Lake Stevens/Catherine Creek

Watershed Management Plan

Prepared for:

Drainage Improvement District #8

City of Lake Stevens

June 1999

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EXECUTIVE SUMMARY

This watershed plan for the Catherine Creek and Lake Stevens Basins was prepared by Drainage District #8 in cooperation with the City of Lake Stevens and Snohomish County. This project was in part funded by the Washington Department of Ecology through the Centennial Clean Water Fund. The intent of this plan is to 1) provide a thorough analysis of the current conditions of streams within the Lake Stevens and Catherine Creek watersheds and 2) to identify structural and non-structural methods to mitigate the impact of land development on the aquatic environment. The primary focus is on water quality. However, since flooding impacts water quality and the aquatic environment the impacts of flooding on the aquatic environment is evaluated. The proposed listing of the Puget Sound Chinook salmon may impact the process and methods of land development in the future.

APPROACH

This plan synthesizes data from the State, the County, the City and the Drainage District. In addition to existing data, field data were collected regarding, water quality, fisheries and the hydraulic characteristics of streams. The field data were gathered for the purpose of calibrating the hydrologic and hydraulic models to past storm events, assessing the current water quality in the streams and estimating the current fisheries resources in the watershed.

RECOMMENDATIONS

The recommendations in this report are both non-structural and structural. Non-structural recommendations are both programmatic and regulatory. Structural recommendations involve the alteration of the environment through targeted construction.

NON-STRUCTURAL

1. Creation of Sensitive Lake Basin Standards - Phosphorus removal, modeled after Lake Sammamish.
2. Maintenance - All structures should be maintained so that they perform as designed. This includes the removal of accumulated sediment from detention ponds and catch basins as well as routine cleaning of filters.
3. Education - Educational programs should continue where possible. This includes flyers in the mail, videos or other programs for the schools, booths at Aquafest and coordination through the watershed keeper.
4. Increased Detention requirements - the current standards set forth in the Ecology and Snohomish County standards under predict the amount of detention required by a factor of 3 to 5. New standards should be enacted which increase detention. The new standards could be based upon into the regionally calibrated USGS HSPF model.

5. Land Acquisition - If land is bought and dedicated to public open space it ensures the preservation of the land in its natural state.
6. Lakefront Restoration - includes the restoration of the littoral portions of the lake, the nearshore areas. Restoration could be achieved by planting native emergent plant species between docks and boat launches to provide fish habitat and refuge.
7. Increased Buffer Requirements - outside the UGA buffer requirements should be increased to reflect the recent work indicating that 300 foot buffers are necessary to preserve the aquatic ecosystem.
8. Erosion Control – Increased enforcement at construction sites and the potential use of polymers to aid in soil stabilization and sediment removal from runoff.

STRUCTURAL

1. Regional Detention Facilities - these projects would require the installation of large regional detention facilities near the stream alignments in order to reduce the current peak flow in streams resulting from storm events.
2. Stream Habitat Restoration - projects have been identified which could increase the fisheries habitat by installing large woody debris in the stream channels. These logs would create hydraulic diversity and thus a varied habitat for fish.
3. Outlet Channel Realignment - The outlet channel used to flow out of Lake Stevens south of downtown Lake Stevens cross the current location of the outflow channel and return to Catherine Creek approximately where the outflow channel joins Catherine Creek. This project would reestablish the old realignment and create fisheries habitat in so reestablishing the alignment.
4. Inline Treatment – This project requires the installation of a stormwater treatment system at selected outfalls to reduce the pollutant loading to the outflow channel.
5. Habitat improvements – includes the redesign of stormwater systems to allow for the passage of fish.
6. Increase Lake Water Level – If water levels were increased in Lake Stevens in the spring, more water would potentially be available at the send of the summer and the early fall to augment flows in the outflow channel and Catherine Creek.

A combination of structural and non-structural projects could be funded with a stormwater utility rate of $2/month in addition to the cost allotted for maintenance.

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CHAPTER 1

INTRODUCTION

PLAN DEVELOPMENT

PURPOSE

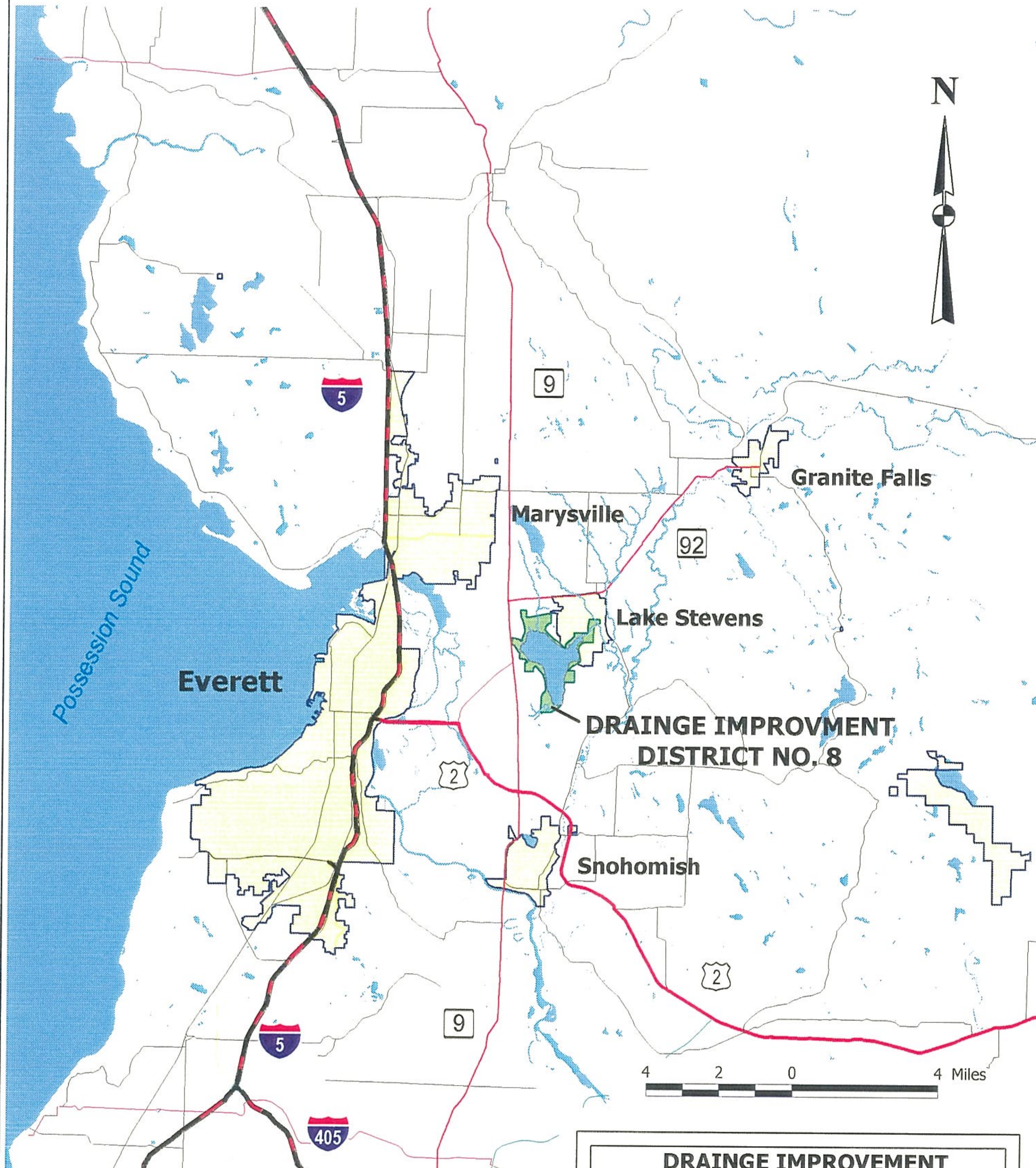
This plan is a comprehensive water quality basin plan for the Catherine Creek and Lake Stevens Basins. The intent of this plan is to identify structural and non-structural methods to mitigate the impact of development on the aquatic environment. The contractual stated purpose of this plan is to "...describe projects for treatment and streambank erosion protection for priority outfalls. When implemented, these projects would remove substantial pollutant loads to streams and lakes. In addition, non-structural measures will be recommended, including basin specific drainage design standards for treatment and runoff control Best Management Practices."

In recent years land development has increased in the area tributary to Lake Stevens and Catherine Creek. This development has impacted stormwater runoff. Probable impacts include:

- Loss of aquatic habitat due to increased sedimentation, loss of riparian habitat and decreased water quality.
- Decreased water quality due to increased pollutants in stormwater and altered thermal regime.
- Increased erosion due to increased peak flows during storm events.
- Increased flooding due to increased runoff during storm events.

Lake Stevens is located approximately five miles east of Everett in Snohomish County, Washington (See Figure 1-1). Lake Stevens is the largest recreational lake in Snohomish County with a surface area of approximately 1,060 acres and a volume of 67,863 acre-feet. As seen in figure 1-2, the lake is large for the size of its watershed. The lake watershed is 3,770 acres.

The head waters of Catherine Creek are Lake Cassidy. This lake is approximately 112 acres in size with a maximum depth of 18 feet. The Catherine Creek watershed is shown in figure 1-2 and, as measured from the confluence with the Little Pilchuck River, is 3,984 acres.



DRAINGE IMPROVEMENT DISTRICT NO. 8

Figure 1-1
Vicinity Map

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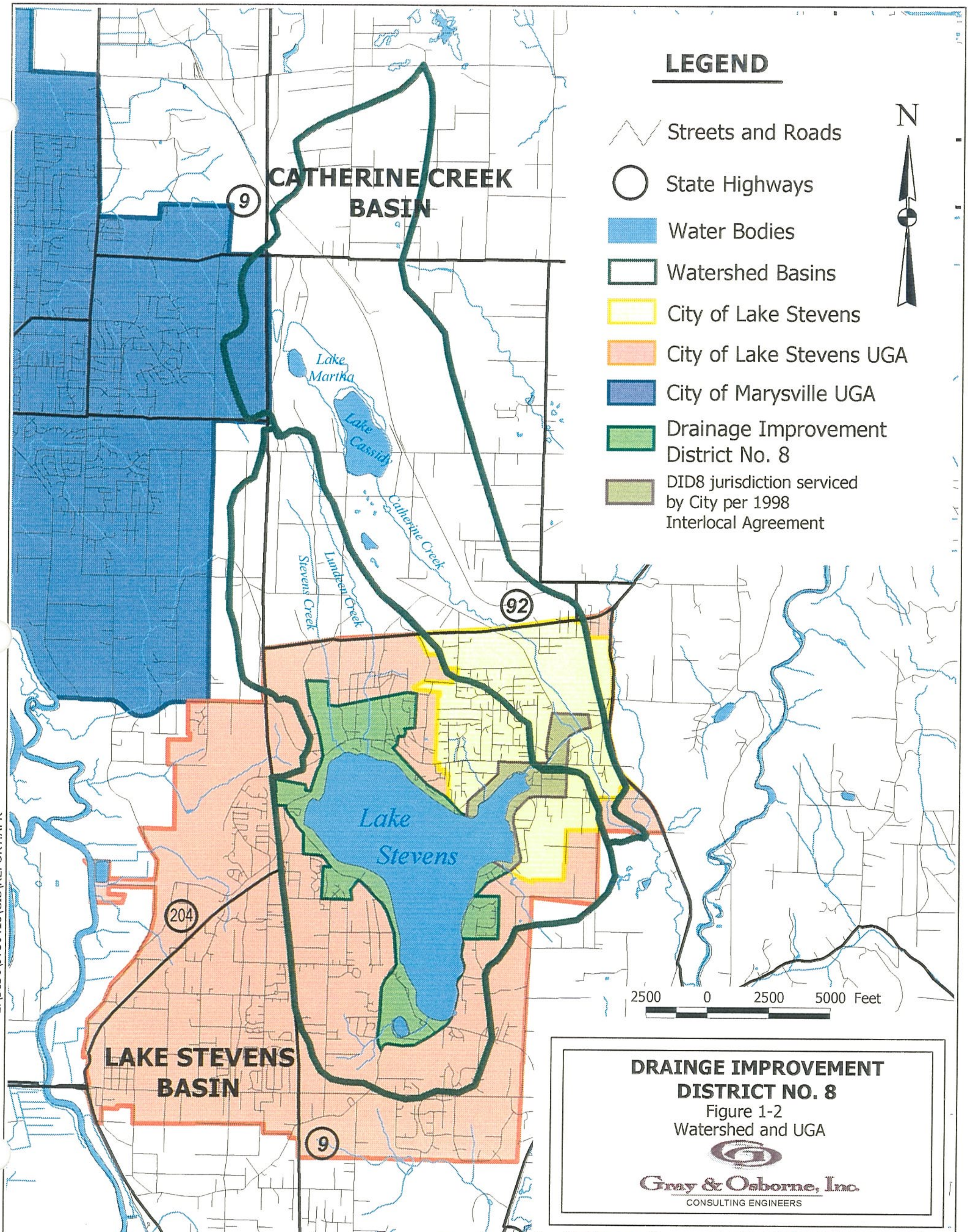

DRAINGE IMPROVEMENT DISTRICT NO. 8
Figure 1-2
Watershed and UGA

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BACKGROUND

This plan was developed utilizing funding from the Centennial Clean Water Fund in the Department of Ecology. In 1996, Snohomish County Drainage Improvement District #8 applied for and received a low interest loan from the Department of Ecology, Washington State Water Pollution Control Fund, to complete a basin plan on the Catherine Creek and Lake Stevens basins. In December of 1996, a contract was signed between the District and Ecology with a loan for $179,753 at 3.5 percent interest to cover 75 percent of the total cost of the project.

Lake Stevens and the Lake Stevens watershed has been the subject of much study (KCM, 1987; KCM, 1989; KCM, 1990; Reid Middleton, 1983; Snohomish County, 1991; and RW Beck, 1997). These studies and planing efforts were focused on improving the in-lake water quality, and improving the quality of storm water runoff. The portions of those studies, which focused on watershed projects to improve water quality and stream habitat, were reviewed as part of this study. The in-lake water quality studies culminated with the installation of the Lake Stevens aerator. In 1994, the City of Lake Stevens, Snohomish County and Drainage District #8 used a grant from the Washington Department of Ecology to install a hypolimnetic aerator in the Lake. The aerator was installed to improve water quality by increasing the oxygen content of the lower portions of the lake and thus reducing internal loading from the phosphorus rich bottom sediments.

The Lake Stevens area has been undergoing rapid growth in the recent past (Table 1-1). In 1995, under the Growth Management Act, the Lake Stevens Urban Growth Area (UGA) was established. Since then, the growth has been focused within the City of Lake Stevens and its UGA. Approximately 17 percent of the Catherine Creek watershed lies within the UGA while approximately 49 percent of the Lake Stevens watershed lies within the UGA (not including the lake itself).

TABLE 1-1

Population in the Lake Stevens and Catherine Creek Basins

Year	UGA Population[1]	City of Lake Stevens Population
1970	--	1,283
1980	--	1,660
1992	15,500	4,240
1997	21,000	5,241
2012[2]	35,800	8,771

1 Includes the area now currently within the UGA.

2 Projected based upon UGA Alternative 6 and 1994City of Lake Stevens Comprehensive Plan

The upper portions of both watersheds are outside the UGA and are relatively undeveloped. However, development is rapidly occurring and should the UGA for either the City of Lake Stevens or Marysville expand, development densities may increase within the basin.

The County is currently reviewing its long range plan for the Lake Stevens UGA. Recent development has occurred at a much more rapid rate than anticipated. The County in response to this rapid development has presented additional population density alternatives for the UGA. Ultimately, this growth will impact the water resources of the area and place additional stress on the natural system.

LAND DEVELOPMENT AND WATER QUALITY/HABITAT DEGRADATION

Land development creates impervious area in a watershed. As development increases rainwater increasingly flows overland as surface runoff rather than slowly infiltrating into the ground. This runoff increases the velocity of flow through streambeds, thereby causing potentially harmful erosion and habitat destruction downstream. A recent study of Puget Sound lowland streams by the University of Washington (May 1996) indicates that these processes begin to impact the rivers and stream when only five percent of the watershed is covered with impervious surfaces. May also found "...direct evidence that altered watershed hydrologic regime was the leading cause for the overall changes observed in instream physical habitat conditions." Increased volume and flow rates caused by surface water runoff can alter habitat by undercutting streambanks and removing vegetation. Loss of riparian vegetation removes an important source of stream temperature regulation, food sources, and nutrients for the aquatic environment.

Excessive channel erosion and sedimentation results in aquatic habitat degradation. Erosion can scour fish redds and undermine trees and brush which provide critical riparian habitat. Conversely, sedimentation can suffocate fish eggs and cause rivers to widen and become shallower. As rivers become wider and shallower, more water is exposed to the sunlight and the thermal regime of the river is altered. This assessment of the water quality in the Catherine Creek and Lake Stevens watersheds therefore includes not only pollutants and their probable sources, but also an assessment of the hydraulic and temperature regimes on the creeks and lakes and the impact on habitat.

The quality of surface water reflects the combination of the natural water quality, prior to development, and the physical and chemical impacts to the surface water from storm water runoff. Both the physical processes discussed above and the chemical constituents in storm water runoff affect the water quality in streams and lakes. "In urban runoff most pollutants occur as solids or are associated with soil or other natural particulates. This condition differs among the specific pollutants. For example, depending on overall chemical conditions, each metal differs in solubility. For instance, lead (Pb) is relatively insoluble, while zinc (ZN) is in solution form. The nutrients phosphorus (P) and nitrogen

(N) typically differ substantially from one sample to another in dissolved and particulate forms" (Horner et al., 1994). Pollutants in urban runoff will vary depending upon the land uses shown in Table 1-2.

TABLE 1-2

Urban Runoff Pollutant Sources

Pollutant Category Source	Solids	Nutrients	Pathogens	DO Demands	Metals	Oils	Synthetic Organics
Soil Erosion	X	X		X	X		
Cleared Vegetation	X	X		X			
Fertilizers		X					
Human Waste	X	X	X	X			
Animal Waste	X	X	X	X			
Vehicle Fuels and Fluids	X		X	X	X	X	
Fuel Combustion						X	
Vehicle Wear	X			X	X		
Industrial and Household Chemicals	X	X		X	X	X	X
Industrial Processes	X	X		X	X	X	X
Paints and Preservatives					X	X	
Pesticides				X	X	X	

Source: Horner et. al., 1994.

Flooding, and particularly increased frequency of flooding, provides obvious evidence of the effects of land use change on increased streamflow in the Catherine Creek and Lake Stevens Basins. Flooding occurs not only due to the increased flows in the creeks created from surface water runoff but also because marginal properties are increasingly being developed as the prime building sites are used up. Frequently those marginal properties are on floodplains.

MITIGATION OF WATER QUALITY AND AQUATIC HABITAT DEGRADATION, AND FLOODING

Land development and conversion are anticipated to continue, along with the associated impact on the hydraulic regime and aquatic environment. However, a combination of structural and non-structural measures, often termed Best Management Practices (BMPs) can be used to mitigate some of the impacts from existing and future land development. Non-structural measures may include increased regulatory requirements for stormwater quality and detention, changes in zoning or setback requirements, open space preservation, and public education. Structural measures may be projects such as regional detention facilities, water quality treatment facilities, or stream restoration projects. This plan takes these options into consideration as shown in the recommended alternatives presented in Chapter 7.

The impacts of the Endangered Species Act (ESA) on development is unknown at the current time. Chinook salmon was listed as a threatened species on March 16, 1999. Coho may be listed within two years. The ESA makes it unlawful to "take" any endangered animal. Within the context of ESA a "take" means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Generally storm water detention facilities, if designed according to the requirements of Ecology's *Stormwater Management Manual for the Puget Sound Basin*, do not fully mitigate the impacts of increased stormwater runoff from development (King County Surface Water Management, 1995). Thus a development may have an adverse impact on a stream and thus constitute a "take". The ESA (Section 11) also contains a provision allowing citizen suits to file third party law suits to prevent such a "take" and to compel any person or governmental entity to comply with the requirements of the ESA. Since Chinook spawn in lower Catherine Creek, below Hartford Drive, and Coho utilize the tributaries into Lake Stevens as well as Catherine Creek above Hartford Drive, the impact of the ESA could be large.

POLITICAL JURISDICTIONS IN THE STUDY AREA

Three political entities have jurisdiction in the Catherine Creek and Lake Stevens watersheds, Snohomish County, the City of Lake Stevens, and Drainage Improvement District #8 (See Figure 1-3, Table 1-3). While DID #8 is the principal grant recipient, it does not have control over the land use decisions that impact stormwater runoff and receiving waters. The City of Lake Stevens is responsible for land use and stormwater drainage within its corporate limits. The County is responsible for stormwater runoff and land use decisions in all remaining area in the watersheds, including Lake Cassidy and the upper Catherine Creek watershed areas. Frequently the District is requested to comment on development which will impact drainage. However, the District cannot, except on rare occasions require changes to proposed stormwater designs. The District therefore cannot implement watershed solutions independently. Successful implementation of this Plan requires the involvement of all three of these agencies.

