rainfall to infiltration and inflow. The model can then be 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 accounts for the effects of antecedent conditions.

A4.2.1 20-Year I/I Flow Estimation Procedure

After the hydrologic model for each basin is calibrated, it is simulated with a 60-year extended time series (ETS) of precipitation as input. The ETS were developed to facilitate application of continuous simulation hydrology despite variability of mean annual precipitation and infrequent rainfall event volumes throughout the study area. The ETS applicable to the King County study area were developed by adjusting the 60-year SeaTac rainfall record to match the storm statistics of the time series records at over 50 precipitation gauges located in the lowlands of western Washington. More specifically, a series of statistical scaling functions were used rather than a single scaling factor. The scaling functions provide for scaling rainfall amounts at the 2-hour, 6-hour, 24-hour, 72-hour, 10-day, 30-day, 90-day, and annual durations.

The 60-year simulation produces a time series of flows at the basin outlet. This 60-year flow time series can be used to determine flow frequency, which includes estimating the 20-year peak I/I flow from each model basin. The procedure for estimating the 20-year peak I/I flow can be summarized in the following steps:

1. Develop and calibrate a basin model using rainfall and flow data measured in the basin.
2. Simulate flow response with the calibrated model using the 60-year extended time series (ETS) of precipitation as input.
3. Extract, rank, and plot the simulated peak I/I flows.
4. Estimate the 20-year I/I flow from the plot of peak flows.

The ETS simulation produces 60 years of simulated flows at the basin outlet. From this information, a plot can be made of peak flow magnitude versus return period such as the one shown in Figure A4-3. A best-fit curve is used to interpolate between the plotted points with a return period greater than 1 year. The estimated 20-year flow was determined by selecting the flow from the plotted best-fit curve with a return period of 20 years.