TABLE 1-3

Political Jurisdiction Area

Political Jurisdiction	Historical Area in Watershed (Acres)	1999 Interlocal Area in Watershed (Acres
Snohomish County	3,030	3,030
Drainage District 8	639	662
City of Lake Stevens	243	220
TOTAL	**3,912**	**3,912**

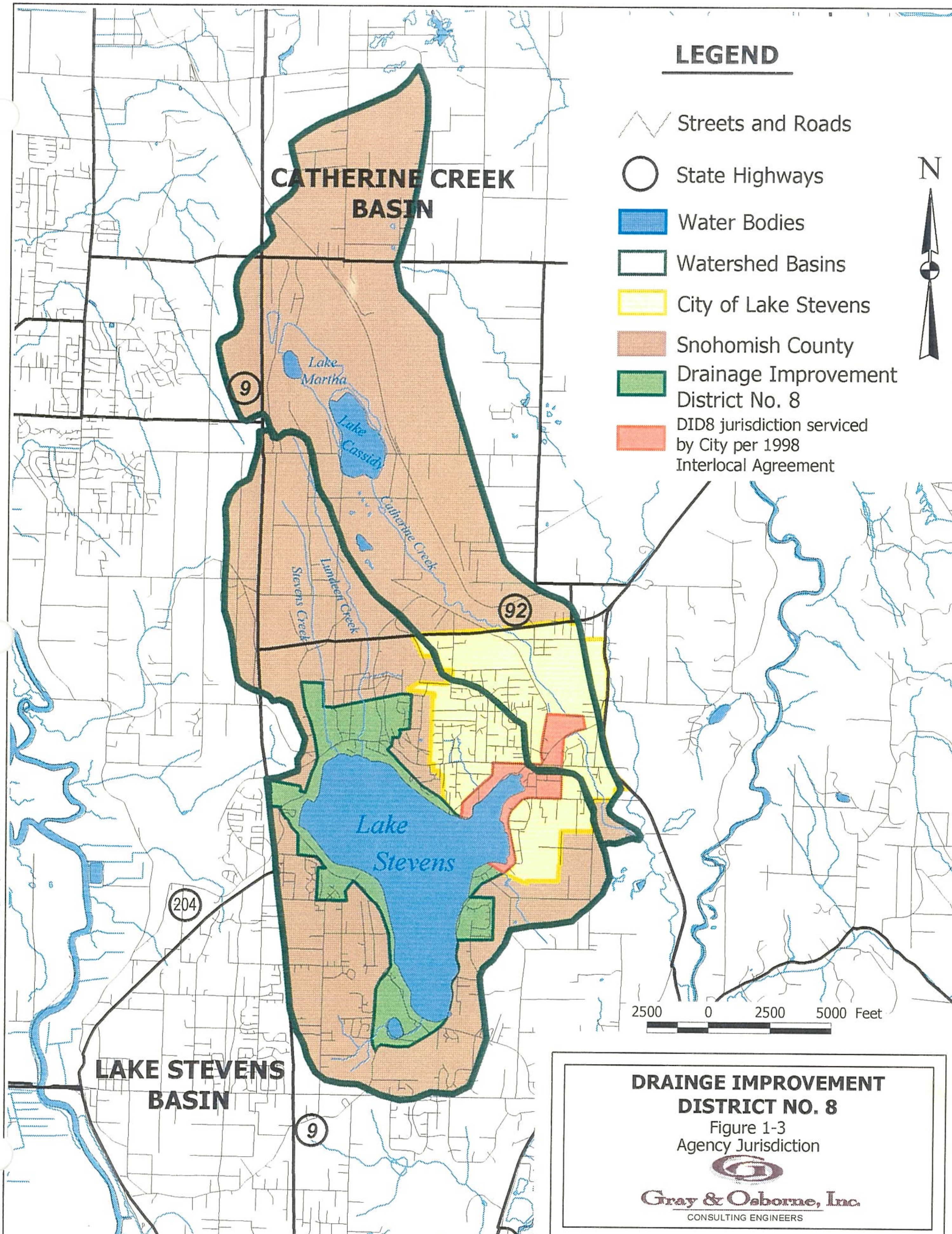

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Figure 1-3

Agency Jurisdiction

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A primary responsibility of the District is to maintain the level of Lake Stevens. This requires maintenance on the outflow channel as well as tributaries and storm drainage facilities discharging to the lake. Maintenance of the lake level reduces flooding in the Lake Stevens and lower Catherine Creek watersheds. A survey conducted by the District in 1993 indicated that the majority of those responding preferred the lake level to be within a range from 209.5 to 211.5 feet. Based upon this survey, this is the target elevation for the lake level.

The three agencies share responsibility for controlling stormwater pollution sources and creating potential solutions with a variety of stakeholders. Successful implementation of this comprehensive stormwater drainage plan requires the participation of the following stakeholders: Department of Ecology, Department of Fish and Wildlife, agriculture, developers, sportsmen, environmental groups, and private citizens.

PUBLIC INPUT

In recognition of the multiple stakeholders involved in activities impacting the Catherine Creek/Lake Stevens watersheds, the District has solicited public input for this Comprehensive Drainage Basin Plan. The District invited representatives from the following watershed stakeholders: City of Lake Stevens, Snohomish County, Washington Department of Fish and Wildlife, Washington Department of Ecology, Bass Anglers' Sportsman Society, Lake Stevens Sewer District, local developers, and watershed residents.

These stakeholders formed a Watershed Committee, which met quarterly with the project Technical Team (Gray and Osborne Engineering, AquaTerra Associates, and Resource Planning Associates) to provide guidance and input to the development of the final report. A total of five meetings were held.

PRIORITIES OF CONCERN (PROBLEM IDENTIFICATION)

Issues of concern were identified through the task force meetings. The final recommendations are an attempt to reflect back a synthesis of the issues of concern and potential solutions to the issues at hand. The recommendations revolve around the central question of "How can development be accommodated at a reasonable cost while mitigating increased flooding, and maintaining fisheries and fisheries habitat in the streams?"

The major issues which came out of the meetings are:

- Identify projects and improve the water quality discharging to the lake and streams.

- Improve area around the outflow channel and Catherine Creek to accommodate increased land use density while at the same time, reducing flood impacts.
- Identify projects to be undertaken to improve aquatic habitat.
- Develop programmatic solutions that could be invoked or adopted in order to ensure no net loss of aquatic habitat.

METHODOLOGY OF ANALYSIS

Potential solutions were identified through a systematic process. The steps involved:

- Gather sufficient field information to establish a baseline of the water quality.
- Gather sufficient field information to establish a baseline of the aquatic habitat.
- Develop a computer simulation hydraulic model which accurately portrayed the observed storm events and resulting stream flows in the watershed.
- Apply different land use scenarios to the computer model to assess the impacts of future land development on instream storm event flows.
- Assess the impact of potential future flows on the streams and habitat.
- Identify potential structural and non-structural methods to reduce or eliminate any adverse impacts.
- Identify projects to increase and improve aquatic habitat.
- Assess the cost of potential solutions.
- Assess the cost of not instituting new regulations or completing structural solutions.
- Select recommended alternatives based upon impact and cost.

CHAPTER 2

HISTORY AND PLANNING CONSIDERATIONS

HISTORY OF THE LAKE STEVENS AND CATHERINE CREEK BASINS

The following historical overview of the development of the Lake Stevens area is compiled from the *Lake Stevens Restoration Study* (1993) and the *History of Lake Stevens and Vicinity* (1957).

The Lake Stevens and Catherine Creek drainage basins have historically been important natural resource areas. Although the principle settlements of the Snohomish Indians were near present-day Everett and Mukilteo, the Snohomish established temporary camps along the Lake and its tributaries while fishing and hunting small game.

Natural resources also inspired the first permanent settlements around the lake. In 1886, J.E. Davis platted 160 acres along the east shore of the lake. By 1890 the homestead became known as "Ferry." The town later changed its name to Lake Stevens in honor of the first governor of Washington, Isaac I. Stevens. One year after Davis platted the area, Hartford was platted one mile to the northeast. The town consisted of a depot, shingle mill, school, services and a foundry.

Productive farmland and abundant forests helped the first settlers in these villages prosper. However, the economic success of the community was limited by its relative isolation. There were no railways, and the wet climate made wagon trails impassable much of the year. During rainy weather, the only transportation route out of town was a ferry along the Pilchuck River to the town of Snohomish. As logging progressed, timber operations were forced to search further away from the lake for timber supplies. Loggers and farmers also needed to look west to Everett and Marysville to market their products, making the need for transportation even more pronounced. These factors led to several attempts to establish rail lines westward to more populated areas and northward into the heavily-forested Stillaguamish River valley. In 1893, a rail line was completed between Hartford and the town of Monte Cristo in the mineral-rich Cascade foothills, and a planked road connected the town with Everett. In that same year, however, disastrous fires destroyed much of the town, including several homes, two hotels, the general store, and the post office. The railroad finally opened in 1895, creating a much needed resurgence in logging, sawmilling, and mining. High water and mudslides made rail operation difficult during the winter months, and the line was abandoned in 1936 after several different owners experienced financial losses.

Early twentieth century life in Lake Stevens and Hartford was strongly influenced by Benjamin Rucker. In 1905, Rucker built a railroad linking Lake Stevens and Hartford, facilitating the transport of raw timber from the Little Pilchuck River to the mills of Lake

Stevens. In 1907, the Rucker Brothers Timber Mill, located along the east shore of the lake, was opened and the cove on the east shore was used for rafting logs. This mill became known as the "world's largest sawmill", cutting timber by day and shingles by night.

Rucker Mill operated until 1925 when it was destroyed by fire. Although timber in the immediate vicinity of Lake Stevens was exhausted by about 1914, the timber industry continued to flourish by importing logs to local mills through the mid-1950s.

Rucker also was inspired by the prospect (and profits) of controlling the water supply for Marysville and Everett, he began digging a trench between Lake Stevens and the Little Pilchuck River. He envisioned using the Lake as a water supply reservoir, and had progressed as far as Catherine Creek before downstream residents along the Little Pilchuck River convinced the governor to halt Rucker's project (Figure 2-1). Rucker's outlet channel was widened in 1954 to eliminate winter high water which had plagued residents for several years. This widening was only marginally successful however as the area in the vicinity of the outflow channel has been subjected to flooding in the recent past.

Since the late 1950s, development has transformed the agricultural and recreational lands around Lake Stevens, creating a predominately residential character in the Catherine Creek and Lake Stevens watersheds. Improved roads, sanitary sewer facilities, and a generally more mobile population have accelerated this transformation within the last 30 years.

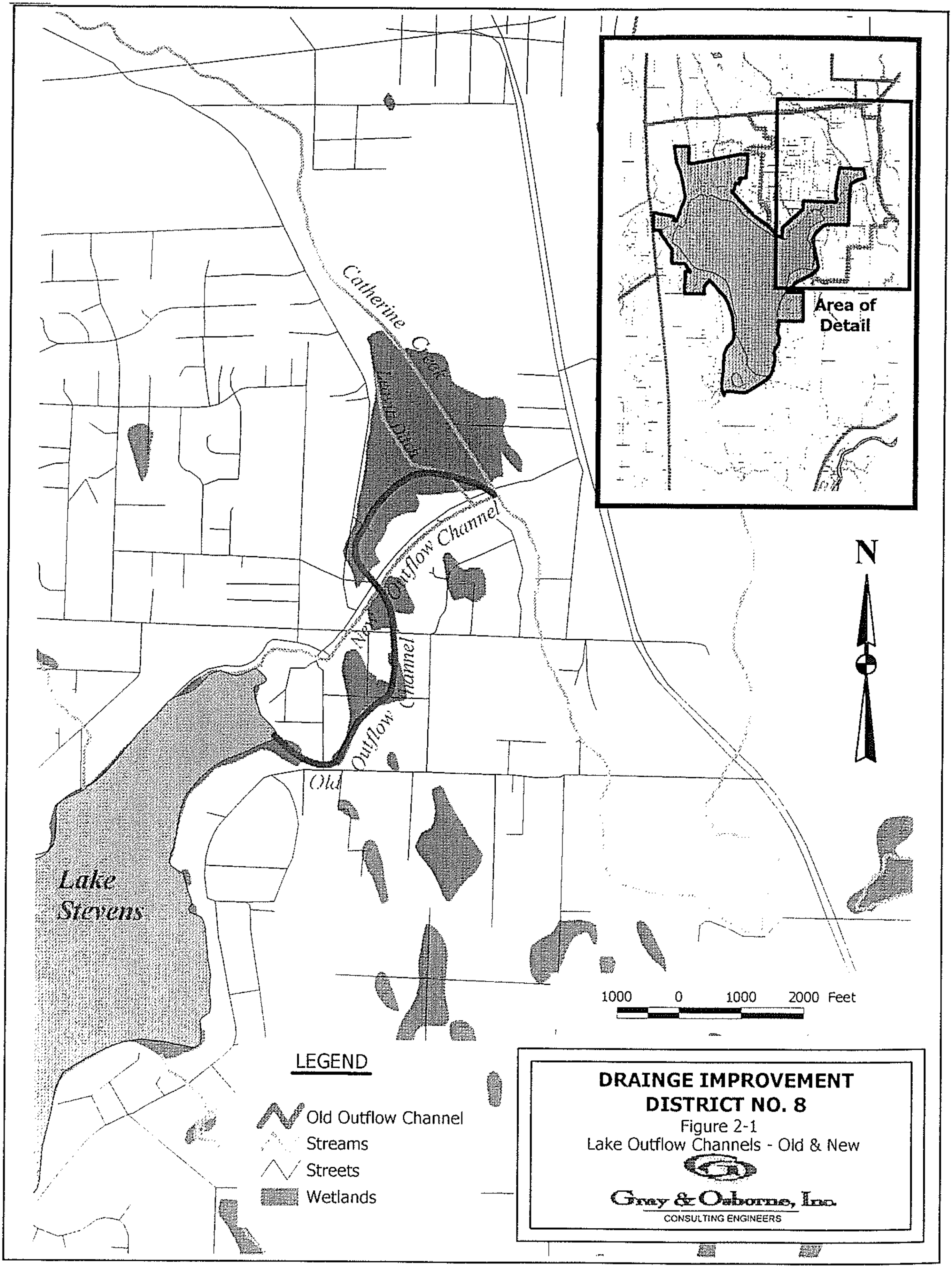
PRIOR WATER QUALITY RELATED WORK IN LAKE STEVENS

Several reports have been conducted in the Lake Stevens watershed. The focus of these studies was to protect the water quality in Lake Stevens. In general, the studies identified sources of pollutants to the lake and recommended projects to decrease the pollutant load.

1979 SNOHOMISH/LAKE STEVENS COMPREHENSIVE PLAN

The 1979 Snohomish/Lake Stevens Comprehensive Plan established the following goals:

- Discourage degradation of water resources and water quality.
- Preservation of natural drainage features and reduction of pollutants before they enter surface water.
- Careful review of development within 100 feet of lakes and streams to protect water quality.


Catherine Creek
Little Ditch
New Outflow Channel
Old Outflow Channel
Lake Stevens
Area of Detail
N
1000 0 1000 2000 Feet
LEGEND
Old Outflow Channel
Streams
Streets
Wetlands
DRAINGE IMPROVEMENT DISTRICT NO. 8
Figure 2-1
Lake Outflow Channels - Old & New
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These policy statements were a good first step towards development of a comprehensive water quality protection plan. The missing element in these objectives however is the link between land use and water quality.

1983 LAKE STEVENS RESTORATION STUDY

The "Lake Stevens Restoration Study" (Reid Middleton, 1983) was the first study to analyze the health of Lake Stevens and assess the source of nutrients into the lake leading to the declining water quality. The major conclusion of this study was that "one or more potent sources of nutrients, other then nonpoint runoff, were entering the lake." This was based largely on the nutrient budget developed for the project. That budget could only identify 25 percent of the total phosphorus loading to the lake calculated from sediment studies. Internal recycling was not identified as a major phosphorus contributor to the lake as anoxic conditions were not observed during that study.

1987 LAKE STEVENS RESTORATION PHASE IIA

Unlike the 1983 study, the Phase IIa study (KCM, 1987) identified internal recycling of phosphorus, accounting for 82 percent of the total phosphorus load to the lake on an annual basis. This internal loading was comprised of two components, sediment release and waterfowl.

The Phase IIa report recommended the use of methods to curb internal loading from sediments, such as a hypolimnetic aeration system, alum addition and waterfowl control. Cathcart Landfill, the major food source for the seagull population on Lake Stevens was closed in 1993 which removed the waterfowl loading to the lake. Hypolimnetic aeration was started in 1995 to reduce internal loading from the sediments.

Regarding nonpoint source pollution, the study stated "Without watershed improvements all in-lake restoration efforts will in time be overcome by the phosphorus loading from the lake basin."

1989 LAKE STEVENS WATERSHED WATER QUALITY MANAGEMENT PLAN

The Lake Stevens Water Quality Watershed Management Plan (KCM, 1989) set forth a list of potential projects, both structural and non-structural, to address water quality in runoff to the lake. Several projects, as described below, have been completed as a result of this and the 1992 Snohomish County report.

1992 LAKE STEVENS WATERSHED MANAGEMENT PLAN

The 1992 Lake Stevens Watershed Management Plan (Snohomish County, 1992) closely follows the 1989 plan. It sets forth recommendations to aid in the improvement of water quality in the streams discharging into Lake Stevens. The following recommendations have been implemented:

- Restoration of Kokanee Creek.
- Restoration of Lundeen Creek - partially complete.
- Create the position of a Watershed Keeper; This position was terminated at the end of 1998.
- Develop and adopt new County Drainage Standards (Title 24).
- Revise the County Grading Code (Title 17).

1997 LAKE STEVENS REPORT FOR SNOHOMISH COUNTY

The 1997 Lake Stevens Report for Snohomish County was compiled by D.C. Beyerlein and J.T. Brascher. The intent of the report was to acquire data that could be used to analyze the hydrologic impacts of urbanization around the Lake Stevens area. A computer simulation model was constructed using the EPA Hydrological Simulation Program - FORTRAN (HSPF). The results of this study can be found in appendix A.

1997 LAKE STEVENS AREA MASTER DRAINAGE PLAN

The purpose of the R.W. Beck 1997 Lake Stevens Area Master Drainage Plan was to "...provide a qualitative assessment of the impact on surface water resources from...land use conversion." The findings from this report were similar to many reports preceding it. However, R.W. Beck also recommended possible pipelines to bypass high flows around sensitive ravines in the Sunnyside area, consideration of larger buffers around fish-bearing streams, designing specific BMPs for known phosphorous loading areas, and an increase in public education.

REGULATORY FRAMEWORK

Stormwater detention and treatment has three major objectives: 1) Minimize the increase in flooding due to land development; 2) Minimize the adverse impacts on streams due to erosion and increased stormwater runoff; and 3) Maintain the water quality and sediment quality in the streams. In order to develop stormwater regulations two major questions must be addressed: 1) What is the level of protection which should be applied to each of the three parameters above?; and 2) What is the effectiveness of the detention or treatment process chosen? The first question requires a legislative policy decision while the second finds its solution in engineering.

FEDERAL REGULATIONS

Three agencies are primarily responsible for the enforcement of regulations which impact storm water. These agencies are the Environmental Protection Agency, the Corps of Engineers and the Fish and Wildlife Service. The Environmental Protection Agency and the Corps of Engineers are involved in storm water management through the Clean Water Act. The National Marine Fisheries Service is indirectly involved in storm water management through the impact of stormwater on fisheries and the proposed listing of the Puget Sound Chinook salmon as a threatened species.

Environmental Protection Agency - N.P.D.E.S. Permits

The Environmental Protection Agency (EPA) is involved in storm water regulations through the National Pollutant Discharge Elimination System process, Sections 318, 402 and 405 of the Clean Water Act. EPA promulgated Phase I rules which required all municipalities with a population greater than 100,000 according to the most recent US census data, to obtain a National Pollution Discharge Elimination System (NPDES) permit for the discharge of stormwater. Authority under the Clean Water Act was delegated to the Department of Ecology. The impact in Snohomish County was that the County worked with Ecology to develop a new drainage code, which was adopted on July 1, 1998 and is discussed below. This was just one of sixteen various actions the County applied in order to meet the requirements of the NPDES. Other actions included a Comprehensive Stormwater Management Program intended to give the County legal authority to control stormwater pollutants, and the utilization of a program responsible for preventing illicit discharges (i.e., wastewater) to stormwater systems.

Phase 2 rules, which apply to all municipalities with populations between 100,000 and 10,000 (and potentially as low as 1,000) or are within an urban area as defined by the U.S. Census Bureau are expected to take effect in 2001. Ecology will be working with local jurisdictions to ensure that storm water regulations are appropriate. For the most part, if a local jurisdiction has adopted Ecology's Storm Water Manual, that will be sufficient for a Phase 2 sized jurisdiction to obtain a NPDES permit.

All special purpose districts within counties with a population of greater than 100,000 which handle storm water are supposed to have an NPDES permit for storm water in place. However, Ecology has delayed setting the framework under which these permits would be issued. The difficulty with these permits is that districts, and Drainage District #8 is no exception, have little or no control over water coming into their jurisdiction. These Districts under an NPDES permit would be responsible for water quality exiting their jurisdiction. Ecology hopes to promulgate some rules or guidelines in 1999 regarding NPDES permits for drainage districts (Wessell, personal communication).

Corps Of Engineers - Wetlands

The Federal regulation administered by the Corps of Engineers that impacts storm water is section 404 of the Clean Water Act. Section 404 requires a U.S. Army Corps of Engineers (Corps) permit for any project which alters or degrades waters of the United States. This includes wetlands, greater than one-third acre in size, and tributaries to navigable waterways. The Corps determines which areas within a site are considered wetlands on a case by case basis after receipt of a development application. Currently the Corps requires that wetland enhancement, preservation or wetland construction occur if the proposal includes loss of existing wetland. The amount of wetlands to be enhanced, created or preserved depends upon the mixture of mitigation approaches and the location of the wetlands, both lost and gained. Generally the Corps will require that a minimum of two acres of wetlands be enhanced for each acre destroyed. If the mitigation involves the purchase of wetlands then the ratio may be as high as five acres bought and preserved through title restrictions for each acre lost.

In addition to Section 404, Section 401 requires a permit for Water Quality Modifications during construction. Section 401 is administered by Ecology. Generally, if a 404 permit is needed a 401 permit will also be required.

National Marine Fisheries Service - Endangered Species Act

The Endangered Species Act is enforced by the National Marine Fisheries Service for species such as Chinook and Coho salmon. In March 1999, the Puget Sound Chinook Salmon was listed as a threatened species. Puget Sound Coho Salmon may be listed within two years. The impact of these potential listings on development and land use are unclear but may be profound. Section 7 of the Endangered Species Act addresses "Incidental Takes." If a project may impact the Chinook Salmon by degredation of habitat, that is considered an "incidental take." In the past, biological assessments have been performed in such situations in which after negotiation with the National Marine Fisheries Service and the implementation of appropriate safeguards, an Incidental Take Statement was issued allowing the project to proceed.

Prior listing of endangered species have generally been in rural areas where the impact of urban populations has been minimal and indirect, for example the Spotted Owl. The listing of Chinook Salmon may have a direct impact on the urban centers around Puget Sound by impacting development and redevelopment. The restrictions placed on properties, and the studies required before development may proceed, could impact the value of land and thus lead to property rights conflicts. Currently there are several state and local efforts underway to assess the impact of the listing and to begin the process of salmon recovery, through legislation, regulation and grant funding. These efforts are discussed later on in this chapter under the "State Regulations" and "Local Regulations" sections.

Federal Emergency Management Agency - Flooding

The Federal Emergency Management Agency (FEMA) provides flood insurance. In order for local jurisdictions to be eligible to participate in the flood insurance program, the jurisdiction must have adopted ordinances which meet the minimum requirements of FEMA for development within the floodplain. As part of Title 27, Snohomish County disallows building within a floodway. They also require that all buildings within the floodplain have a floor elevation of at least one foot above the base flood elevation (the 100-year flood event). In addition, critical facilities are required to have their lowest floor elevation at a minimum of three feet above the base flood elevation.

STATE REGULATIONS

Several state regulations exist which impact the management of storm water. First and most direct is Ecology's 1992 *Storm Water Management Manual for the Puget Sound Basin.* This Manual has had a large impact on development as it has substantially increased the storm water treatment and detention requirements for site development. Adoption of this manual by local governments has lead to increased control of storm water runoff. The basics of this manual are discussed below in the "Drainage Ordinances" section.

Recent State Legislation

Due to the proposed salmon listing the State legislature has passed several bills geared towards protecting and increasing salmon runs in the state. **House Bill 2496** provided $3.5 million dollars in grants for salmon recovery projects. In addition $700,000 went to local governments to plan restoration activities and $800,000 for technical assistance to volunteer groups. **House Bill 2514** authorized the creation of local watershed plans. This effort recognizes the need and conflict of the demand placed on water between fish and humans. Planning on the watershed scale allows for a method to reconcile these demands within natural river basin boundaries and not jurisdictional boundaries. **House Bill 2339** provides for the certification of wetland mitigation banks. This will allow for regional management of wetlands rather than the site by site destruction, creation and management which has been occurring to date.

Ecology is also updating the Shoreline Master Program in the Washington Administrative Code (WAC 173-116). This will set new minimum guidelines for local governments to follow in managing streams, lakes and marine shorelines. Recent studies (May 1997) have shown the importance of riparian buffers in protecting river habitat. Increased requirements for buffer setbacks may be required as a result of the new state standards. Local jurisdictions will be required to update their shoreline programs to reflect the new state guidelines within two years of Ecology adopting its guidelines.