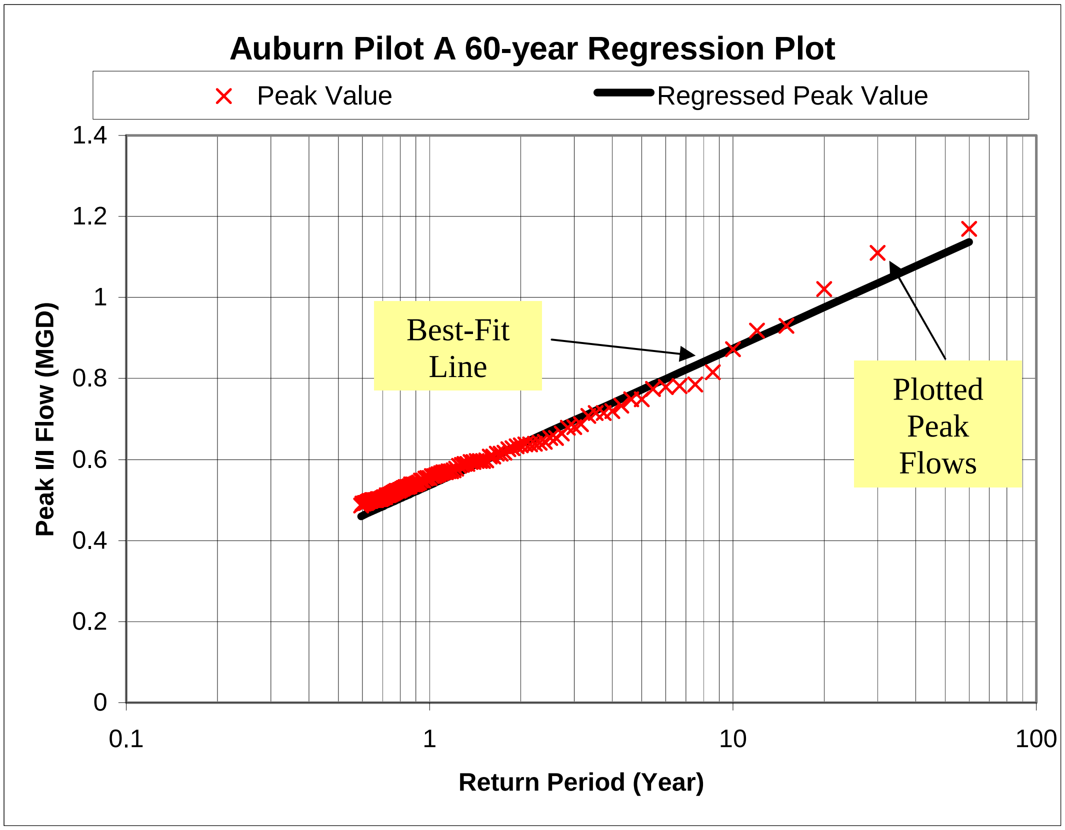


Figure A4-3. Assigning Return Intervals to Peak Simulated Flows

This process relies on several key assumptions. The ETS were derived using the SeaTac rainfall record, which is the longest continuous record of rainfall data in the eastern Puget Sound lowlands. It was assumed to be representative of rainfall patterns likely to occur in the service area, after adjustments were made to account for annual and peak rainfall differences throughout the region. Another key assumption is that a calibrated model can simulate flow response from any rainfall time series. Representation of multiple flow components and calibration to varied conditions provides a reasonable basis for such an extrapolation assuming that the events calibrated to are large enough to be able to project out to the 20-year event.

Appendix A5

Assumptions for Regional I/I Control Program

Appendix A5

Assumptions for Regional I/I Control Program

Both planning and I/I reduction assumptions were developed for I/I modeling and cost effectiveness analysis efforts. The planning assumptions are needed to determine capital conveyance and treatment facilities capacity improvements in the absence of any I/I reduction projects. Certain I/I reduction assumptions are needed to determine what I/I reduction projects are cost effective.

The E&P Subcommittee purposely wanted to be cautious in their assumptions and therefore selected an approach to assumptions that would not overestimate the capital facility and I/I reduction project benefits or underestimate the I/I reduction project costs.

The following sections of this appendix detail both the planning and I/I reduction assumptions followed by a summary table (Table A5-1) of chosen assumptions.

A5.1 I/I Planning Assumptions

Planning assumptions are necessary to extrapolate from existing conditions to maximum sewer system build-out. These assumptions are used to model future facility needs, including size and timing of new sewer system components. The assumptions and hydraulic modeling also provide a foundation for the I/I reduction cost effectiveness analysis. King County and the Metropolitan Water Pollution Abatement Advisory Committee (MWPAAC) Engineering and Planning (E&P)

Subcommittee collaborated on formulating the planning assumptions, with the intention that the assumptions:

- Be reasonable and realistic
- Help avoid under-building of sewer facilities
- Help minimize or avoid over-building of sewer facilities
- Lead to facilities that meet the Growth Management Act requirement that the regional system be able to convey wastewater flows from each local agency without overflow when the 20-year flow events occur.

A5.1.1 Design Factors

The County and the Earth Tech Team elected to use the peak sanitary sewer flow that can be expected once every 20 years as the modeling flow for sizing capital facilities and costs. A "design storm" approach was considered but rejected because building a system based solely on the amount of rain from a 20-year storm does not take into account the antecedent moisture conditions. Antecedent moisture is the buildup of groundwater over time that affects total I/I during a particular storm event. For example, antecedent moisture conditions can lead to such high groundwater levels in this region that a rainfall event of 1.3 inches can result in a system flow equivalent to a rainfall event of 1.9 inches.

In March 2004 the County and local agencies, via the E&P Subcommittee, agreed on a design flow of 20-year peak flow plus a 5-percent safety factor. The 20-year peak flow is based on the statistical analysis of 60 years of peak rainfall data from Sea-Tac airport.

A5.1.2 Population Growth Rates

The I/I control program proposed for a maximum sewer system service area population is a straight line extrapolation of the most recent population data and projections from the Puget Sound Regional Council (PSRC). This "saturation" population is projected to occur by 2050. For a residential population, the approximate saturation population is 1,500,000; for commercial, it is 800,000; for industrial, it is 100,000.

In considering the population assumption, the County and E&P Subcommittee discussed several related issues such as urban growth boundaries, traffic zones, and densification.

The County and local agencies, via the E&P Subcommittee, agreed to use PSRC forecasts through 2030 and apply a straight line population projection through 2050.

A5.1.3 Water Conservation

The Regional Wastewater Services Plan (RWSP) anticipated the following consumption of water by different categories:

- Residential: 60 gallons per capita per day (gpcd)
- Commercial: 35 gallons per employee per day (gped)
- Industrial: 75 gped

Water conservation efforts in the region will reduce wastewater flows, so this reduction in flows should be accounted for in the modeling for capital facility needs. These conservation efforts led to lower water usage in the year 2000 than the RWSP forecasts, as evident in the actual water consumption in 2000:

- Residential: 56 gpcd in Seattle and 66 gpcd outside Seattle
- Commercial: 33 gped
- Industrial: 55 gped

The most recent consumption data (2003) shows additional reductions:

- Residential: 52.1 gpcd in Seattle and 62.4 gpcd outside Seattle
- Commercial: 32.4 gped in Seattle and 30 to 33 gped outside Seattle
- Industrial: not available

After discussion, the E&P Subcommittee and the County agreed to use a water conservation planning assumption of a 10-percent reduction in per day consumption by 2010, with no additional reduction thereafter. Water consumption projections are shown in Table A5-1.

Table A5-1. Projected Water Consumption

Type of Consumption	2000 Gallons-per-day Rate	2010 and Beyond
Residential (Seattle)	56	50
Residential (non-Seattle)	66	60
Commercial	33	30
Industrial	55	50

A5.1.4 Degradation

Degradation is the slow change in condition of the sewer collection system that allows an increase in I/I flows. Degradation is due to cracks in the pipe, pulled joints, connections at manholes, construction damage, and/or traffic damage to manholes, etc.

There is little data documenting how fast and how much degradation occurs in a collection system.

The RWSP assumes that I/I flow will increase by 30 percent from 1990 to 2020 due to degradation. For the revised flow predictions with the MOUSE™ (modeling of urban sewers) model, the Earth Tech Team assumed that degradation from 2000 would be 7 percent per decade, with a limit of 28 percent over a 40-year period. For example, if a specific basin has I/I in 2000 of 1,100 gallons per acre per day (gpad), after 10 years it will increase 7 percent to 1,177 gpad.

New sewer systems should degrade less than old systems; thus, degradation is a percentage of the existing I/I. Since a newer system has lower I/I than an older one with respect to flow, it has lower degradation. For example, a newer system may have 1,000 gpad of I/I while an older one may have 10,000 gpad of I/I. Seven percent of 1,000 gpad is 70 gpad, whereas 7 percent of 10,000 gpad is 700 gpad. Using a fixed percentage acknowledges that newer systems degrade less (on a total I/I basis) than older leakier systems.

The County and E&P Subcommittee agreed that no matter what degradation assumption is used to model facility needs, future system monitoring will continue, to ensure facilities are not built sooner than needed.

The County and E&P Subcommittee agreed on a planning assumption of 7 percent degradation per decade starting from 2000 up to 28 percent for existing pipe. For new construction, the degradation assumption of 7 percent per decade will start after the date of construction, with a maximum of 28 percent.

A5.1.5 Septic Conversion

The number and rate at which septic systems are converted to sewered areas impacts system flows and facility needs. As of 2000, approximately 43,000 houses in the regional wastewater service area were estimated to be on septic systems. These are located primarily in the northern, eastern, and southern edges of the County’s service area.

The urban growth boundary restricts sewer services to developments within the urban growth area. As the urban growth area’s population grows, land values rise. This leads to redevelopment of areas presently served by septic systems. Many of the parcels served by septic systems are larger lots that can be subdivided for further development and converted from septic to sewer.

Other information on the service area includes:

- Total developable parcels: 300,500
- Total sewered parcels: 246,500
- Vacant developable parcels: 11,000

The RWSP projected that 100 percent of the sewerable area will be converted from septic systems by 2020. Several local agency representatives were doubtful that 100-percent conversion would be possible by that date or even by 2030.

The County and E&P Subcommittee agreed on a planning assumption that 90 percent of the area with potential for sewerage as of 2000 will be sewered by 2030 and that 100 percent of this area will be sewered by 2050.

A5.1.6 New System I/I Allowance

Regardless of how well a collection system is constructed, I/I can leak into the system. Historically, an allowance of 1,100 gpad was included in the design flow for both the conveyance and treatment of sewage.