WATER QUALITY STANDARDS

Water quality standards for the State of Washington are presented in Chapter 173-201A of the Washington Administrative Code (WAC). This chapter defines the different categories of surface waters within the state and establishes water quality standards associated with each of the various categories. The purpose of the chapter is stated as follows:

> The purpose of the chapter is to establish water quality standards for surface waters of the state of Washington consistent with public health and public enjoyment thereof, and the propagation and protection of fish, shellfish, and wildlife, pursuant to the provisions of chapter 90.48 RCW and the policies and purpose thereof.

Water Quality Classifications

Section 173-201A-120 General Classifications states: "(2) All lakes and their feeder streams within the state are classified Lake Class and Class AA respectively, except for those feeder streams specifically classified otherwise.". No mention is made of Lake Stevens, Catherine Creek, the Little Pilchuck or any of the tributaries to Lake Stevens.

Water Use Criteria

Section 173-201A-030 General Water Use And Criteria Classes states that water of class AA "shall markedly and uniformly exceed the requirements for all or substantially all uses." Section 173 -201A-030 also specifies water quality criteria for Class AA waters and Lake Class waters (Table 2-1).

Acute and Chronic Criteria

In addition to the standards developed by the Washington Department of Ecology and the U.S. Environmental Protection Agency, have established fresh water acute and chronic concentrations for a variety of pollutants, including most heavy metals, some pesticides, and some organic pollutants (Tables 2-1 and 2-2).

In addition to the current standards given in Table 2-1 the Department of Ecology has also established an antidegradation policy (WAC 173-201A-070). This policy states:

1. Existing beneficial uses shall be maintained and protected and no further degradation which would interfere with or become injurous to existing beneficial users shall be allowed.

2. Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.

TABLE 2-1

Department of Ecology Water Quality Criteria

Parameter	Washington State Class AA Criteria	Washington State Class A Criteria	Lake Class
Fecal coliform	Geometric Mean not greater than 50 colonies/100 mL and no more than 10% of all samples exceeding 100 colonies/ 100 mL.	Geometric Mean not greater than 100 colonies/100mL and no more than 10% of samples exceeding 200 colonies /100 mls	Shall not exceed a geometric mean value of 50 colonies/100 mL and not have more than 10% of all samples exceeding 100 colonies/ 100 mL.
Dissolved Oxygen	> 9.5 mg/L.	> 8.0 mg/L.	No measurable decrease from natural conditions.
Total Dissolved Gas	<110 % of saturation at any point.	Shall not exceed 110% of saturation	<110 % of saturation at any point.
Temperature	Shall not exceed 16.0°C due to human activities.	Shall not exceed 18.0°C due to human activities.	No measurable change from natural conditions.
pH	6.5 to 8.5.	6.5 to 8.5.	No measurable change from natural conditions.
Turbidity	Shall not exceed 5 NTU over background if background less than 50, otherwise less than 10 increase.	< 5NTU above background when background < 50 NTU, otherwise < 10% increase	Shall not exceed background by more than 5 NTU.
Aesthetic	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell touch or taste.	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell touch or taste.	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell touch or taste.
Phosphorus	No Standards.		No Standards.
Enterococci (proposed)	33 organism/100mLs, 30 day mean	33 organism/100mLs, 30 day mean	
Metals	Acute and Chronic Standards vary with hardness	Acute and Chronic Standards vary with hardness	Acute and Chronic Standards vary with hardness

TABLE 2-2

U.S. Environmental Protection Agency Water Quality Criteria

Parameter	EPA Freshwater Aquatic Toxicity Criteria (mg/L) at 20mg $CaCO_3$/L Acute Toxicity	at 20mg $CaCO_3$/L Chronic Toxicity	at 100mg $CaCO_3$/L Acute Toxicity	at 100mg $CaCO_3$/L Chronic Toxicity
Cadmium	0.0006	0.0003	0.0039	0.0011
Chromium (3+)	0.363	0.055	1.700	0.210
Chromium (6+)	0.016	0.11	0.016	0.11
Copper	0.0039	0.003	0.018	0.012
Mercury	0.0024	0.000012	0.0024	0.000012
Nickel	0.363	0.040	1.400	0.157
Lead	0.0105	0.0004	0.0820	0.0032
Zinc	0.030	0.027	0.120	0.110
Iron	---	1.000	---	1.000
Nitrates	No standard.	No standard.	No standard.	No standard.
Nitrites	No standard.	No standard.	No standard.	No standard.
Phosphorus	No standard.	No standard.	No standard.	No standard.

Best Management Practices

Lastly, under WAC 173-201A-160 (3) Nonpoint source and storm water pollution "Best management practices shall be applied so that when appropriate combinations of individual best management practices are utilized, violation of water quality criteria shall be prevented. If a discharger is applying all best management practices appropriate or required by the department and a violation of water quality criteria occurs, the discharger shall modify existing practices or apply further water pollution control measures, selected or approved by the Department, to achieve compliance with water quality criteria."

At major construction sites within the watershed in 1998, simple best management practices, such as covering the soil to prevent erosion, were routinely not enforced until major problems occurred. For example, at one large development, recently graded soils were left uncovered for the majority of the summer despite the fact that the County and City both require the soils should not be left exposed for seven days in the summer or for more than two days after October 1. Enforcement action eventually forced the contractor to apply reasonable temporary erosion and soil stabilization measures, but only after rainfall caused significant sediment transport to occur.

The intent of sediment erosion control is to keep sediment out of the streams and lake. A survey in the fall of 1998 of four construction sites in the Lake Stevens and Catherine Creek basins revealed the following. Approximately 30 percent of the catch basin filters had been sliced, rather than cleaned or replaced. This action allowed sediment laden storm water runoff to enter the drainage system. Bulldozers located on a development site were seen roving through thick layers of mud (Figure 2-2). Hay bails were set in such a manner as to allow water to run under them (Figure 2-3). Silt fences were installed but not keyed into the slope (Figure 2-4). Silt fences were installed but then breached creating pathways for water and sediment to move offsite (Figure 2-5). Sediment was moving directly offsite as sediment ponds had not been installed (Figure 2-6). Unless erosion control measures are properly installed in a timely manner and maintained they will not work.

LOCAL REGULATIONS

Local regulations have been passed in an attempt to control and minimize the impacts of increased storm water runoff. In addition to the regulations on the books there has been an increased focus on storm water, water quality and instream flows as a result of the proposed salmon listing.

TriCounty Workgroup

King, Pierce and Snohomish Counties as well as Seattle, Bellevue, Tacoma, Everett, and the Puyallup, Muckleshoot, Tulalip Stillaguamish Indian Tribes have formed a working group to develop a salmon rehabilitation program. The specific programs that will be developed from this group are unclear as of this writing. A combination of funding for local and volunteer efforts, capital improvement projects and regulations is likely.

Drainage Ordinances

The current drainage requirements are contained in Snohomish County Code Title 24 and the City of Lake Stevens Code 14.64.140. The City of Lake Stevens Code simply adopts the Ecology Storm Water Management Manual. Any stormwater facility design in the Lake Stevens/Catherine Creek watershed must meet the requirements of one of these drainage codes. Table 2-3 presents a summary of the detention requirements.

Figure 2-2
Poor Construction Practices

Figure 2-3
Ineffective Hay Bale Installation

Figure 2-4
Silt Fence Installed but Not Keyed Into the Ground

Figure 2-5
Breached Silt Fence Allowing Water and Sediment to Move Offsite

Figure 2-6
Storm Water and Sediment Moving Offsite

TABLE 2-3

Core Requirements for Stormwater Discharge
Snohomish County and Washington Department of Ecology Manuals

	Washington Department of Ecology(1)	Snohomish County(1)
2-year Storm Event	50 % of pre-developed 2-year	50 % of pre-developed 2-year
10-year Storm Event	pre-developed 10-year	pre-developed 10-year
100-year Storm Event	pre-developed 100-year	pre-developed 100-year
Volume Safety Factor	20% to 50%	30%(2)
Threshold Criteria	5,000 sq. ft. impervious	200 sq ft impervious

1 The manuals both have a minimum requirement of 5,000 square feet of new impervious surface before detention requirements take effect.

2 Snohomish County has additional requirements if the facility is located within one-quarter mile of downstream flooding.

In addition to the detention requirements, the manuals have requirements for stormwater treatment. Both manuals require that runoff from the six-month storm be treated prior to release. Treatment can be through a variety of systems including an oil water separator, a bioswale, a filter infiltration or a wet pond.

Shoreline Master Program

Under WAC 173-14 authority of the program is delegated to local jurisdictions. The Washington State Shoreline Master Act (RCW 90.58) applies to development within 200 feet of "Shorelines of the State." Shorelines of the State are defined as the total of "Shorelines of Statewide Significance" and "Shorelines." The term "Shorelines" applies only to streams of greater than 20CFS "Mean Annual Flow." Locally the program is governed by Snohomish County Code (Title 21, SCC) and the City of Lake Stevens Code (LSC, Chapter 14.92). Under these codes Lake Stevens is protected as a "shoreline of statewide significance", requiring a permit for all development worth over $2500 within 200 ft of the shoreline, with some exemptions. The exemptions include: 1) The construction of a single family residence less than 35 feet high; 2) the construction of bulkheads typical to single family residences; and 3) within the City of Lake Stevens the construction of a dock less than $10,000 in value. The streams discharging to the lake and the outflow channel, as well as Catherine Creek are not regulated under the Shorelines program, as their mean annual flow is less than 20 CFS.

Zoning

Zoning is perhaps the single most important factor influencing storm water runoff. Generally increased density leads to increased runoff. The Snohomish County Comprehensive Plan and the Snohomish County Code Title 18 establishes zoning for all unincorporated areas in Snohomish County. Likewise, City of Lake Stevens Code

Chapter 14.36 provides zoning for the City of Lake Stevens. The intent of the zoning is to manage development and housing density, so that it happens in a controlled manner. Zoning changes may occur as the result of comprehensive planning efforts or specific requests by developers.

Environmental Policy Ordinance

The State Environmental Policy Act (SEPA) set forth minimum requirements above which any development will have to assess the impacts of the proposed development on the surrounding environment through a SEPA checklist. The authority of this program is delegated to local jurisdictions (SCC, Title 23 and LSC, Chapter 14). Leading jurisdictions will evaluate these impacts and will then decide to impose a "Determinination of Significance" (DS), a "Mitigated Determination of Nonsignificance", or simply a "Determination of Nonsignificance"(DNS). If a DS ruling is granted, the applicant must provide an Environmental Impact Statement (EIS). The EIS will provide an in-depth analysis of the impacts and will discuss possible mitigation measures. The public and other affected agencies will have 30 days to comment on the issues presented in the EIS. If a DNS is granted, no further analysis is required by the developer. If the issue involves another agency or if it includes non-exempt demolition activities, non-exempt grade and fill permits, a mitigated DNS, or contains an action under the Growth Management Act, the DNS issue will require a 14 day public comment period. It should be noted that typically, the construction of any development of up to four residential units is exempt from SEPA determination.

LAND USE PLANNING

Land use planning is conducted by Snohomish County. Figure 2-7 shows the existing land use for the watershed areas. The County is currently working on a sub-area basin plan for the Lake Stevens Urban Growth Area (UGA). As part of this plan, the County has developed six alternatives for land use which are now under consideration in the Lake Stevens UGA. At the time of this report, any one of the alternatives or a combination of the alternatives could be selected. Selection of a particular land use impacts the amount of runoff, the constituents in the runoff and the concentration of those parameters.

The hydrologic and hydraulic models for this project were developed in the spring of 1997. At that time the County was proposing three land use alternatives for the Lake Stevens UGA. Since the development of the models, three additional alternatives have been proposed. Alternatives 4, 5, and 6 predict an increased population in the UGA relative to Alternatives 1, 2, and 3. The hydrologic model is based upon Alternative 2. The proposed land use for Alternatives 2 and 6 are shown in Figures 2-8 and 2-9.

Future population estimates are in part based upon the work done by Snohomish County Tomorrow. Snohomish County Tomorrow is a collaborative process of the County and the Cities within the County to plan for the future. Population was estimated based upon historical population trends and anticipated future trends. Alternatives 1, 2, and 3 are based upon the original work done by Snohomish County Tomorrow which in 1994 estimated the population at 26,090 in the year 2012. During the planning process growth trends showed that 50 percent of the projected population increase over the 20-year planning period had occurred in the first 5 years. Because of this Alternatives 4, 5, and 6 were developed. These later scenarios are based upon revised forecasts that reflect increased building permit issuance over the past fifteen years. Alternative 5 removes the Cavalero Hill area from the UGA and Alternative 6 assumes an increased growth rate in the initial years of the planning period.

As seen in figures 2-8 and 2-9, the major difference in designated land use between the Scenarios 2 and 6 are two-fold. First, in Alternative 6 there are increased areas of high density use. These areas generally are outside of the Lake Stevens and Catherine Creek watersheds. Secondly, within each land use area there are different zoning categories which might be used to fulfill that land use. For example, Urban Low Density covers four to six dwelling units per acre. Three different zoning codes R-9600 (4 units per acre), R-8400 (5 units per acre) and R-7200 (6 units per acre) will fit this range of densities. The change in zoning will impact the build-out populations within the UGA. Since the County has not yet completed the planning process, revisions of the model assumptions regarding land use were not deemed necessary.

DRAINAGE ORDINANCES - HISTORICAL BACKGROUND

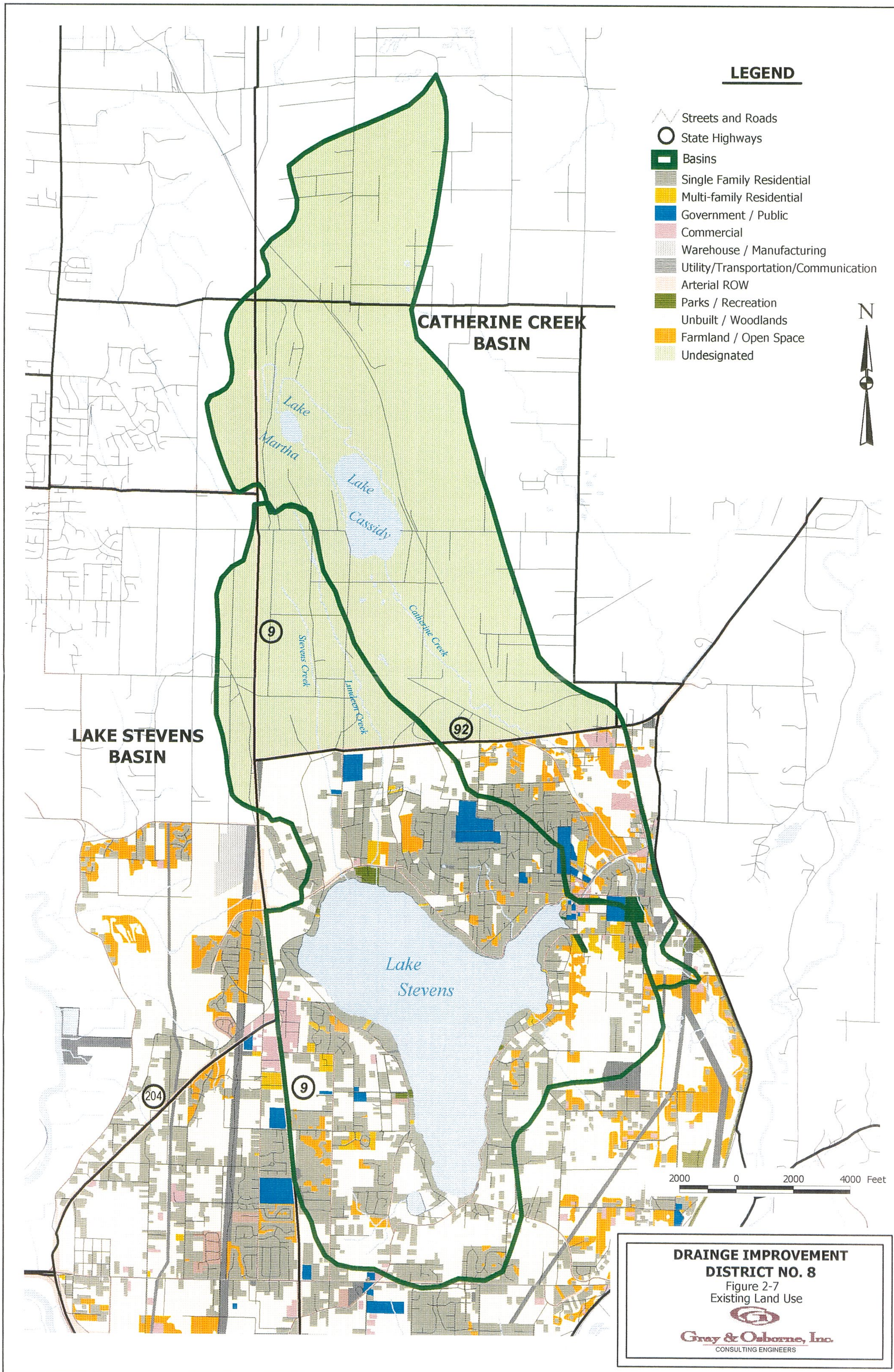
Drainage ordinances have evolved through the years in an attempt to minimize the impacts of land development on flooding and the aquatic environment. The early drainage ordinances, in the 1970s and 1980s required the use of the rational equation and had detention requirements aimed at minimizing the impacts of development on increased flooding. As shown in Table 2-4, development, without detention, has the potential to increase peak flow rates by an order of magnitude. This same order of magnitude should not be applied to the entire watershed for only portions of the watershed undergo development. However, table 2-4 shows that as development increases, so will peak flow rates instream.

TABLE 2-4

Peak Flow Rates (cfs) for Land Types and Design Storms

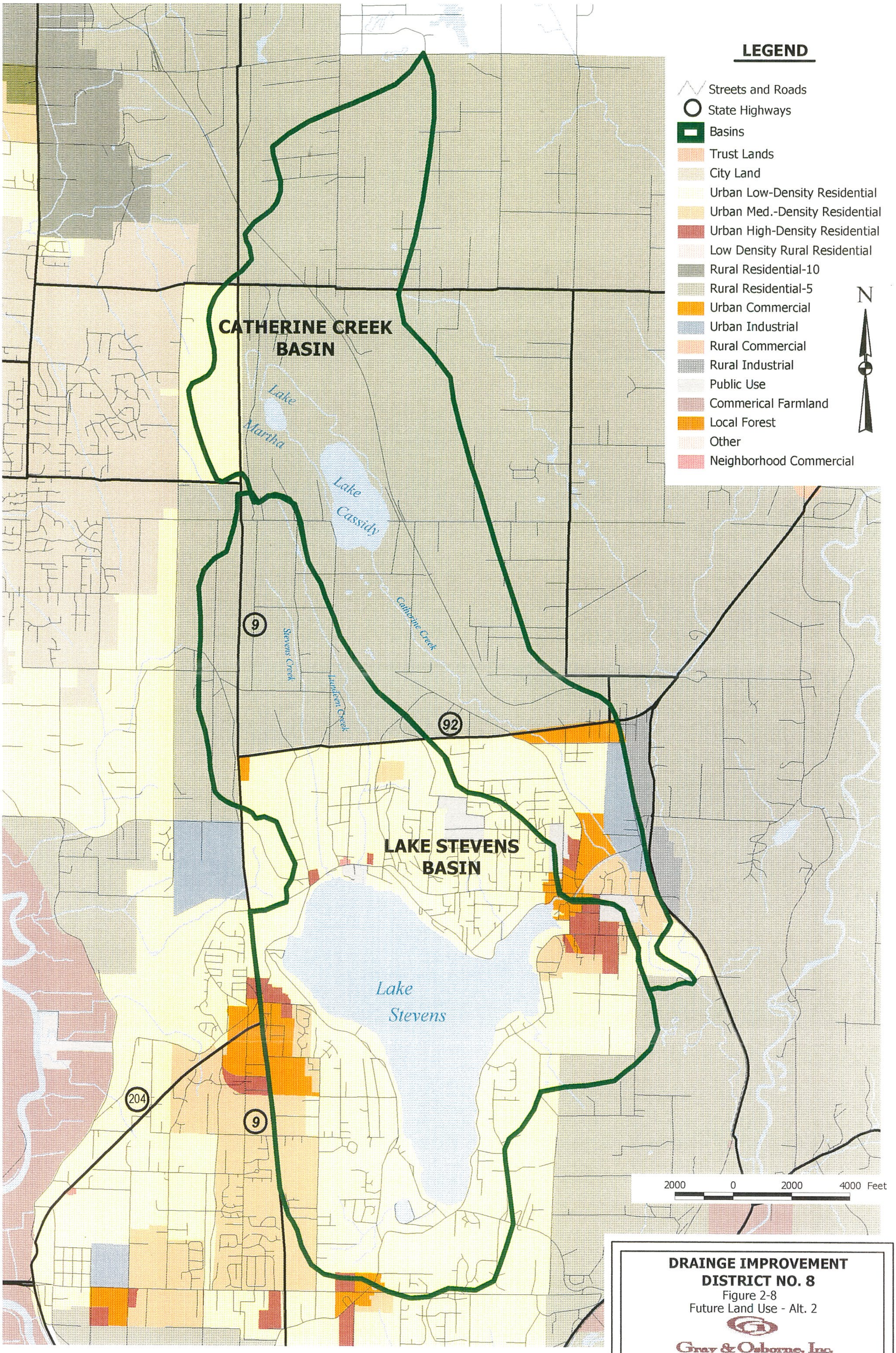
Land Cover Type	2-Year Storm	10-Year Storm	100-Year Storm
Forest	0.1	0.3	0.8
Residential	1.3	3.0	5.0
Commercial	3.8	6.2	8.8

Horner, et al., 1994. Fundamentals of Urban Runoff Management: Technical and Institutional



DRAINGE IMPROVEMENT DISTRICT NO. 8
Figure 2-7
Existing Land Use

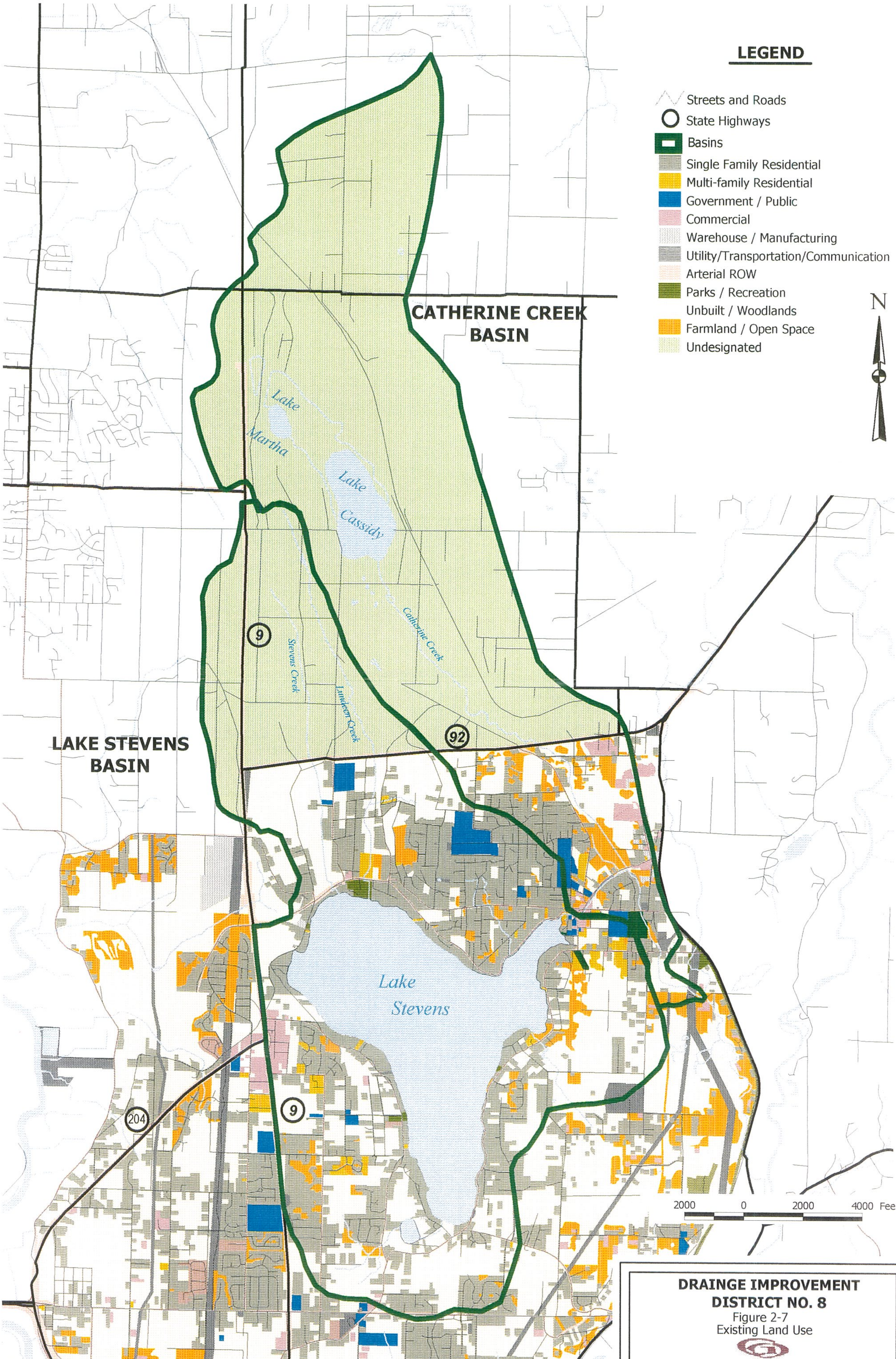
Gray & Osborne, Inc.
CONSULTING ENGINEERS



DRAINGE IMPROVEMENT DISTRICT NO. 8

Figure 2-8
Future Land Use - Alt. 2

Gray & Osborne, Inc.
CONSULTING ENGINEERS



DRAINGE IMPROVEMENT DISTRICT NO. 8
Figure 2-7
Existing Land Use

Gray & Osborne, Inc.
CONSULTING ENGINEERS

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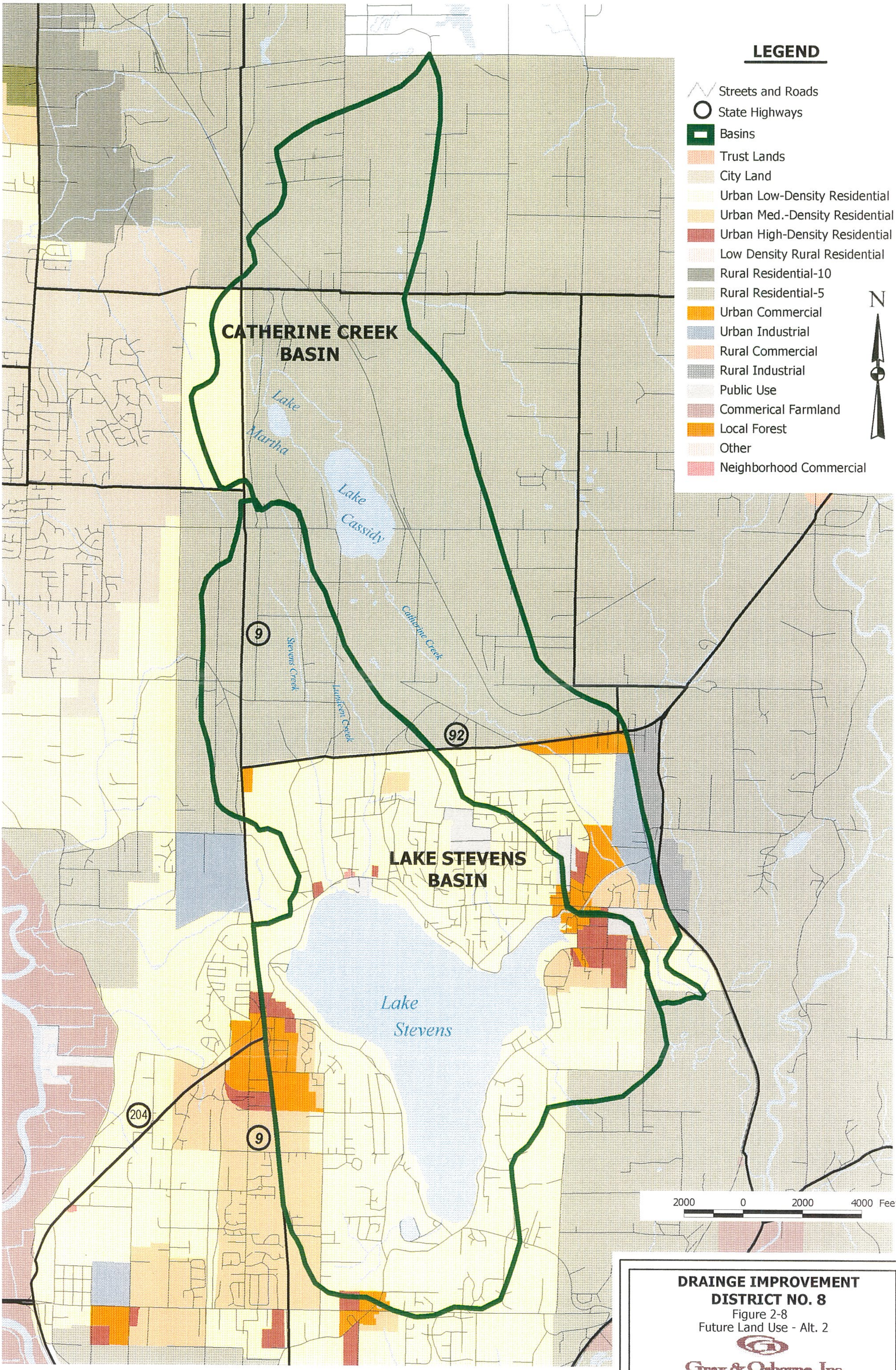
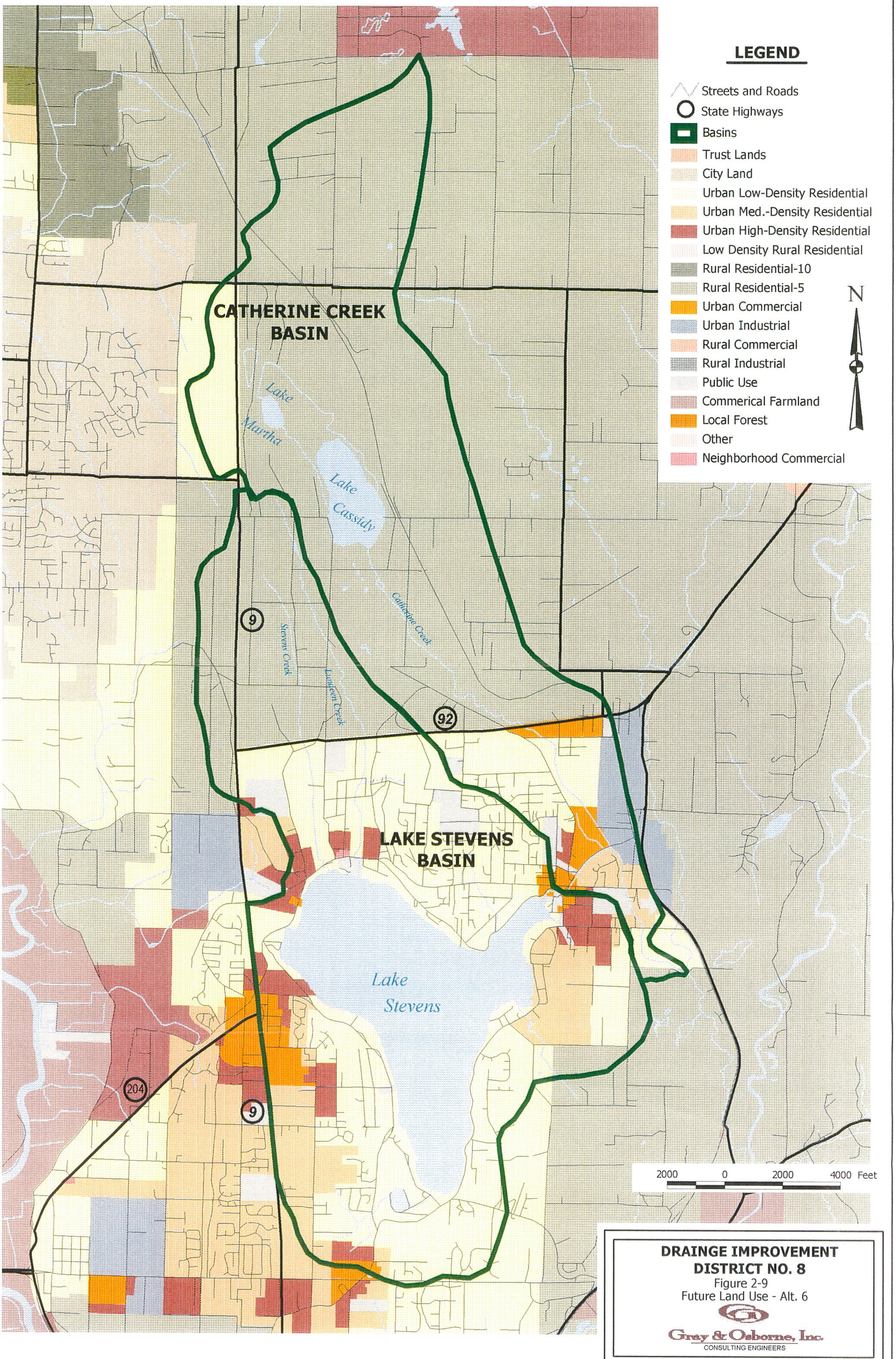


DRAINGE IMPROVEMENT DISTRICT NO. 8
Figure 2-8
Future Land Use - Alt. 2

Gray & Osborne, Inc.
CONSULTING ENGINEERS


LEGEND
Streets and Roads
State Highways
Basins
Trust Lands
City Land
Urban Low-Density Residential
Urban Med.-Density Residential
Urban High-Density Residential
Low Density Rural Residential
Rural Residential-10
Rural Residential-5
Urban Commercial
Urban Industrial
Rural Commercial
Rural Industrial
Public Use
Commerical Farmland
Local Forest
Other
Neighborhood Commercial
N
CATHERINE CREEK BASIN
LAKE STEVENS BASIN
Lake Martha
Lake Cassidy
Catherine Creek
Stevens Creek
Lundeen Creek
Lake Stevens
9
92
204
2000 0 2000 4000 Feet
DRAINGE IMPROVEMENT DISTRICT NO. 8
Figure 2-9
Future Land Use - Alt. 6
Gray & Osborne, Inc.
CONSULTING ENGINEERS

The size (and thereby the effectiveness) of detention facilities is dependent upon the methodology used to estimate the magnitude, duration and volume of runoff before and after development occurs and the effectiveness of the detention sizing methodology. In a 1987 study, King County found that significant damage had been done to local streams. The cause of stream degradation was found to be threefold. First, the design standards were not sufficient to prevent an increase in the peak flow from storms. Second, detention systems were not properly maintained and therefore did not work properly. Third, the systems were frequently not built as designed. In response to this study King County adopted a new drainage ordinance in 1990.

The 1990 manual required the use of the Santa Barbara Urban Hydrograph method to calculate runoff characteristics and detention requirements, as discussed below. The new requirements resulted in significantly more detention than previously required and storm water quality treatment for runoff rates less than that of the six month storm. In 1992 the Department of Ecology released its *Puget Sound Storm Water Management Manual for the Puget Sound Basin*. This manual has similar requirements to that of the 1990 *King County Surface Water Manual*, but with some additional detention requirements for low intensity storms. In 1990 the Snohomish County Council passed the 1990 Aquatic Resources Protection Program (ARPP), which established requirements for vegetated buffers and discouraged alterations of streams and wetlands. However, the ordinances designed to implement ARPP were soon repealed by popular vote. When this defeat occurred, the County reverted to its 1979 Drainage Manual for guidance in Storm Water design. That manual was the governing manual in Snohomish County until 1998 when Snohomish County adopted a manual similar to Ecology's with some additional requirements for detention in flood prone areas. The City uses the 1992 Ecology Manual.

The additional detention requirements in the new manuals and ordinances evolved from empirical observations in sediment transport studies. These observations helped to develop consistent detention standards. Results indicate "that in most cases the threshold discharge (for sediment transport) will be a flow significantly less than necessary to fill the bankfull channel and only a fraction of the two-year discharge" (Booth, 1993). This observation has led Ecology to develop stream protection detention standards that require the 2-year peak flow to be reduced by 50 percent.

It is important to note that after the release of the 1989 King County and 1990 Ecology manuals, additional research showed that the computation methodology in these manuals underestimated the volume of storm water runoff by three- to five-fold (K. Whiting, 1997). Therefore, because Snohomish County and the City of Lake Stevens are still using the computational runoff methods listed in the Ecology manual, they are producing detention systems that are insufficient to mitigate increased flows in regional streams.

1998 Storm Water Regulation

In response to the research mentioned above, King County developed a new storm water manual, which was adopted in the fall of 1998. This manual requires the calculation of detention based upon a hydrologic model regionally calibrated by the U.S. Geological Survey. This new model, the King County Runoff Time Series model (KCRTS), increases the predicted detention to meet discharge limits.

The 1998 manual sets standards based upon the particular problems in the area. The manual has three flow control standards, a peak-flow matching standard (Level 1), a stream/erosion protection standard (Level 2) which targets both peak and duration, from 50 percent of the 2-year peak up to the 50-year event, and both peak flow and duration matching up to the 100-year event. The new manual also includes a menu of storm water quality requirements designed to protect downstream resources. The water quality treatment chosen is in part "tailored to the sensitivities and resource protection needs of the downstream receiving water."

The Washington Department of Ecology is currently in the process of updating its manual. Additional detention requirements will likely be required in the new manual.

Implications Of The New King County Storm Water Manual And The Cost Study On The Lake Stevens/Catherine Creek Watershed

The King County Surface Water Management Drainage Investigations Unit completed a study comparing drainage facility costs under the 1990 Surface Water Design Manual with projected costs under the new manual (Johnson, 1997). The conclusion was that if regulations increase flexibility to facility designs so that lot area lost to detention and construction materials are minimized, the impact on development costs is minimal. A full discussion of this study is presented in Appendix B.

The King County cost analysis study is a useful indicator of the relative costs of revising drainage regulations and design requirements. While resource areas and land use patterns in Snohomish County may not correspond exactly to those of King County, the study provides valuable insight into development situations which will produce increased or decreased facility costs. Small projects may experience cost increases as a result of the new regulations. Larger projects may experience cost savings due to design revisions that reduce the lot area necessary for facilities. The potential cost impacts in Snohomish County of adoption of drainage codes similar to that of King County's would depend on the size of the project, the amount of impervious area and the distribution of impervious area.

CHAPTER 3

PHYSICAL CHARACTERISTICS AND NATURAL RESOURCES

Natural resources have long played a role in the history of Lake Stevens. The physical parameters which define the Lake Stevens and Catherine Creek areas are discussed below.

GEOLOGY

The geology of the area is dominated by the Pleistocene glaciation. The maximum advance of this glaciation occurred about 15,000 years ago and covered the land surface of the region within excess of 3,000 feet of ice. The final phase of the Pleistocene glaciation was the Vashon Stade which left a mixture of silt, sand and gravel. Three major deposits of the Vashon Stade deserve mention.

The deepest deposit of the Vashon Stade is the advance outwash, also known as the advance sands. As the glaciers advanced from the north, glacial meltwater left a layer comprised predominately of sand and gravel. As the glaciers approached, sand deposition generally gave way to the deposition of coarser deposits due to the proximity of the supply materials. Thus the advance deposits coarsen upwards. Municipal wells drilled into this formation by the City of Lake Stevens are productive, yielding approximately 1,200 gallons per minute. However the water quality is poor with high concentrations of both iron and manganese.

Overlying the advanced sands is the Vashon Till. This deposit was laid down underneath the glacier. It is comprised of a mixture of clay, silt, sand and gravel and is a dense to very dense material. The thickness of the Vashon Till, also known as hardpan, ranges up to 100 feet in thickness. In some places the till may be absent due to erosion. Locally it can yield sufficient water for domestic purposes but is generally an aquitard, restricting the movement of water both vertically and horizontally. The low permeability reduces recharge to the underlying advance outwash deposits but it provides good protection from surface contamination.

The third and uppermost unit is the recessional sands and gravels which were deposited as the glaciers melted and the glacial front receded to the north. If thick enough, the recessional sands may locally yield sufficient water for domestic purposes. However, since it is the uppermost aquifer it may be subject to surface contamination.

PRECIPITATION

Average precipitation in the watershed is approximately 40 inches per year. Approximately 75 percent of the precipitation falls during the period October through March (Figure 3-1).

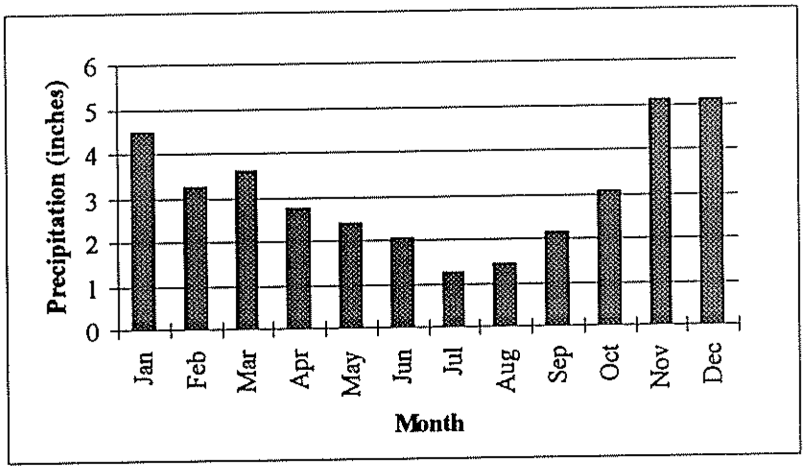


Figure 3-1 Average Monthly Precipitation At Everett, Washington

Storms are characterized in terms of the probable return interval, based upon historical precipitation records. For example, a 10-year storm has a probability of occurring once every ten years but may occur more or less frequently depending upon future weather patterns.

Precipitation data can be evaluated by several methods. A common way to evaluate the magnitude of a rainfall event is to assess how much rain fell over a given time period. The National Oceanic and Atmospheric Administration compiled a series of maps giving the amount of rain in a 24-hour storm for western Washington for various return periods, i.e., a 2-year storm, 10-year storm and a 24-hour storm. The rainfall for the Lake Stevens area is given in Table 3-1. The data from these maps have been incorporated in the design of storm water detention systems in the Puget Sound basin.

TABLE 3-1

Rainfall For Storm Events (Inches)

Return Period	24 - Hour Storm
6 - Month	1.1
2 - Year	1.7
10 - Year	2.5
100 - Year	3.5

GROUNDWATER

As discussed in Section 3.1 ground water is largely restricted to two aquifers. The upper, outwash aquifer supplies the baseflow to the creeks. The extent of this outwash aquifer is limited in the Stevens Creek and Lundeen Creek watersheds and cannot support stream flow in late summer. Ground water does support a year round baseflow in lower Catherine Creek and the Lake Stevens outflow channel (Table 3-2). Since the tributaries to the Lake Stevens dry up in the summer, the lake water level may be supported by the water table of the deeper aquifer. Lake Stevens is approximately 150 feet deep and experiences an annual water surface elevation managing from about 209 to 212 feet. The District attempts to minimize this fluctuation.

TABLE 3-2

Summer Baseflows In Creeks Within The Watershed

Monitoring Station	Summer Baseflow (CFS)	Winter Baseflow (CFS)
Station A - Lake Stevens Outflow Channel	2[1]	40
Station B - Catherine Creek at 20th Street	11	80
Station C - Stitch Creek	2	3
Station D - Catherine Creek at 36th Street	<2	25
Station F - Lundeen Creek	<2	15
Station G - Stevens Creek	<2	10

1 The outflow channel baseflow is highly dependent upon the flow restriction in place at the weir (i.e., the number of boards in the weir.

SOILS

Soils for both basins are shown in Figure 3-2. The soil has formed from glacial outwash deposits and, in areas of depression, from eroded sediment and vegetative material. The deposits have been altered through time and now comprise, along with the vegetative material, the soil horizons seen today.

The soils in the watersheds are comprised largely of two groups: Tokul Gravelly Loam and Mukilteo Muck (USDA, 1983). The most dominant group is the Tokul Gravelly Loam, which forms on glacial till and volcanic ash deposits. It is a "moderately deep, moderately well drained soil" (USDA, 1983). Soil depths range down to about 40 inches where the compact glacial till is encountered. The soils are wet for only a portion of the growing season but occasionally remain wet long enough to adversely impact non-wetland plants.