The amount of I/I leakage into the regional system from new sewer connections, sewer mains, manholes, and other facilities impacts system flows and facility needs. Flow monitoring during the wet seasons of 2001/2002 and 2002/2003 showed that the measured amount of peak hourly I/I found in new systems ranges from a low of 270 gpad to 11,200 gpad. Several new systems had less than 800 gpad of I/I.

In contrast, the RWSP assumed that new systems have I/I levels similar to existing systems in 1999 (the rates for those systems ranged from 1,600 gpad to 4,100 gpad). The average I/I for the overall existing system in 2004 was 3,600 gpad.

The County and E&P Subcommittee agreed on an assumption of 1,500 gpad for new system I/I, recognizing that 7-percent degradation per decade increase the I/I to approximately 2,000 gpad after 4 decades.

A5.1.7 Uncertainties Affecting Facility Sizing

Safety Factors

It is common practice and sound engineering judgment to add a contingency or safety factor for sizing facilities to handle unforeseen circumstances. For the regional sewer system, this applies to pipes, pump stations, and treatment plants. Adding a contingency factor allows the system to accommodate higher peak flows without overflows or other unwanted consequences.

Caution must be exercised when using uncertain factors. It is common to include "safety factors" in individual planning components; when these are combined, it can overstate the uncertainties. The increase for a 25-percent contingency factor in flow is roughly a 10-percent increase in cost.

The County and E&P Subcommittee agreed to use a safety factor of 25 percent of additional capacity when sizing facilities. Below are several factors that were considered in using the 25-percent safety factor.

Existing Peak Flow Estimates

An uncertainty that can affect facility sizing needs is the potential for inaccuracy in estimating existing peak flow from monitored data. Due to variances in rainfall monitoring, flow monitoring, and modeling, it is not always possible to predict peak flows with a high level of certainty. While models are calibrated using the best information and technology available, the peak flows that serve as the basis for facility sizing are estimates and are not perfectly accurate.

Potential for Sewering Outside Urban Growth Area

Sewers are required in urban growth areas and these areas are the source of wastewater system flows. However, sewers are needed, and built, outside urban growth area for environmental and/or public health reasons. This can lead to increased peak flows.

"Four to One" Policy for Development along Urban Growth Boundary

Chapter 3 of the County's *Comprehensive Plan* contains a "Four to One" development policy along the Urban Growth Boundary. This policy states that 1 acre of Rural Area land may be added to a city's Urban Growth Area in exchange for a dedication to the County of 4 acres of permanent open space. It is not known how this policy impacts peak flows.

Economic Changes

The local economy represents another possible impact on peak flows, since economic surges tend to bring new industries, companies, and population growth, all of which increase flows in the regional system.

Climatic Changes

Global climate change may impact the frequency and severity of rainstorms in the future. In light of this possibility, prudence suggests an uncertainty factor be applied for the design of facilities so they can handle peak flows.

A5.2 I/I Reduction Assumptions

To determine whether or not a proposed I/I project is cost effective compared to building a new capital facility, specific costs of I/I reduction must be delineated. To this end, the County and local agencies discussed and agreed on assumptions related to I/I reduction in the spring of 2004. The assumptions included costs of various I/I reduction techniques, the percent I/I removal of each technique, and the percent of a given basin that requires rehabilitation.

A5.2.1 I/I Reduction Costs

The pilot projects provided total and average costs for different categories of expenditures for rehabilitation of various system components. Using the pilot project figures, the Earth Tech Team and the County proposed cost assumptions for pipe bursting and cured-in-place pipe (CIPP) rehabilitation of sewer mains, manholes, laterals, and side sewers.

Local agency representatives thought these cost assumptions were low. The E&P Subcommittee and the County agreed by consensus on the following costs for I/I removal. These costs will be used in the cost effectiveness analysis.

- Sewer main rehabilitation: $110 per lineal foot
- Direct disconnect: $3,000 each
- Manhole rehabilitation: $3,600 each
  (NOTE: consider life expectancy in cost effectiveness analysis)
- Lateral rehabilitation: $3,900 each
  (NOTE: based on 1 per lot; size-on-size)
- Side sewer rehabilitation: $3,500 each
- Lateral and side sewer rehab: $6,800 each

As I/I reduction project experience provides additional cost information, these figures will be revisited and revised if warranted.