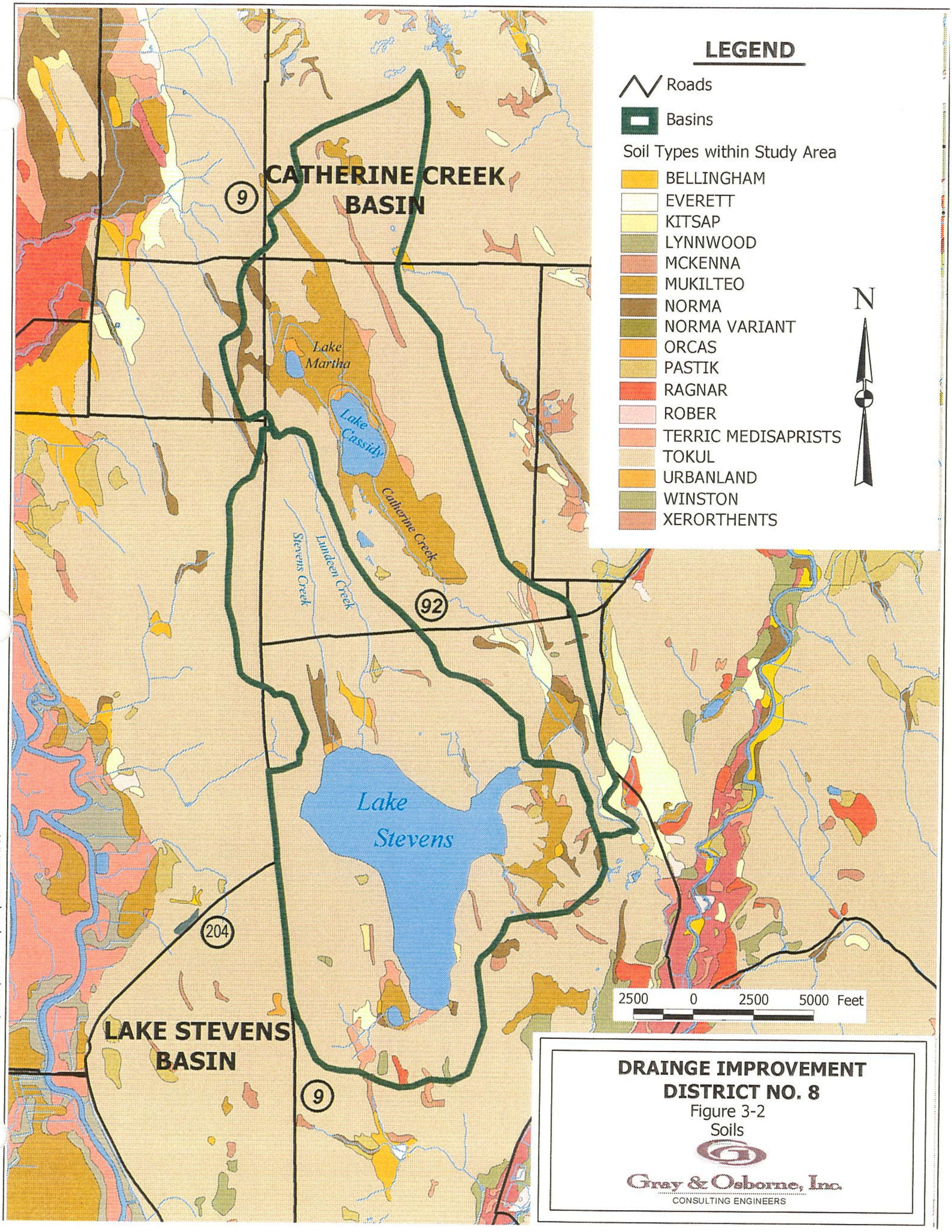


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Figure 3-2

Soils

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Permeabilites (infiltration rates) in the Tokul gravel range from approximately 0.6 to 2.0 inches per hour above the till layer but are reduced to less than 0.06 inches per hour in the till (USDA, 1983). Since the rate of infiltration generally exceeds rainfall, except in cases where the soil has been disturbed and compacted, the likelihood of erosion due to runoff is slight. The dominant vegetation species on the Tokul Series are Douglas Fir and Western Hemlock. These trees will reach average heights of 173 and 166 feet respectively at an age of 100 years. Septic systems in this soil series may be prone to failure during the saturated conditions common in the winter months.

The second most dominant soil series is Mukilteo Muck (Figure 3-2). This soil has been classified as hydric (wetland) soil and where present, may restrict land development due to engineering concerns and wetland protection regulations. Mukilteo Muck has a moderate permeability (0.6 to 2.0 inches/hour) but typically has a water table at or near ground surface for much of the year (USDA, 1983). Due to the saturated conditions the dominant plants are wetland plants such as rushes and sedges. Typically the soils form in flat areas, resulting in ponding of winter time precipitation. Septic systems are likely to fail in this soil type in the winter months.

TOPOGRAPHY

The Catherine Creek/Lake Stevens watershed is a typical upland glaciated terrain of rolling hills, with occasional glacially formed hills called drumlins. The elevation ranges from a high of 470 feet at the top of the drumlin west of Lake Cassidy, to a low of approximately 160 feet at the confluence of Catherine Creek and Little Pilchuck Creek (Figure 3-3). Slopes are generally less than 10 percent with the exception of the southwest side of Walker Hill and the area to the west of Lake Cassidy where slopes range up to 25 percent.

VEGETATION

Prior to logging in the 1800s, the Lake Stevens watershed was covered with a dense forest dominated by Douglas Fir, Western Hemlock, Western Red Cedar, and Red Alder. Past logging activities and development have altered basin vegetation significantly leaving the current pattern of open areas, and young second or third growth forest.

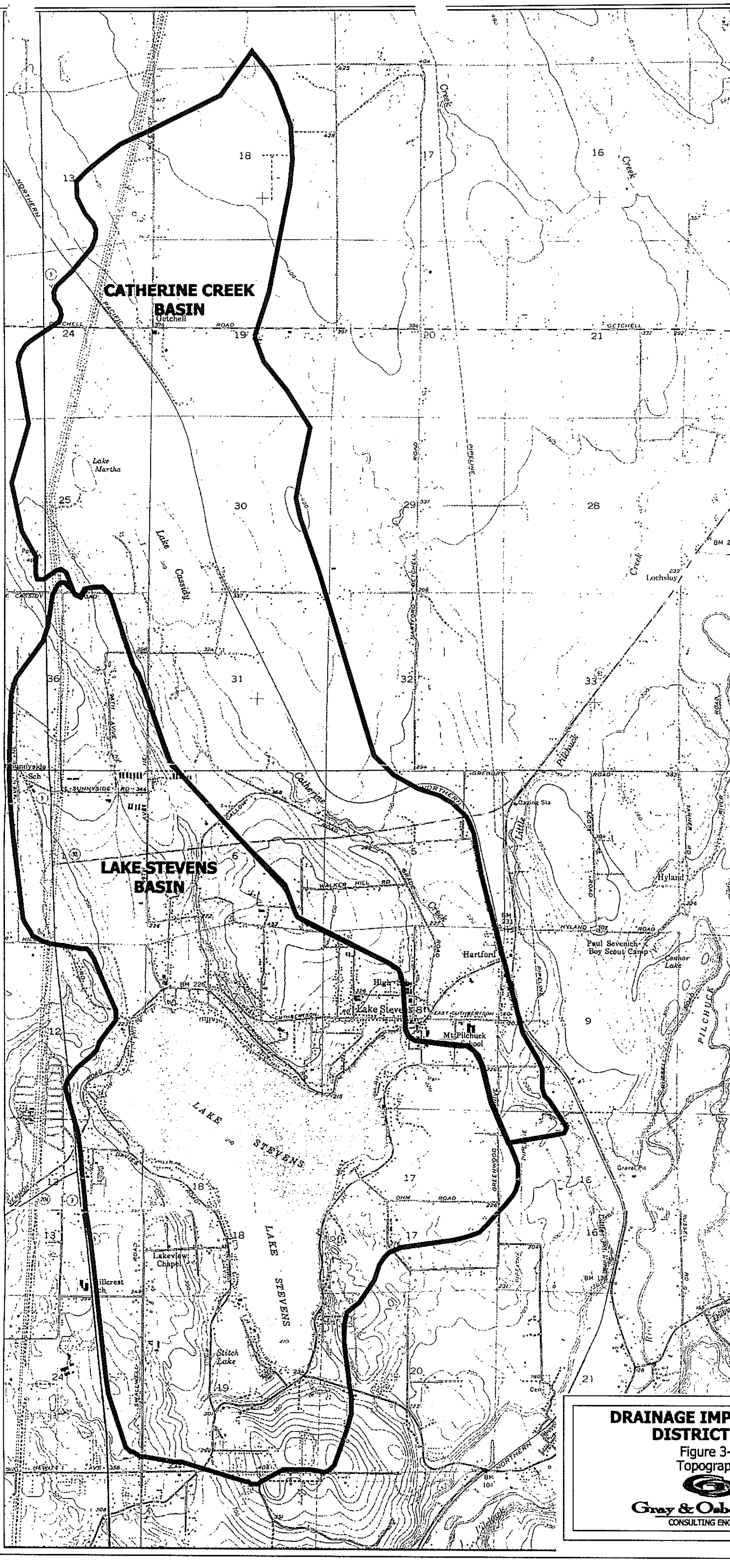

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Figure 3-3
Topography

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WETLANDS

The functions and values of wetlands are created by the interaction of hydrology, vegetation, and soils. Wetlands are delineated using all three parameters. Wetland hydrology is generally considered to exist when the soils are saturated to within 1 foot of the ground surface for more than 12.5 percent of the growing season and in some cases for more than 5 percent of the growing season. A prevalence of wetland plants occurs when more than 50 percent of the dominant plant species are obligate (almost always occur in wet conditions and hydric soils) or facultative (can occur in aerobic or anaerobic conditions) wetland plants. Hydric soils are those soils that are saturated long enough to develop anaerobic conditions. The largest density of wetlands is in the vicinity of Lake Cassidy (Figure 3-4), with a large wetland also occurring in the area north of Hartford Drive and East of Grade Road.

Wetlands benefit water quality by filtering the water which passes through them. This filtering action removes much of the suspended sediments and associated pollutants present in stormwater runoff. The ability of wetlands to remove suspended material is in part a function of the change in water level elevation within the wetland and the "residence time" of water in the wetland.

Wetlands, both natural and constructed, have been and are used for water quality treatment. Currently however the use of natural wetlands for water quality treatment of storm water runoff is not permitted. Although wetlands are effective at removing suspended sediments, they are not effective at reducing dissolved constituents from storm water (See Table 3-3).

TABLE 3-3

Removal Efficiency Of Pollutants By Natural Wetlands

Parameter	Median Removal Efficiency (%)	High Removal	Low Removal
Total Suspended Solids	75	95	0
Total Phosphorus	5	65	-75
Total Nitrogen	21	60	-38

Negative value indicates higher concentrations below wetland than above.

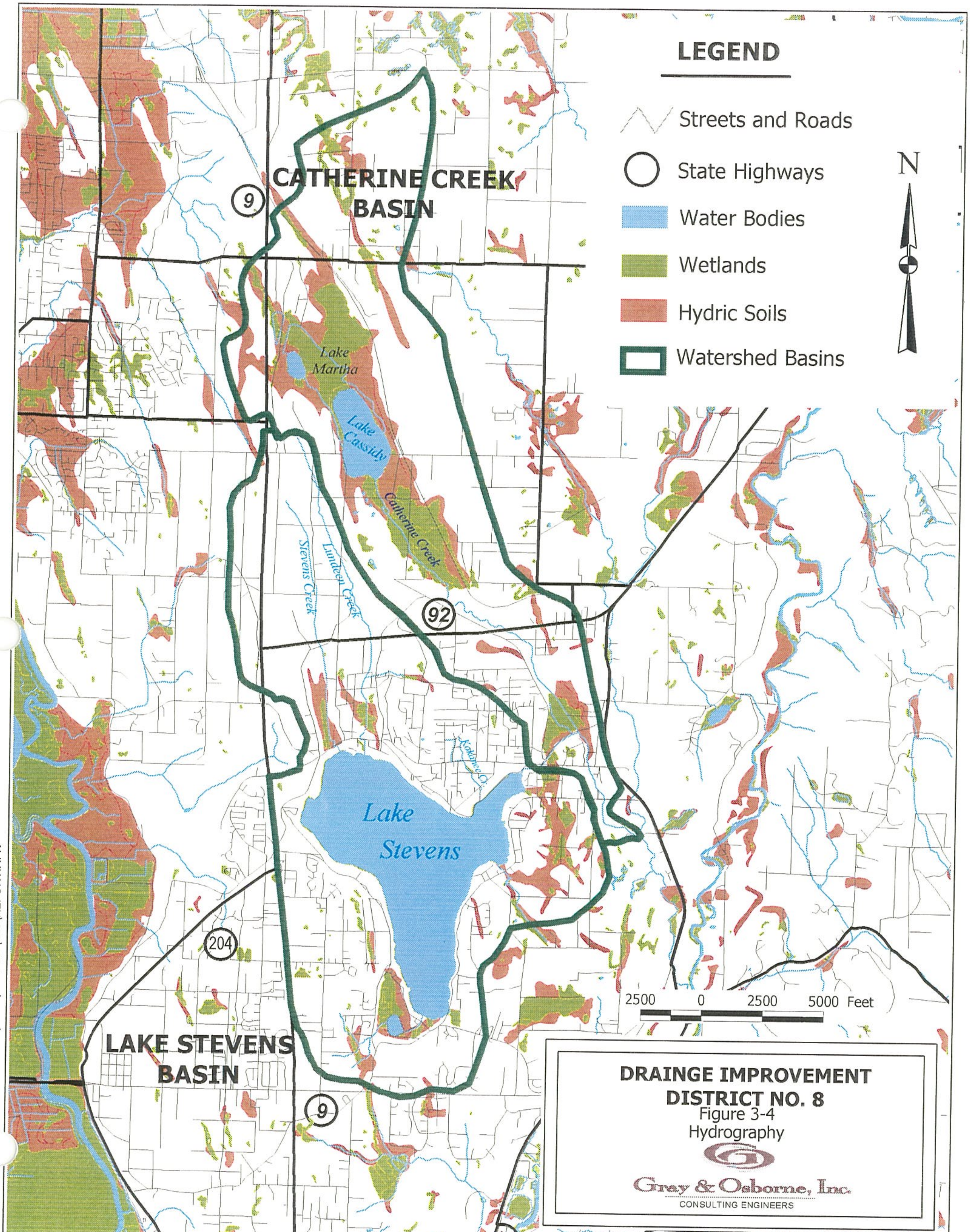

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Figure 3-4
Hydrography

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Frequently wetlands can lower total suspended solids (TSS) but in the process of plant growth, death and decay, total phosphorus, much of which in particulate form, is converted to soluble form. As the wetland plants decay, soluble phosphorus is released into the water column. Soluble phosphorus stimulates rapid plant growth and can induce algae blooms in lakes. Natural wetlands are usually in a dynamic equilibrium and the net change in biomass is negligible. However the biomass in constructed wetlands usually increases at least during the early years of existence, leading to a net uptake of phosphorus. Thus, constructed wetlands may have slightly higher removal efficiencies than natural wetlands.

Wetlands also provide critical functions in flood protection. First, they provide a flat broad area for the flood waters to spread out, minimizing the rise in flood stage. Second, wetlands attenuate storm flows by providing storage and slowly releasing water to the downstream channel. The attenuation of stream flows minimizes the impacts of flood waters on aquatic habitat downstream. Filling wetlands usually results in a rise in flood stage, increased velocities in streams and the degradation of aquatic habitat downstream including the loss of wetland habitat itself. Impacts of filling wetlands along Catherine Creek north of Hartford Drive are discussed in Chapter 4.

In recognition of the need to protect these valuable functions, wetlands were formerly classified in the Snohomish County Critical Areas Ordinance into Category 1, 2, 3, or 4 (Snohomish County Code 32.10.510). Table 3-4 summarizes the major features of the classes and the required protective buffers around the wetlands.

TABLE 3-4

Wetland Classification And Required Buffers

Wetland Category	Classification Definition	Rural Buffer	Urban Buffer
Category 1	>10 acres containing three or more wetland classes including open water, or documented by WDFW as regionally significant habitat, or bog/fen >1 acre, or mature forested wetland >10 acres	100 feet	75 feet
Category 2	>5 acres containing three or more wetland classes, mature forested wetlands <10 acres, or bog/fen <1 acre	75 feet	50 feet
Category 3	Non-riparian <1 acre with >90% coverage by invasive plant species	50 feet	50 feet
Category 4	Wetlands which do not satisfy criteria for Categories 1, 2, or 3	25 feet	25 feet

FISH AND WILDLIFE

WILDLIFE

The variety of topography, soils, and vegetation described above has created a variety of habitat niches for wildlife in the study area. Lake Stevens is used by a large assortment of birds. These include songbirds, red-tail hawks, sharpshinned and Cooper's hawks. Osprey and Blue Heron have also been known for feeding and roosting around the lake. Other common species include black-tailed deer, beaver, coyotes, meadow voles, and muskrats. Large animals such as cougar have been recently observed in the northern portions of the watershed.

A variety of insects and benthic (or bottom-dwelling) animals exist within the study region. Various benthic animals include phantom midge and sparse bloodworm populations. The benthic environment is discussed further in Chapter 6. Fish within the area feed upon caddisflies, mayflies, and stoneflies.

FISHERIES

The Lake Stevens and Catherine Creek watershed has traditionally supported a variety of fish runs. Among those species have been, kokanee, coho and chinook salmon, cutthroat trout and bass. Lake Cassidy has long been recognized as an excellent bass fishery. The fishery resources and the impacts of future land development on fisheries will be discussed in Chapter 6.

THREATENED/ENDANGERED SPECIES

Several federally listed endangered, threatened, or candidate species occur in the plan area (see Table 3-5). The United States Endangered Species Act (ESA) of 1973 requires that federal agencies involved in funding, licensing, permitting, or providing other authorization for projects resulting from this comprehensive basin plan conduct a biological assessment of the project area to determine if a listed or proposed species is present and if appropriate habitat exists. Federal projects requiring an assessment include any public works project which receives federal funding. Puget Sound Chinook salmon was recently listed as a threatened species and Puget Sound Coho salmon may be listed as threatened or endangered in a year or two. The potential impacts of these listings on development and land use within the Puget Sound are discussed in Chapter 6.

TABLE 3-5

Endangered, Threatened, Or Candidate Species

Species	Status	Comments
Bald Eagle (*Haliaeetus leucocephalus*)	Listed	5 nesting territories; nesting occurs from about 1/1 to 8/15; wintering eagles may occur between 11/31 and 3/31
Peregrine Falcon (*Falco peregrinus*)	Listed	
Northern Spotted Owl (*Strix occidentalis caurino*)	Listed	Nesting activities may occur between 3/1 and 9/15
Marbled Murrelet (*Brachyramphus marmoratus marmoratus*)	Listed	Nesting occurs between 3/1 and 9/15
Puget Sound Chinook Salmon (*Oncorhynchus tshawytcha*)	Threatened	Listed March 16, 1999
Puget Sound Coho Salmon (*Oncorhynchus kisutch*)	Threatened	Possible listing in 1999

EXISTING STORMWATER SYSTEM

A survey of the existing detention facilities was conducted in the fall of 1998 to identify systems could be retrofitted to increased detention and or water quality treatment. The results of this survey are shown in Figure 3-5. The majority of the facilities consisted of oversized pipes or vaults. Due space limitations these systems could not be retrofitted without a significant expenditure of funds. Newer detention ponds were found around the Stevens Creek area as well as the east of the lake. These ponds were designed to current DOE standards which, as mentioned in Chapter 2, have demonstrated to be insufficient to handle the increased flows created by development. Again space limitations precluded an easy retrofit of these systems. Table 3-6 displays the size of each detention system.

In addition to the survey an aerial analysis of the lake front and the major tributaries was performed in August of 1998 by A. W. Research Laboratories. The intent of the aerial survey was to identify major outfalls to the lake and or streams and to assess changes since the 1986 aerial analysis. The aerial analysis identified many non-point sources but no major outfalls. The conclusion drawn from the aerial analysis is that the water quality of the lake is being impacted from a myriad of small pollutant sources. There did not appear to be any major sources impacting the water quality of the lake at the time of the August 1998 aerial analysis.

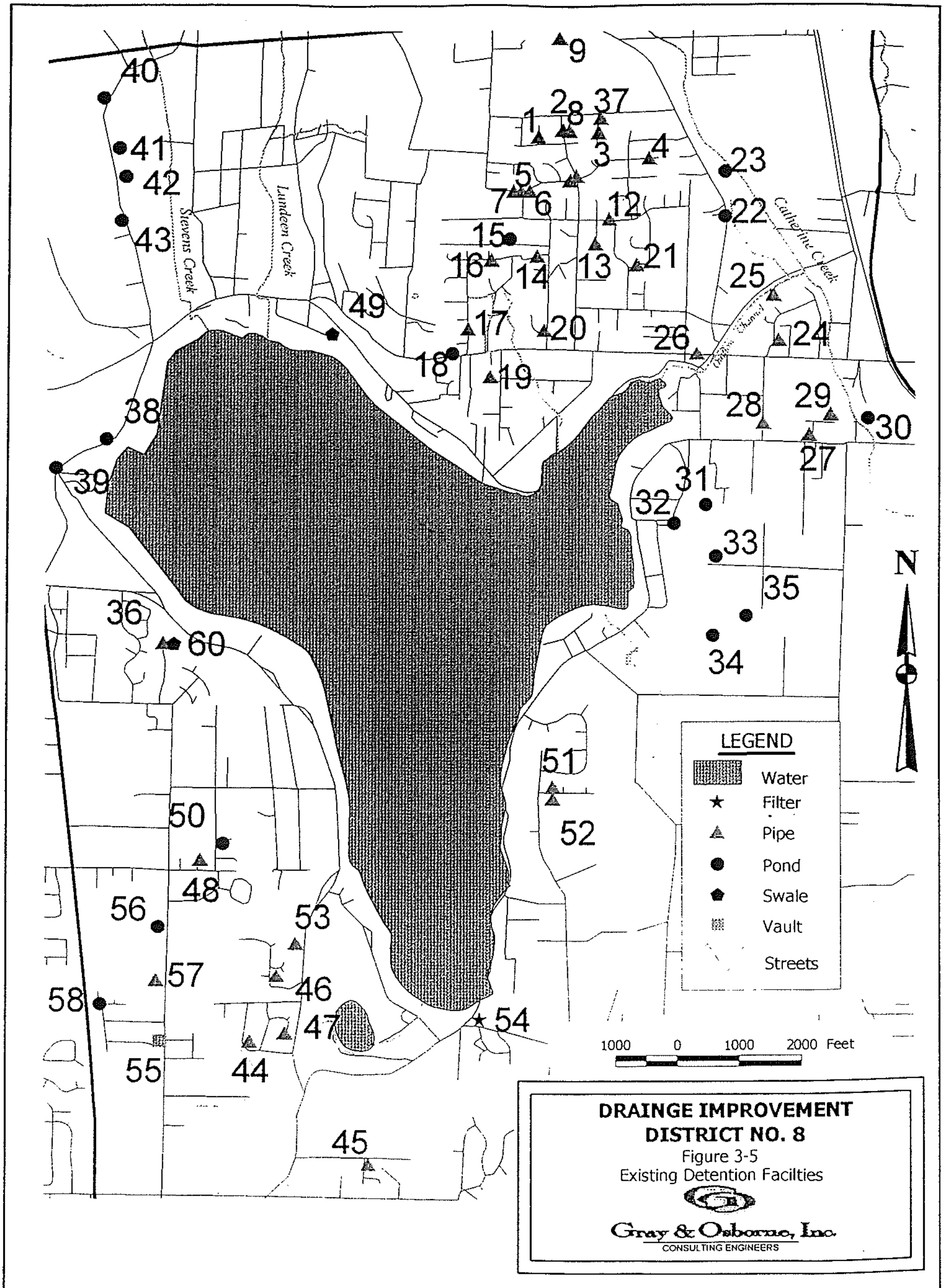

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Figure 3-5
Existing Detention Facilties

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TABLE 3-6

Inventoried Detention Sizes

ID No.	Type	Size (cf)	ID No.	Type	Size (cf)
1	Pipe	11,696	31	Pond	N/A
2	Pipe	4,280	32	Pond	636
3	Pipe	4,077	33	Pond	N/A
4	Pipe	1,511	34	Pond	N/A
5	Pipe	145	35	Pond	N/A
6	Pipe	1,909	36	Pipe	10,053
7	Pipe	7,606	37	Pipe	245
8	Pipe	1,508	38	Pond	N/A
9	Pipe	40,000	39	Pond	N/A
10	Pipe	6,043	40	Pond	N/A
11	Pipe	4,630	41	Pond	11,154
12	Pipe	12,203	42	Pond	11,681
13	Pipe	2,555	43	Pond	10,650
14	Pipe	4,856	44	Pipe	6,112
15	Pond	N/A	45	Pipe	160
16	Pipe	7,351	46	Pipe	120
17	Pipe	10,776	47	Pipe	5,327
18	Pond	N/A	48	Pipe	13,087
19	Pipe	N/A	49	Swale	N/A
20	Pipe	742	50	Pond	2,900
21	Pipe	3,732	51	Pipe	4,575
22	Pond	N/A	52	Pipe	1,777
23	Pond	N/A	53	Pipe	3,190
24	Pipe	2,827	54	Filter	N/A
25	Pipe	5,249	55	Vault	20,451
26	Pipe	N/A	56	Pond	29,766
27	Pipe	N/A	57	Pipe	5,773
28	Pipe	N/A	58	Pond	20,049
29	Pipe	1,414	60	Swale	N/A
30	Pond	N/A			

CHAPTER 4

HYDROLOGY AND HYDRAULICS

INTRODUCTION

Urban development impacts the quality and quantity of storm water runoff entering surface water bodies and ground water. As permeable soil and vegetation are replaced with impermeable pavement and buildings, water increasingly flows overland as surface runoff rather than slowly infiltrating into ground or surface water. This increases the fluctuation of river discharge, with greater volumes, higher peak flows and a more rapid response to precipitation during storms.

> "Runoff that was previously slowly released to streams through interflow now runs quickly off the surface directly into the streams. This increases both the velocity and total quantity of flow, causing streambank erosion and general habitat destruction. Sediment from increasingly eroded and unstable streambanks and cleared areas is deposited downstream, filling ponds, streambeds, and storm water facilities." (WDOE, 1992.)

In order to better understand the impacts of urban development, hydrologic and hydraulics models were developed as part of this study. Hydrology is the study of the interaction and transformation of precipitation to streamflow. This includes the interception of precipitation on vegetation and other surfaces, movement of water into and through the soil, runoff on the surface and via subsurface routes, and evapotranspiration. Together these interactions comprise the hydrologic cycle. As described below, we have used a computer model to simulate the hydrology of the Lake Stevens and Catherine Creek watersheds. This computer model, "Hydrologic Simulation Program Fortran" (HSPF), allows for estimation of the magnitude, frequency, and duration of different flood events under various development densities.

Hydraulics is the study of the movement of water once it is in a stream, river, or lake. The hydraulics are in part dependent on the hydrology. In this report, the term "hydraulics" focuses on the specific flood flows and depths that result from flooding in Lake Stevens, its outlet channel, and Catherine Creek. The complexity of the flooding problem in the Hartford Drive area required the use of a separate computer model, "Full Equation Model" (FEQ), to simulate the movement of the flood waters. FEQ computes flood depths, velocity and direction of flood water movement for given discharges and will simulate the changing water levels throughout a given time period. This model was used to give us information on historic flood events and then evaluate how different alternative solutions either reduce or increase flooding.

EXISTING CONDITIONS

The modeling effort, discussed below, is based upon the conditions observed in the watershed. These observations were both quantitative and qualitative. The quantitative observations come from the District installed gauging stations which allowed for the development of a relationship between stream stage, stream discharge and precipitation (Figure 4-1). Qualitative observations include observations of flow patterns and stream processes. These qualitative observations provide for a "reality check" on the modeling effort. For example, during the January 1, 1997 flood, water was observed going different directions over Hartford Drive into and out of the outflow channel at different times of the flood. This observation lead to a major revision of the hydraulic model in order to simulate these conditions. The quantitative stream monitoring data gave no indication of this occurrence.

FLOOD DAMAGE IN THE WATERSHED

Significant flooding has been reported in three locations within the watershed. The first is along the north side of Hartford Drive across from the outflow channel. The second is at the mouth of Stevens Creek where it discharges into Lake Stevens and the third is the Lake Stevens Business Loop road, east of the bingo parlor.

Flooding has occurred on the north side of Hartford Drive frequently in recent years (1994, 1996, and 1997), with periodic flooding of homes since 1980. During the January 1, 1997 flood, water damage was incurred in all the homes on the north side of Hartford Drive (See Figure 4-2). The January 1997 flood spurred the City in cooperation with the District to submit a Hazard Mitigation Grant in an attempt to secure funding to adequately address this issue. That grant application was unsuccessful.

In addition to the homes on Hartford Drive, flooding has been recurrent at the mouth of Stevens Creek where it discharges to the lake. In the January 1997 flood, a retaining wall on the east bank of the creek was undercut and destroyed. Scouring occurred underneath a house to the extent that the portions of the foundation were suspended above the ground surface. This damage was repaired by the District at a cost of $73,566 of which FEMA paid for $42,583 (see Figure 4-3).

Homes near the shores of Lake Cassidy and Lake Stevens are on occasion threatened by seasonal and storm-related high water. As land development continues in the watershed, flooding along streams is likely to increase, unless measures are taken to increase detention and better control storm water runoff.

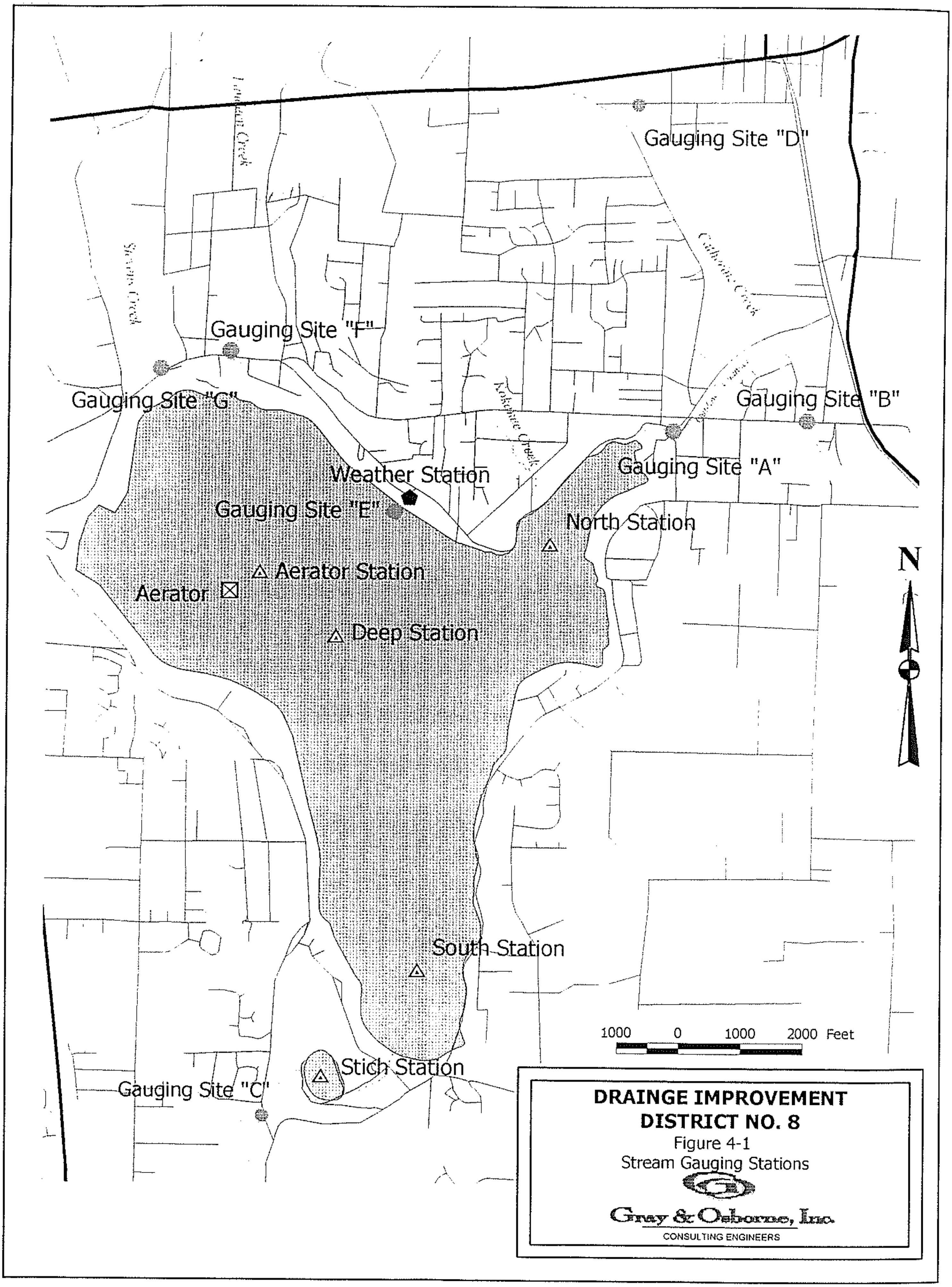

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Figure 4-1
Stream Gauging Stations

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Figure 4-2

Flood Conditions along Hartford Road
January, 1997

Figure 4-3

Rabin / Calles Property – Stevens Creek Flooding and Channel Repair

HYDROLOGIC MODELING

The purpose of hydrologic modeling is to predict the impacts of land use changes on streamflow. There are two parts to the modeling effort. The first is the calibration of the model. The second is the prediction of future flows based on future land use conditions.

Calibration of the model is important because it demonstrates the ability of the model to represent the actual observed conditions found in the watershed. A good calibration is essential if the model is to approximate future conditions and management alternatives.

The prediction of future flows and flood frequency is based on expected future land use conditions. Future land use is a function of expected development within the watershed, existing growth patterns in Snohomish County and the land use zoning for the areas that drain into Lake Stevens and Catherine Creek. The details of the future land use forecast are described below.

To model the Lake Stevens/Catherine Creek watersheds, the watersheds were divided into 41 subcatchments (Figure 4-4). Each subcatchment represents a portion of the watershed. The subcatchments are linked together to represent the streams and lakes. Precipitation, soil type, evaporation, stream information and land use information are all input and linked to the subcatchments and their hydrologic characteristics.

RELATIONSHIP BETWEEN PRECIPITATION, STREAM FLOW AND LAND USE

The relationship between precipitation, stream flow and land use is dependent upon several factors. These include rainfall intensity and duration, soil type, vegetation cover, slope, impervious surface, depth to water and the length of time it takes the runoff to reach a stream. Conversion of land from forest to pasture to residential use increases the amount of storm water runoff and decreases the response time. The amount of increased runoff due to development varies depending upon the factors sited above. "For the more frequent 2-year and 10-year storms, greater impervious coverage and a shorter drainage area response time produce peak runoff rates 5 to 10 times greater after development" (Horner et. al., 1994). The intent of storm water detention facilities is to prevent this

Increase in peak flow rates. The effectiveness of the detention systems is dependent upon the design methodology, which determines the detention volume and the discharge rate from the system, the quality of the construction of system and the maintenance of the system. As discussed below, to date the detention systems designed in the Lake Stevens area underestimate the volume of detention required to fully mitigate the impacts of development on stream flow. The result is more frequent high flow events than in the past, which has lead to increased flooding and aquatic habitat degradation.

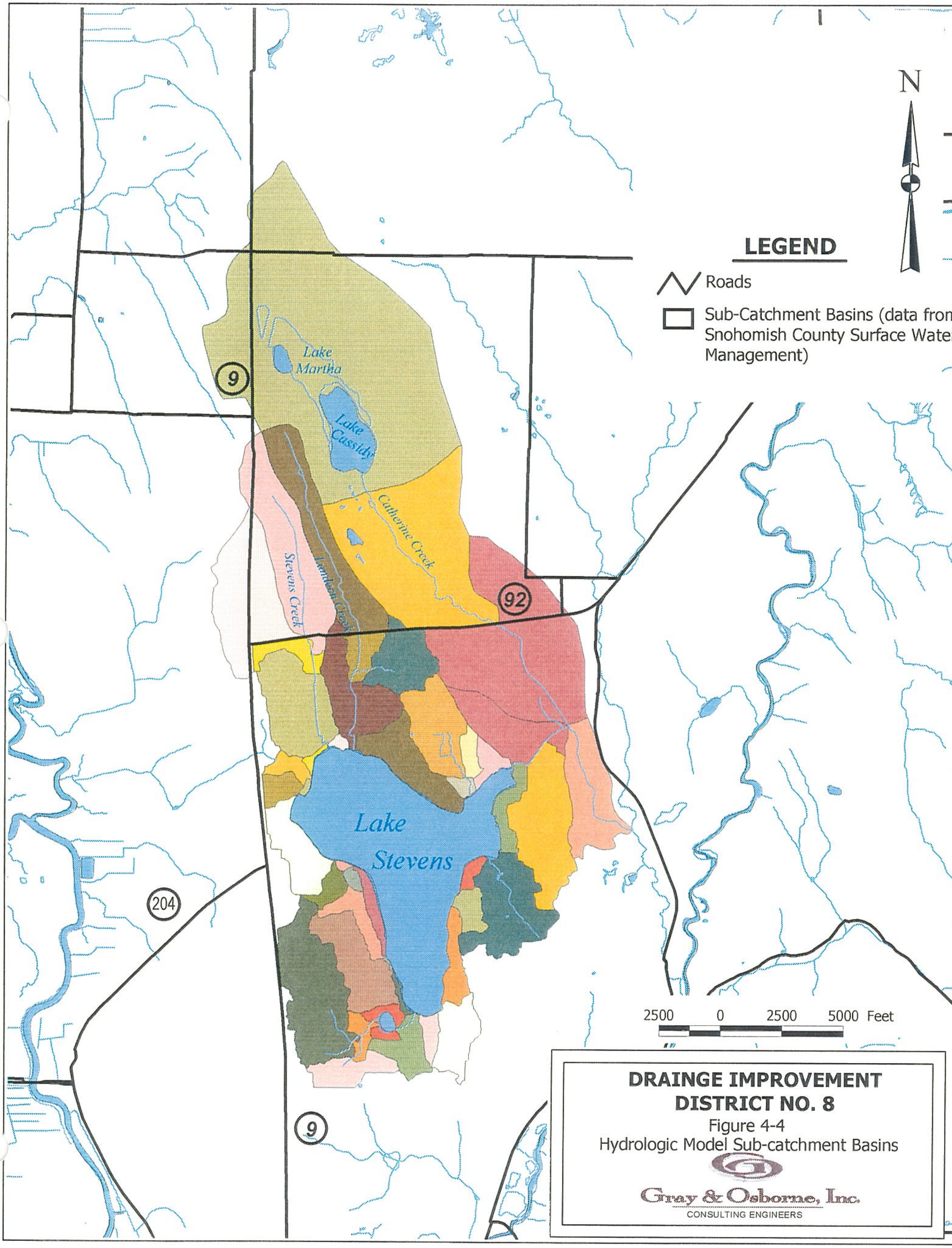

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Figure 4-4

Hydrologic Model Sub-catchment Basins

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PRECIPITATION, EVAPORATION, AND STREAMFLOW INPUT

The continuous simulation hydrologic model for this project computes on an hourly interval (time step) all of the components of the hydrologic cycle. Recorded hourly precipitation data and daily evaporation data are input to the model. The model uses the recorded hourly precipitation and daily evaporation to compute the amount of water in the soil (soil moisture), the amount of water returned to the atmosphere (by evaporation and transpiration), and the amount of water that becomes runoff.

Runoff is divided into three types: surface runoff, interflow, and ground water. Surface runoff, as the name implies, is the water that travels over the surface of the land to a conveyance system (pipe, ditch, stream, or river) or other body of water (pond, lake, or ocean). Surface runoff moves relatively quickly to its destination and is usually the major source of water in a flood.

Interflow moves slower than surface runoff but faster than ground water. It travels through the top layer of soil, and generally lags behind surface runoff in reaching a stream by only a matter of hours.

Ground water is the slowest of the three types of runoff. Water soaks into the ground and then travels deep into the soil where it reaches the water table. This water then travels slowly towards a stream, arriving there days, weeks or months after it fell as rain. Ground water seeping into streams during dry periods is the only water that keeps these streams from going dry during periods of drought.

Precipitation

Precipitation drives the runoff response. Therefore it is important to use a precipitation record in the model that accurately reflects the precipitation that fell on the watershed. In addition, if a flood frequency analysis is to be performed, 40 to 50 years of computed streamflow information is preferred. Historical precipitation is required at an hourly interval by the model. To accurately represent the distribution of the rainfall. Rainfall distribution in terms of the intensity of rainfall has a large impact on whether the rainfall will become surface runoff, interflow, or ground water, or never get to the stream (because it is evaporated instead). One inch of rain in an hour, an intense but short shower, produces a lot more surface runoff and total runoff than one inch of rain spread out over 24 hours (approximately 0.04 inches per hour). An hourly precipitation record is of sufficient resolution to distinguish the difference in rainfall intensity and distribution.

There is no precipitation gage in the Lake Stevens watershed with sufficient historical data to fulfill the needs of the HSPF model. An hourly precipitation gage is located to the northwest of Lake Stevens at the Hewlett Packard campus on Soper Hill Road. This gage is owned and operated by Snohomish County Surface Water Management and has been in operation since 1992.

To construct a long-term (40+ years) precipitation record, the National Weather Service precipitation gage at Everett was used. This gage has been recording hourly precipitation since October 1948. The Everett precipitation record was compared with the Soper Hill record data to see how they differ in total volumes for years in which both gages were operating. Because there was less than two years of overlapping data, it was not possible to do a statistically significant comparison. We assumed that the Everett and Soper Hill precipitation amount are statistically similar. Therefore, the Everett record was used in the model for the years (1948 through 1992) prior to the establishment of the Soper Hill gage.

Evaporation

Evaporation is a major factor in the hydrologic cycle. A typical watershed in the Puget Sound lowlands receives approximately 40 inches of precipitation a year. Of this 40 inches approximately half (or 20 inches) returns to the atmosphere as evaporation or transpiration (transpiration is the act of vegetation removing moisture from the soil and returning it to the atmosphere). The other 20 inches of precipitation becomes runoff to streams, lakes and other waterbodies.

Evaporation is input to the model as potential evapotranspiration (PET). PET is the maximum amount of water that can be returned to the atmosphere at any one time. Actual evapotranspiration is calculated in the model based on the PET demand and the amount of water available in the soil and on the land surface for evaporation and transpiration.

PET is input to the model in the form of pan evaporation data. This is evaporation data measured in a standard Class A pan. The nearest Class A pan is located in Puyallup at the Washington State University Experimental Field Station. Puyallup is approximately 60 miles south of Lake Stevens, but because evaporation does not vary greatly in the Puget Sound lowland watersheds, the distance from the study area is assumed to not be significant.

Daily pan evaporation data were used in the model. The model divides the daily evaporation data into 24 hourly values to compute hourly actual evapotranspiration. Pan evaporation data was adjusted to PET data by multiplying the pan evaporation by 0.80.

Streamflow

The purpose of the HSPF model is to evaluate the impacts of future land use development on streamflow. Prior to being able to simulate future flows, the model results have to be compared to existing conditions to ensure that the simulated streamflow is representative of actual field conditions. This comparison is used to calibrate the model to the conditions observed in the watershed.

The District established a series of stream gages to collect recorded streamflow data on the streams in and near the Lake Stevens watershed (Figure 4-1). Seven sites were selected for model calibration. At six of the sites, streamflow data are collected. At the seventh site on the north end of Lake Stevens, lake levels are observed daily.

The calibration effort and computation of current and future flood frequency was originally conducted in May 1997 in support of Snohomish County's EIS for the Lake Stevens Urban Growth Area (UGA). At that time, less than a year's worth of recorded streamflow data was available for the calibration effort. However, the 14 months of recorded Lake Stevens water surface elevation data allowed for simulating lake level fluctuations. The periods of the recorded streamflow and lake elevation data are summarized below in Table 4-1.

TABLE 4-1

Stream Gauging Stations

Site	Location	Period of Record[1]
A	Lake Stevens outlet channel near 124th Avenue N.E.	Sep 1996 - Feb 1997
B	Catherine Creek at 20th Street bridge	Dec 1996 - Feb 1997
C	Stitch Creek at North Davies Road	Dec 1996 - Feb 1997
D	Catherine Creek at 36th Street bridge	Dec 1996 - Feb 1997
E	Lake Stevens at Withrow residence	Jan 1996 - Feb 1997
F	Lundeen Creek near Lundeen Parkway	Dec 1996 - Feb 1997[2]
G	Stevens Creek near Lundeen Parkway	Dec 1996 - Feb 1997

1 Data available at time of initial calibration.
2 No rating curve to convert stage to discharge had been created for the Lundeen Creek stream gage at the time of the calibration. No separate calibration was done for Lundeen Creek.

At each of the gauging sites (excluding E and F), stream stage (water depth) was converted to equivalent streamflow using a rating curve. The rating curve for a particular gage is computed from measured water depths and stream velocities. This requires an individual using a stream velocity meter to record velocity readings perpendicularly across the stream channel at specified depths and distances from one stream bank to the other side. A weighted average of cross section area and stream velocity are used to compute streamflow in units of cubic feet per second (cfs). With enough measurements at times of different flows, a rating curve or equation can be created to convert recorded stream depth or stage (in feet) to discharge or streamflow (in cfs).

Table 4-2 shows the rating equation used for each gage site to convert stage to discharge along with the maximum measured stage and discharge. Data has continued to be collected by the District from these gages. However, for modeling purposes the rating curve established early on in the monitoring process yielded data which provided for good model calibration. For the purpose of efficiency, more recent streamflow data were not incorporated into the model.

TABLE 4-2

Stream Gauging Stations

Gage	Rating Equation	Max Measured Stage (ft)	Max Measured Discharge (cfs)
A	-9.949x^3 + 37.336x^2 – 2.9058x	2.32	71
B	(x/0.0407)^1.1236	2.84	97
C	(x-0.3511)/0.556	1.1	13
D	27.44x^2 - 13.088x - 0.9974	1.8	65
E	no equation; lake stage	N/A	N/A
F	no equation	0.78	3.1
G	(x/1.1383)^3.968254	3.9	60

x equals stage in the rating equations. The rating equations were generated using best fit curve algorithms available in Excel 97 spreadsheet software.

A more detailed discussion of the recorded streamflow and stage data is presented in the Lake Stevens report for Snohomish County found in Appendix A (Beyerlein and Brascher, 1997).

Land Information Input

Land information plays a large role in what the precipitation does and becomes once it lands on something. Rainfall on a parking lot quickly becomes runoff whereas rainfall on a forest does not..

Three major components: soil, vegetation, and topography, influence the rate of runoff. In the model, the soil, vegetation, and topographic information are combined into different land types. Each land type has a different set of hydrologic parameter values (discussed below) that produces a unique runoff response to rainfall. Some land types produce a lot of runoff, others little.