A5.2.2 Percent Basin Rehabilitated and Percent Reduction

In addition to cost estimates for various I/I rehabilitation techniques, other assumptions are needed to develop cost estimates for I/I reduction projects for cost effectiveness analysis. These include:

- Percent of a basin to be rehabilitated, for example, the number of feet of sewer pipe (sewer main, lateral, or side sewer) or the number of manholes or direct disconnects in a given I/I project
- How much I/I would be removed by each technique

The County and the Earth Tech Team suggested assumptions for these variables to the E&P Subcommittee in the spring of 2004. The development and discussion of these elements was centered on the knowledge gained from the pilot projects. For example, while it may be likely that more than 4 percent of the houses in a model basin could be illicitly connected to the local agency's system, it is not always possible to identify these and, after they are identified, it is not always possible to disconnect them.

As with cost estimating, the E&P Subcommittee and County opted to approve conservative estimates when in doubt. This was intended to ensure that projects found to be cost effective in the first analysis would truly be cost effective.

Table A5-2 shows the percent basin rehabilitated and percent reduction assumptions agreed upon after discussion by the E&P Subcommittee.

Table A5-2. Percent Basin Rehabilitated and Percent I/I Reduction Assumptions

Technique	% Basin Rehabilitated – Final Assumption	% I/I Reduction – Final Assumption
Direct Disconnect (DD)[1]	4%	10%
Replace Everything + DD	95% Main 95% Manhole (MH) 95% Lateral/Side Sewer (Lat/SS) +4% DD	80%
Rehabilitate Public Portions of Basin + DD	50% Main 50% MH 50% Lat/SS +4% DD	40%
Private Property with Some Laterals + DD	50% Lat. & SS 45% SS only	60%

[1]This technique includes removal of roof gutter drains to the sanitary sewer system.

A5.2.3 Cost Estimating Factors

For the cost effectiveness analysis, estimates were needed for several other factors affecting project costs. These include construction cost factors such as utility conflicts, traffic control and dewatering as examples of costs listed in the County's Conveyance System Improvements (CSI) Program.

The County and the Earth Tech Team proposed these factors for the E&P Subcommittee's consideration. Table A5-3 shows the agreed upon cost estimating assumptions.

Table A5-3. Cost Estimating Assumptions

Cost Estimating Factors	Final Assumption
Allied Cost Factor	52% of estimated construction costs *(NOTE: May need to add mitigation costs for environmental or other concerns)*
Common Work Savings (For Total System Replacement)	Use 42% allied cost factor *(NOTE: May need to add mitigation costs for environmental or other concerns)*
Utility Conflicts	None (included in construction costs of pilot projects)
Traffic Control	None (if no traffic control needed): $0 Avg: $5/LF Main Heavy: $10/LF Main
Dewatering	Project-specific
Sales Tax	8.8% of construction estimate (or according to jurisdiction's tax rate)
Project Contingency	30% of construction estimate

A5.2.4 Financial Assumptions

To determine cost effectiveness, costs and benefits of I/I reduction projects must be compared with the costs of planned CSI and treatment plant projects. Because the proposed I/I reduction projects and the planned CSI and treatment plant projects occur over the next 50 years, the cost effectiveness analysis must account for the timing differences as well as the cost of the County's capital funding. Calculating the costs and benefits of an I/I removal project or capital improvement project involves predicting:

- The increase in the cost of goods and services over time, or the inflation rate; and
- The County's cost of capital, for example, bond rates, or the discount rate.

Using these two factors, the net present value of the costs and benefits can be calculated for each I/I reduction project and planned project. The net present value is the current value of the costs and benefits occurring in the future. The RWSP uses an inflation rate of 3 percent and a discount rate of 6 percent. NOTE: the importance of the discount and inflation figures lies not in the actual numerical level of each but in the difference between the two numbers.

Discount Rate

The discount rate used in the cost effectiveness analysis is the County's cost of capital based on the difference between the historical bond rates and inflation. The historical bond buyers' index from 1980 to 2003 was 7.33 percent, though it has been below 6 percent since 1996. Over the same period the average difference between inflation and the bond rates was 3.15 percent. The E&P Subcommittee requested that the County present two separate cost effective analyses of I/I removal projects using discount rates of 6 percent and 5.5 percent.