For the Lake Stevens and Catherine Creek watersheds, 17 specific land types have been identified and used in the model. They are:

1. TFF: till soil, forest vegetation, flat slope terrain (0-5% slope)
2. TFM: till soil, forest vegetation, moderate slopes (5-15 slope %)
3. TFS: till soil, forest vegetation, steep slopes (>15% slope)
4. TPF: till soil, pasture vegetation, flat slopes (0-5% slope)
5. TPM: till soil, pasture vegetation, moderate slopes (5-15% slope)
6. TPS: till soil, pasture vegetation, steep slopes (>15% slope)
7. TLF: till soil, lawn vegetation, flat slopes (0-5% slope)
8. TLM: till soil, lawn vegetation, moderate slopes (5-15% slope)
9. TLS: till soil, lawn vegetation, steep slopes (>15% slope)

10. OF: outwash soil, forest vegetation, all slopes
11. OP: outwash soil, pasture vegetation, all slopes
12. OL: outwash soil, lawn vegetation, all slopes
13. SF: saturated soil, forest vegetation, all slopes
14. SP: saturated soil, pasture vegetation, all slopes
15. SL: saturated soil, lawn vegetation, all slopes
16. EIA: effective impervious land, no vegetation, all slopes
17. Lake: open water bodies (lakes), no soil, no vegetation, no slope

Till soils have been compacted by glacial action. As a result, some soils overlie a compressed soil layer commonly called "hardpan" or till. This hardpan has very poor infiltration capacity. As a result, till soils produce a relatively large amount of surface runoff and interflow. A typical example of a till soil is an Alderwood soil (SCS class C).

Outwash soils have a high infiltration capacity due to their sand and gravel composition. Outwash soils have little or no surface runoff or interflow. Instead, almost all of their runoff is in the form of ground water: An Everett soil (SCS class A) is a typical outwash soil.

Saturated soils are usually found in wetlands. They have a low infiltration rate and a high ground water table. However, these soils which are generally saturated can dry out and when they do they have a high storage capacity and produce very little runoff. However, once they become saturated they convert almost all precipitation into surface runoff, interflow, and ground water. Mukilteo muck (SCS class D) is a typical saturated soil.

Forest vegetation represents the typical second growth Douglas fir found in the Puget Sound lowlands. Forests have a large interception storage capacity. This means that a large amount of precipitation is caught in the forest canopy before reaching the ground and becoming available for runoff. Precipitation intercepted in this way is later evaporated back into the atmosphere. Forests also have the ability to transpire moisture from the soil via its root system. This leaves less water available for runoff.

Pasture vegetation is typically found in rural areas where the forest has been cleared and replaced with large hay and grass lots. Often these pasture areas are used to graze livestock. The interception storage and soil evapotranspiration capacity of pasture is less than forest partially due to compression of the soils by mechanized equipment during clearing activities or by livestock. Pasture areas typically produce approximately 10 percent more total runoff than forest areas, and a doubling of peak flows compared to forested areas.

Lawn vegetation is representative of the suburban vegetation found in typical residential developments. Soils in these areas usually have been compacted by earth moving equipment, often with a layer of top soil removed. Sod and ornamental bushes replace native vegetation. Undetained peak flows from a typical four unit per acre subdivision may increase by a factor of five relative to forested areas, in large part due to the effective impervious area. Total undetained flow volumes may double.

The slope of the land or terrain affects the speed at which the surface runoff reaches the stream. Because outwash and saturated soils have so little surface runoff compared to till soils, no attempt is made to separate out the different slopes for these two categories of soil. Only till soils are separated into flat, moderate, and steep slopes.

Impervious land, as the name implies, allows no infiltration of water into the pervious soil. All runoff is surface runoff. Impervious land typically consists of paved roads, sidewalks, driveways, parking lots and building roofs. Natural impervious land can be found in the form of exposed surface bedrock, but this is rare in most watersheds in the Puget Sound area.

For the purposes of hydrologic modeling, only effective impervious area is categorized as impervious. Effective impervious area (EIA) is the area where there is no opportunity for surface runoff from an impervious site to infiltrate into the soil before it reaches a conveyance system (pipe, ditch, stream, etc.). An example of an EIA is a shopping center parking lot where the water runs off the pavement and directly into a catch basin where it then flows into a pipe and eventually to a stream.

In contrast, some homes collect the roof runoff into roof gutters and send the water to downspouts. When the water reaches the base of the downspout it can be directed either into a pipe or dumped on a splash block. Roof water dumped on a splash block then has the opportunity to spread out into the yard and infiltrate into the soil. Such roofs are not considered to be effective impervious area. Other situations where impervious surfaces are not considered effective impervious area include driveways, sidewalks, and patios that slope such that the runoff drains onto lawns or landscaped areas instead of to ditches or storm sewer systems.

The EIA value is estimated based on the land use (forest, low density residential, high density residential, multifamily, commercial, etc.) and previous experience in other Puget Sound lowland watersheds. The following EIA percentages were used in the HSPF model to determine the number of impervious acres (Table 4-3).

TABLE 4-3

Effective Impervious Area

Land Use	EIA %	Total % Impervious
Forest	0	0
Pasture	0	0
Lawn	0	0
Low density residential (<1 dwelling unit/acre)	4	15
Medium density residential (1-3 du/ac)	10	15 – 34
High density residential (3-7 du/ac)	26	34 – 56
Multifamily (>7 du/ac)	48	> 56
School	48	
Roads	86	100
Commercial and industrial	86	>70 varies
Lakes	0	

The nomenclature for the land use categories used in the model, for example "Medium Density Residential", is different from that used by the County's planning department. The current Growth Management Act planning process considers Urban Medium Density to be 6 to 12 units per acre (Figure 2-8 and 2-9). During the transformation of the land use data into model input data this difference in nomenclature was accounted for.

Vegetation often varies by the type of land use. Medium and high density residential, multifamily, school, roads, and commercial and industrial are all assumed to have lawn as their typical pervious area vegetation. In low density (rural) residential areas the vegetation is often a mixture of lawn (in front of the house), pasture (in back), and maybe some forest. For low density/rural residential land the pervious area was split to 70 percent pasture and 30 percent forest.

Lakes (Lake Stevens, Stitch Lake, and Lake Cassidy) are modeled as part of the stream channel system and are not assigned an EIA. In the model, rain falls directly on the lake surface; lake evaporation is also computed directly based on lake surface area.

Land development information was used to model current and future land use conditions. Current land use conditions are as of 1996. Current conditions were developed based on available aerial photography and Snohomish County GIS information. Current land use acres divided by land type are presented in Table 4-4. Land use was estimated for each of the 17 land types for each of the 41 subcatchments. Tables 4-4 and 4-5 present a summary of the data.

TABLE 4-4

Current Land Use

Land Type	Acres
Forested	2952
Pasture	1778
Lawn	1672
Effective Impervious Area	768

Future land use conditions are based on the idea of full build-out in the watershed. No date or year is assigned to future land use because the timing of full build-out is unknown. Full build-out assumes that the watershed will eventually be developed to the maximum level allowed by Snohomish County and the City of Lake Stevens. The county and city comprehensive plans and UGA boundaries were used to determine the amount and location of future development to be included in the model.

Future conditions assume no storm water mitigation on future development. This is the worst case scenario for future development. This scenario is based on the 1979 drainage standards required as of May 1997 for new development under Snohomish County's Title 24 regulations. The 1979 regulations require mitigation, but in practice, the level of mitigation required by the original Title 24 is insufficient to keep future peak flows from increasing due to increased development. For modeling purposes, the 1979 mitigation requirements are the same as no mitigation. Future full build-out land types by acre are shown in Table 4-5. (Note: In August 1998 the Snohomish County Council approved a revised Title 24 that requires stormwater mitigation to Department of Ecology standards. However, the new mitigation requirements are only for plats recorded after August 1998. Development on previously platted lots is not affected.)

TABLE 4-5

Future Land Use

Land Type	Acres
Forested	657
Pasture	2522
Lawn	2602
Effective Impervious Area	1389

As discussed earlier even the new detention standards are likely to be insufficient to control increases in storm water runoff, particularly for the larger storms. Thus the assumption of no detention is likely to simulate future conditions more closely than building theoretical detention systems into the model. (See Chapter 2, Drainage Ordinances).

Stream Information Input

Stream channel system information is required to model the flow of the water in the streams flowing into Lake Stevens, out the Lake's outlet channel, and down Catherine Creek to its confluence with Little Pilchuck Creek. The speed at which water moves through the stream channel network depends on the size and shape of the stream channels and adjacent floodplain, the slope of the channels, the roughness of the channels and floodplain surfaces, and the size and location of obstructions in the channel network.

Much of the stream channel information was collected by Snohomish County Surface Water Management as part of the County's study of the area. Additional survey work in September 1997 added data on the outflow channel, Hartford drive and peak flooding from the New Year's Day 1997 storm.

CALIBRATION

The model computes the water balance and runoff is routed through the stream channel system. To make sure that the amount and timing of calculated (or simulated) streamflow accurately represents actual stream conditions, the model must be calibrated to known (or recorded) streamflow. The accuracy of the model is judged by the comparison of the model's simulated streamflow with recorded streamflow.

HSPF Model Parameters

Calibration requires selecting appropriate parameter values that represent the physical hydrologic processes for the watershed, testing the values by comparing the model results with recorded streamflow data, and modifying parameter values where appropriate to achieve a better match between simulated and recorded results.

The Lake Stevens HSPF model results were compared with recorded streamflow at the District gage sites (Figure 4-1). Comparison plots of simulated and recorded streamflow are presented in Figures 4-5, 4-6, 4-7, 4-8, and 4-9 for sites A, B, C, D, and G, respectively. A comparison plot of simulated and recorded lake stages (elevations) is shown in Figure 4-10 for Site E.

Because of the short time period for most of the recorded streamflow data (less than one year) the calibration was most heavily weighted in terms of trying to accurately simulate Lake Stevens water surface elevations (lake stages). The recorded lake levels included the flood of New Year's Day 1997 (1 January 1997) which reached a peak water surface elevation of 213.1 feet (1929 NGVD). As shown in Figure 4-10, the calibrated model does a good job in reproducing this peak lake flood elevation in addition to simulating summer low lake levels.