Inflation Rate

Inflation is the increase in the cost of goods and services over time. The average inflation rate from 1984 to 2003 was 3.12 percent. The County and the E&P Subcommittee agreed to use a 3-percent inflation rate for the cost effectiveness analyses.

Operations and Maintenance Cost Savings

The E&P Subcommittee also reviewed the regional collection system, pump station, and treatment system operation and maintenance costs. These are needed because the cost effectiveness analysis will use operation and maintenance cost savings in the analysis in addition to the capital costs.

For the cost effectiveness analysis, it was agreed to use the same assumptions that were used in the RWSP with certain specific updated information related to operation and maintenance of: new pipes, new pump stations, new sewage storage facilities, and treatment plants.

The specific numbers are included in the summary Table A5-4 below.

Summary of I/I Program Assumptions

The final planning assumptions are listed in Table A5-4.

Table A5-4. Final Assumptions

Subject	Final Assumption
Design flow	• 20-year peak flow + 5%, based on Sea-Tac 60-year rainfall record (the additional 5% is the factor to accommodate the difference between the best fit curve and the third-highest 20-year flow)
Future Population	• Puget Sound Regional Council (PSRC) forecast through 2030; apply straight line projection through 2050
Water conservation (base flow projections)	• 10% reduction by 2010; no additional reduction thereafter
Degradation	• Existing pipe: 7% per decade starting from 2000 up to 28% • New construction: 7% per decade starting after date of construction, up to 28%

Subject	Final Assumption
Septic conversion	• 90% of unsewered but sewerable area in 2000 sewered by 2030 • 100% sewered by 2050
New system I/I allowance	• 1,500 gallons per acre per day (gpad)
Sizing of facilities	• 25% safety factor (when sizing facilities, a safety factor of 25% of additional capacity will be used)
I/I reduction costs	• Sewer main rehabilitation: $110 per linear foot • Direct disconnect: $3,000 each • Manhole rehabilitation: $3,600 each (NOTE: consider life expectancy in cost effectiveness analysis) • Lateral rehabilitation: $3,900 each (NOTE: based on 1 per lot; size-on-size) • Side sewer rehabilitation: $3,500 each • Lateral and side sewer rehab: $6,800 each
Percent basin rehabilitated	• Direct disconnect (DD): 4% • Replace everything + DD: 95% sewer main, 95% manhole, 95% lateral/side (Lat/SS), Sewer (Lat/SS) + 4% DD • Rehabilitate public portions of basin + DD: 50% sewer main, 50% manhole, 50% Lat/SS + 4% DD • Private property with some laterals + DD: 50% Lat/SS, 45% SS only
Percent I/I reduction	• Direct disconnect (DD): 10% • Replace everything + DD: 80% • Rehabilitate public portions of basin + DD: 40% • Private property with some laterals + DD: 60%
Cost estimating factors	• Allied cost factor: 52% of estimated construction costs (NOTE: May need to add mitigation costs for environmental or other concerns) • Common work savings (for total system replacement): Use 42% allied cost factor *(NOTE: May need to add mitigation costs for environmental or other concerns)* • Utility conflicts: None (included in construction costs of pilot projects) • Traffic control: None (if no traffic control needed); Avg: $5/linear foot sewer main; Heavy: $10/linear foot sewer main • Dewatering: Project-specific

Subject	Final Assumption
	• Sales tax: 8.8% of construction estimate (or according to jurisdiction's tax rate) • Project contingency: 30% of construction estimate
Discount rate	• 6% and 5.5%
Inflation rate	• 3%
Operations and maintenance (O&M) analysis	Same methodology as the Regional Wastewater Service Plan (RWSP). Update the following numbers: • New pipes: $.15 per linear foot annually • New pump station: $4,104 *million gallons per day + $60,384 • New storage facility: $34,091 *million gallons + $4,546 • Treatment plant: $15,000 to $30,000 per million gallons per day of average annual flow reduction. Plant-specific. Covers energy and disinfection costs. * Reflected total O&M at the plants.