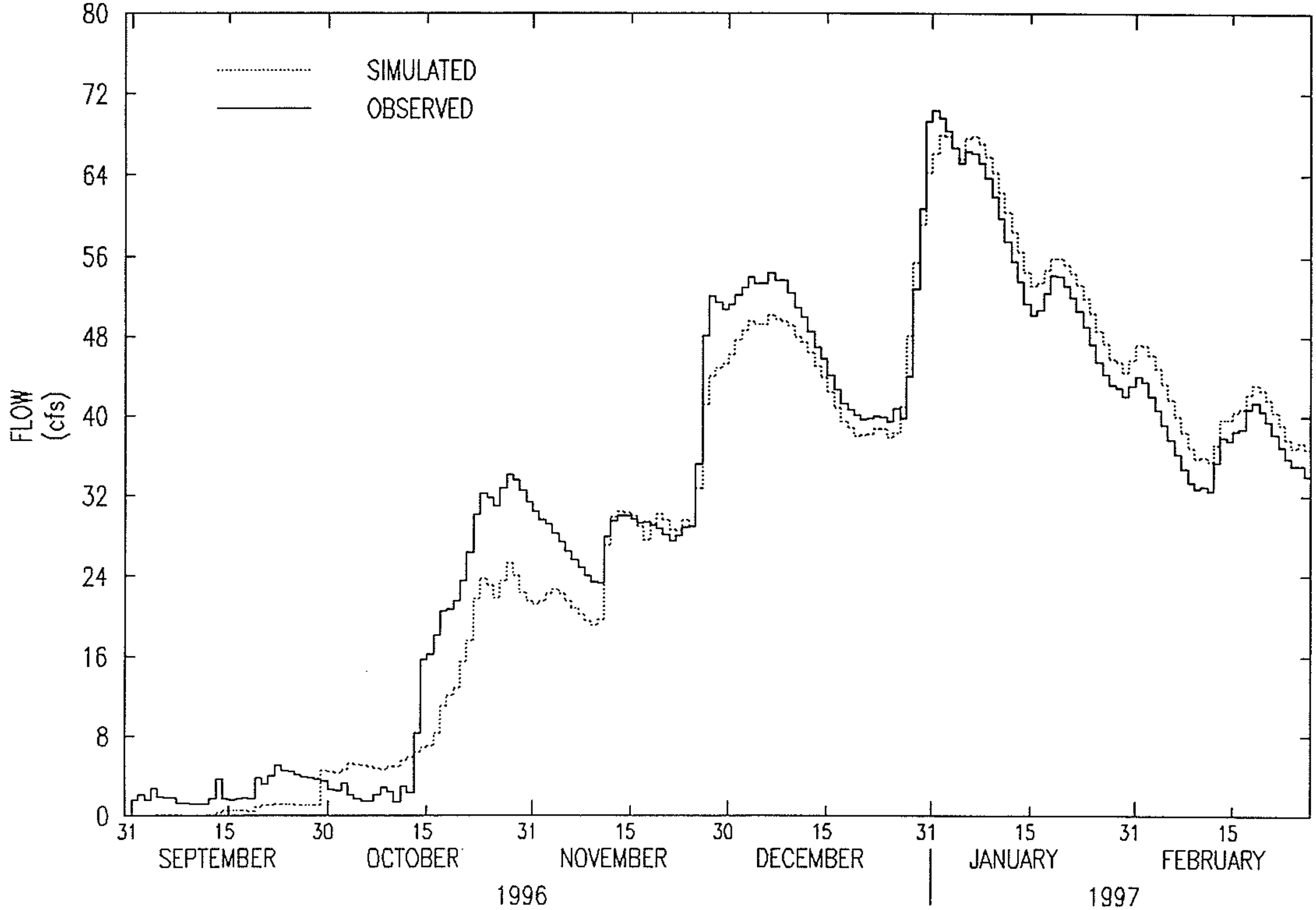


FIGURE 4-5
HYDROGRAPH SITE A
MAY 18, 1997

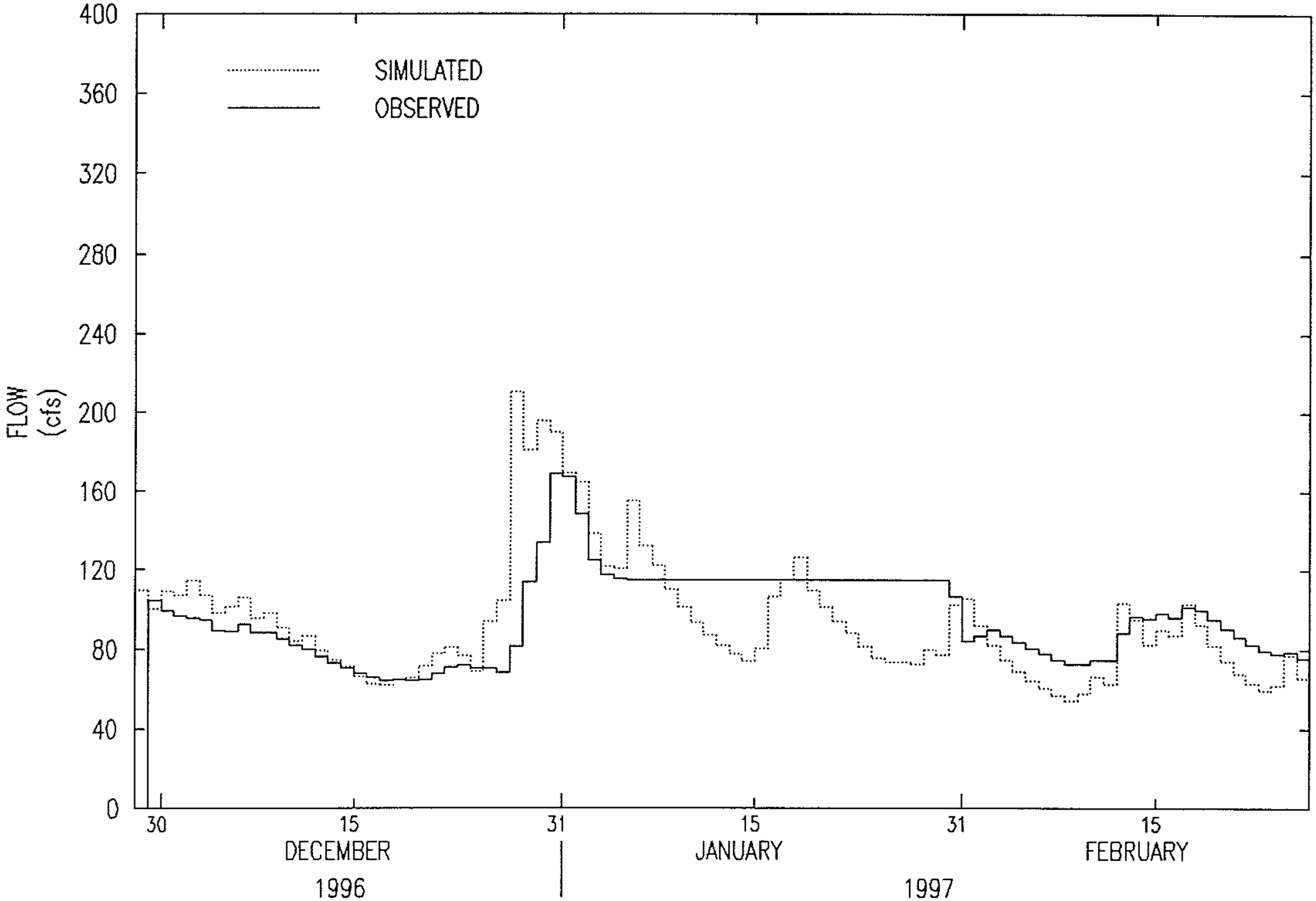


FIGURE 4-6
HYDROGRAPH SITE B
MAY 18, 1997

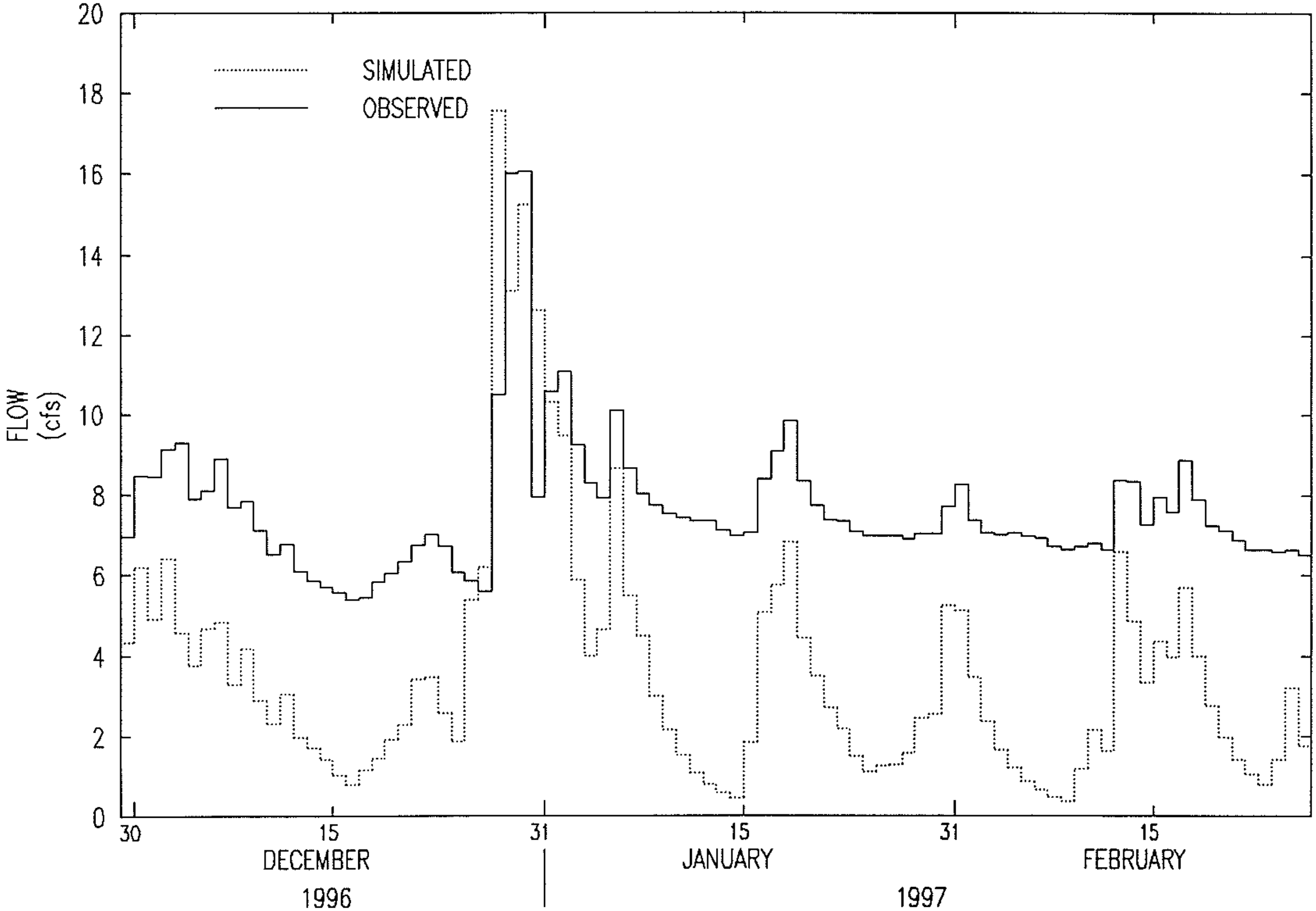


FIGURE 4-7
HYDROGRAPH SITE C
MAY 18, 1997

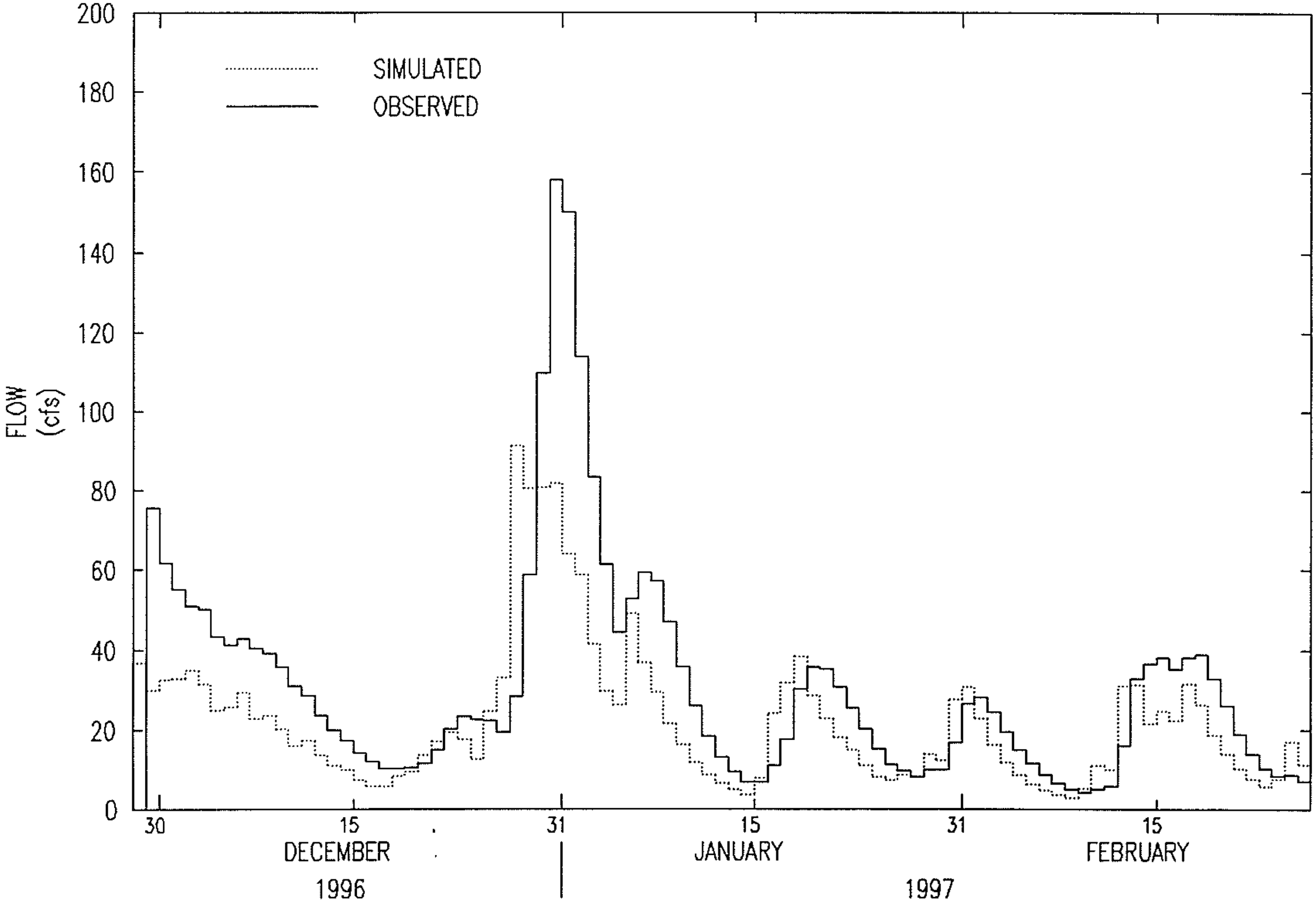


FIGURE 4-8
HYDROGRAPH SITE D
MAY 18, 1997

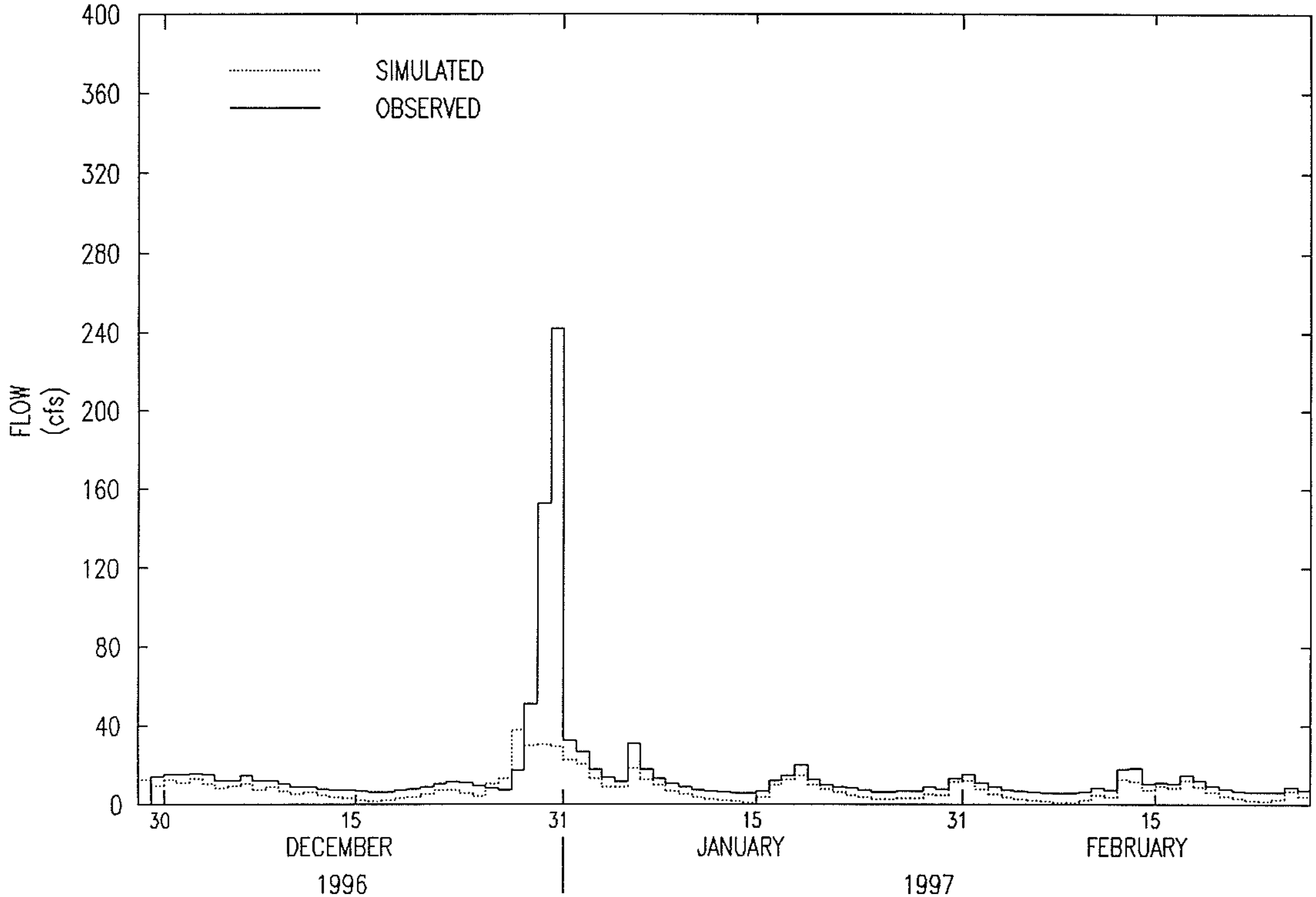


FIGURE 4-9
HYDROGRAPH SITE G
MAY 18, 1997

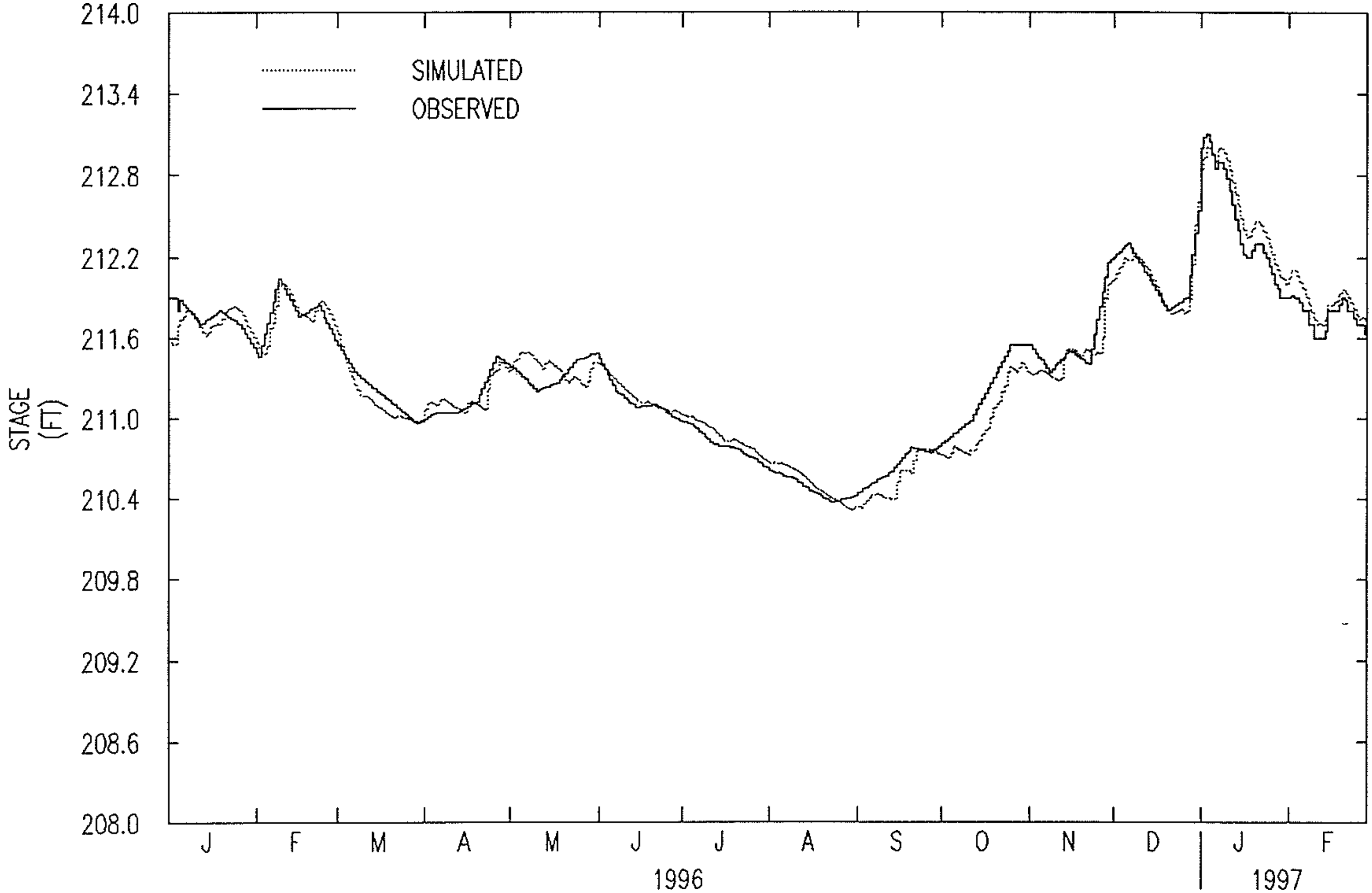


FIGURE 4-10
HYDROGRAPH OF LAKE LEVEL
MAY 18, 1997

Additional information related to the calibration of the HSPF model for Lake Stevens and Catherine Creek can be found in appendix A in the Lake Stevens report for Snohomish County, (Beyerlein and Brascher, 1997).

With the calibrated model, long-term (40+ year) simulations could be made to generate simulated streamflow for current and future land use conditions. These long-term simulations are used to compute flood frequency and to evaluate potential future streamflow problems in the watershed.

LONG-TERM SIMULATIONS

Calibration of the Lake Stevens HSPF model allowed for its use to evaluate the impacts of land use changes on flood flows and lake elevations. The evaluation of land use impacts was conducted by modifying the HSPF model to represent different land use conditions. For each land use condition a long-term (48 year) simulation is modeled to generate hourly streamflow data at different points of interest in the study area. These flow data are statistically analyzed to determine how different land uses change the streamflow and lake levels over a long period of time.

Flood Frequency

The 48 years of hourly streamflow data were analyzed by computing the flood frequency of the stream at specific locations. Flood frequency results are typically summarized in terms of the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year floods. The 2-year flood has a 50 percent chance (or probability) of occurring in any single year. The 100-year flood has a 1 percent chance of occurring in any one year. A flood larger than a 100-year flood can occur, but has a probability of less than 1 percent. For regulatory purposes (flood insurance and detention requirements, etc.) the 2-year, 10-year, and/or 100-year flood are often used as standards by which decisions are made.

There are numerous procedures used to compute flood frequency. Each is based on a different theoretical statistical distribution and assumptions. The standard procedure selected for nationwide use for flood insurance studies by the U.S. Water Resources Council is the Log-Pearson Type III distribution. The procedure is described in the publication *Guidelines For Determining Flood Flow Frequency*, Bulletin #17B of the Hydrology Committee, U.S. Water Resources Council, Washington, DC, revised September 1981. This flood frequency procedure was used to compute flood frequencies for the streams entering Lake Stevens, the outlet channel, and Catherine Creek.

Current Land Use Conditions

Current land use flood frequency results are presented in Table 4-6 for each stream reach in the study area. The results are used as the baseline condition by which the flood frequency results based on future land use changes can be compared.

TABLE 4-6

Current Land Use Flood Frequency Results

Location	2-Year Discharge (cfs)	10-Year Discharge (cfs)	100-Year Discharge (cfs)
Site A	43	55	68
Site B	129	188	273
Site C	21	30	42
Site D	64	108	97
Site F	26	39	54
Site G	33	48	66

This use of current land use results as the baseline does not mean that the only flood problems are the result of future development in the watershed. In fact, there has been substantial changes from historical (predevelopment) conditions to current land use conditions and flood flows have increased correspondingly. For more information on the historic flood frequency see the Lake Stevens report for Snohomish County in Appendix A (Beyerlein and Brascher, 1997).

FUTURE LAND USE CONDITIONS

The land use conditions both existing and future are presented in Chapter 2. In the development of future land use Snohomish County has presented six alternatives. The model uses the data from Alternative 2 developed in the spring of 1997. This alternative is based on one set of Snohomish County's projected development patterns for the Lake Stevens area and includes higher density development in the Lake Stevens Urban Growth Area (UGA) and lower density development outside of the UGA. Since the receipt of the data for this model from the Surface Water Management Division of the County, the County Planning Department has developed additional alternatives of possible land use development. Alternative 6 is the most recent and reflects a somewhat higher population than that in Alternative 2. For a given area, increased population means increased density and usually increased effective impervious area. Thus, based solely on land use conditions, the model may be under predicting the impacts of development. A density of greater than three units per acre is considered high density for modeling purposes. The recent County proposals indicate zoning may be increased to six units per acre rather than four units per acre.

Table 4-7 shows the flood frequency results for future land use.

TABLE 4-7

Future Land Use Flood Frequency Results

Location	2-Year Discharge (cfs)	10-Year Discharge (cfs)	100-Year Discharge (cfs)
Site A	44	56	69
Site B[(1)]	156	232	347
Site C	31	41	53
Site D	74	123	196
Site F	35	48	61
Site G	48	71	100

1 Assumes Hartford Drive current elevation, Hartford Drive wetlands and culverts under Hartford Drive.

Future land use conditions without mitigation are equivalent to the implementation of minor stormwater mitigation facilities that are typically undersized and poorly maintained. They provide little or no benefit and often give the public the mistaken impression that flooding problems will be controlled. And, as discussed in Chapter 2, stormwater mitigation based on current Department of Ecology and Snohomish County standards is not sufficient to prevent an increase in flood flows, particularly for larger flood events.

New development will require detention facilities to be installed. However, future land use conditions in the model do not include storm water detention facilities. Each detention facility is site specific, designed for the particular size and hydrologic/hydraulic characteristics of the site. Thus, each storm water detention facility is different, and the runoff characteristics for each facility are uniquely designed.

An option for modeling individual onsite detention facilities is to place a detention facility at the downstream end of each subcatchment. These "model facilities" would be designed to reflect the current county detention requirements and release rates. However, this methodology likely over estimates the efficiency of onsite detention. Onsite storm water detention may perform below expectations due to poor design, poor construction or poor maintenance.

In conclusion, the land use assumptions in the model may under predict the land use development in the watershed. This under prediction is offset by the lack of modeled detention on future development. Lastly, as discussed in Chapter 2, detention to the level of the current Ecology and Snohomish County standards is probably not sufficient to prevent an increase in the storm related discharge in streams, particularly for the larger events.

RESULTS

Table 4-8 shows an increase in 2-year flood values ranges from 6 to 51 percent for the study streams that enter Lake Stevens. Kokanee Creek shows the smallest increase in 2-year flood flows. This small creek drains a residential area on the north side of Lake Stevens. The increase in two-year flood flows is only six percent. The reason for the smaller than average increase from current to future is because the Kokanee Creek drainage is in a mature residential area that will probably see only small changes in the amount of development in the future. Little new impervious area is expected and this is reflected in the small increase in flood flows.

TABLE 4-8

Projected Increases In Flow For 2-Year Storm

Stream Location	Increase In 2-Year Flood	
Stevens Creek entering Lake Stevens	44%	
Lundeen Creek entering Lake Stevens	36%	
Stitch Creek entering Lake Stevens	51%	
Catherine Creek above Hartford Drive	15%	
Catherine Creek at Little Pilchuck	11% (1)	15% (2)
Kokanee Creek at North Lakeshore Drive	6%	

1 Assumes the wetlands north of Hartford Drive and the culverts remain.
2 Assumes that 50 percent of the wetlands are filled in and that the culverts are replaced with a bridge.

Catherine Creek 2-year flood flows increase 15 percent above the confluence with the Lake Stevens outlet channel. Downstream of the confluence the amount of increase is, in part, dependent upon the amount of development in the wetland area north of Hartford Drive and whether or not the culverts under Hartford Drive are replaced with a bridge to allow more water to pass. The increase in flows ranges from 11 to 15 percent downstream of the confluence. Much of the Catherine Creek watershed is located north of Highway 92 and is outside the Lake Stevens UGA. While development is expected to occur outside of the UGA, it will be at relatively low densities. This is reflected in the expected increase of only 15 percent in the 2-year flood north of Hartford Drive.

The 100-year flood increases (see Table 4-9) are typically in the same range as the 2-year increases, with one notable exception. Lundeen Creek shows an increase of only 14 percent from current to future conditions for the 100-year flood.

TABLE 4-9

Simulated Increase In Flows For The January 1, 1997 Flood

Stream Location	Increase In 100-Year Flood	
Stevens Creek entering Lake Stevens	54%	
Lundeen Creek entering Lake Stevens	14%	
Stitch Creek entering Lake Stevens	25%	
Catherine Creek above Hartford Drive [1]	4% [2]	24% [3]
Catherine Creek at Little Pilchuck	12% [4]	41% [5]
Kokanee Creek at N Lakeshore Drive	8%	

1 Flow underneath Hartford Drive immediately upstream of the confluence with the Outflow Channel.
2 Assumes flow over Hartford Drive and into the wetlands north of the culverts under Hartford Drive.
3 Assumes flood flows cannot flow over a raised Hartford Drive, 50 percent of the wetlands filled and a bridge replaces the culverts under Hartford Drive.
4 Assumes existing Hartford Drive, wetlands and culverts.
5 Assumes flood flows cannot flow over a raised Hartford Drive, 50 percent of the wetlands filled and a bridge replaces the culverts under Hartford Drive.

The reason for this smaller than average increase in peak flood flows is because much of upper Lundeen Creek is outside of the Lake Stevens UGA and is already developed into rural residential lots and open pasture. The level of development in this rural area is not expected to significantly increase based upon the currently proposed UGA limits. The lower portion of Lundeen Creek is in the UGA and is subject to higher intensity development. However, much of this area is already filled in with suburban residential lots.

As noted for the 2-year flood, the Kokanee Creek 100-year flood increase is less than 10 percent. Only small changes in land use from current to future in this drainage are expected, thus the projected flow increase is relatively small.

The Catherine Creek 100-year flood increase is greater downstream of the confluence with the Lake Stevens outlet channel than upstream. Upstream of the confluence the increase is 17 percent; downstream it is 27 percent.

The percent increase in the size of flood flows takes into account the complex hydraulic interactions that occur when the outlet channel flood waters flow over Hartford Drive and pond on the land north of the road. These interactions and the ponding (to be discussed in the hydraulics section below) mitigate the increase in peak flow values between the current and future land use conditions at the confluence of the Outflow Channel and Catherine Creek and on downstream to the Little Pilchuck River (Table 4-9).

HYDRAULIC MODELING

Hydraulic modeling was utilized to predict the impacts of land development on stream flow. The model effort can be broken into two major parts. The first is calibration of the model and the second is predicting future flows based on future conditions. Calibration of the model to existing conditions is key to the entire modeling effort. In order to simulate existing and future conditions two models were used. The hydrologic model (HSPF) was used to convert precipitation into streamflow based upon the parameters discussed above. The hydraulic model (FEQ) was used to convert stream discharge into stage in order to estimate the increased stage in the streams.

Hydrologic modeling predicts the size and probability of certain floods occurring. It can not provide a detailed picture of specific flood movements in the vicinity of Hartford Drive where water from Lake Stevens, Catherine Creek, and the hillside above Grade Road all interact to flood the residences along the north side of Hartford Drive. Hydraulic modeling was required to investigate in more detail the sources of flooding in the area of Hartford Drive.

Flow in the vicinity of Hartford Drive comes from three directions. The Lake Stevens outlet channel can flood across Hartford Drive when the lake is high in the winter. Catherine Creek can flood across the open area on the north side of Hartford Drive and overtop the road. Lastly, runoff from the hillside above Grade Road flows down across Grade Road to the ditch system on the East side of the road (Leavitt Ditch). The runoff is collected there and routed into a ditch that enters the outlet channel just to the east of the Leavitt residence on the north side of Hartford Drive.

The amount and direction of flooding across Hartford Drive depends on how much water is on each side of the road. In other words, if Catherine Creek flood waters rise to the height of the road and start to overtop the road, the amount and depth of flow over the road will depend on the relative heights of the water in the outlet channel and on the north side of the Hartford Drive. The same is true for flooding in the opposite direction. The depth of flooding north of Hartford Drive is dependent upon the height of water in the outflow channel due to a backwater condition.

The hydraulic model for this area takes into account the flood elevation on each side of Hartford Drive and how it changes during a flood. This accounting then allows for flooding in both directions over Hartford Drive at different times of the storm.

CALIBRATION

The FEQ model was calibrated using flood information collected during the New Year's Day 1997 flood. This is the largest flood within the precipitation record utilized by HSPF. High water marks or elevations were measured for this flood at two locations. The first was the lake gage on Lake Stevens (Site E) where lake elevation was recorded at 213.1 feet (note: all elevations in this report are based on 1929 National Geodetic Vertical

Datum). The second was at the Leavitt residence on the north side of Hartford Drive where the flood waters reached an elevation of 211.4 feet. Table 4-10 shows the comparison of simulated and recorded high water marks at these two locations.

TABLE 4-10

Simulated Versus Recorded High Water Marks

Location	Recorded High Water Mark (ft)	Simulated High Water Mark (ft)
Lake Stevens (Site E)	213.1	212.9
Leavitt residence	211.4	211.4

ALTERNATIVES ANALYSIS

The focus of the alternatives analysis was to evaluate how different land uses and proposed flood solutions will impact the flooding in Lake Stevens, the outlet channel, the Leavitt ditch, Catherine Creek and over Hartford Drive.

Eight alternatives were initially selected for analysis. FEQ computed flood elevations and flows for the 2-year flood and the January 1, 1997 flood for each alternative. The eight alternatives are listed below.

Existing Conditions

1. Current land use; 100 percent of the wetlands north of Hartford Drive retained; existing Hartford Drive road elevations; existing Hartford Drive culverts for Catherine Creek.

Future Conditions With Land Use Changes Only

2. Future land use; everything else the same as Alternative 1.

Partial Fill Of Hartford Drive Wetlands

3. Current land use; only 50 percent of the wetlands north of Hartford Drive retained; existing Hartford Drive road elevations; existing Hartford Drive culverts for Catherine Creek.

4. Future land use; everything else the same as Alternative 3.

Hartford Drive Elevated

5. Current land use; 100 percent of the wetlands north of Hartford Drive retained; Hartford Drive road elevations raised to prevent overtopping; existing Hartford Drive culverts for Catherine Creek.

6. Future land use; only 50 percent of the flat pasture north of Hartford Drive retained; Hartford Drive road elevations raised to prevent overtopping; existing Hartford Drive culverts for Catherine Creek.

Hartford Drive Culvert Replacement With Bridge

7. Current land use; 100 percent of the wetlands north of Hartford Drive retained; existing Hartford Drive road elevations; Hartford Drive culverts for Catherine Creek replaced with a bridge.

8. Future land use; 50 percent of the wetlands north of Hartford Drive retained; existing Hartford Drive road elevations; Hartford Drive culverts for Catherine Creek replaced with a bridge.

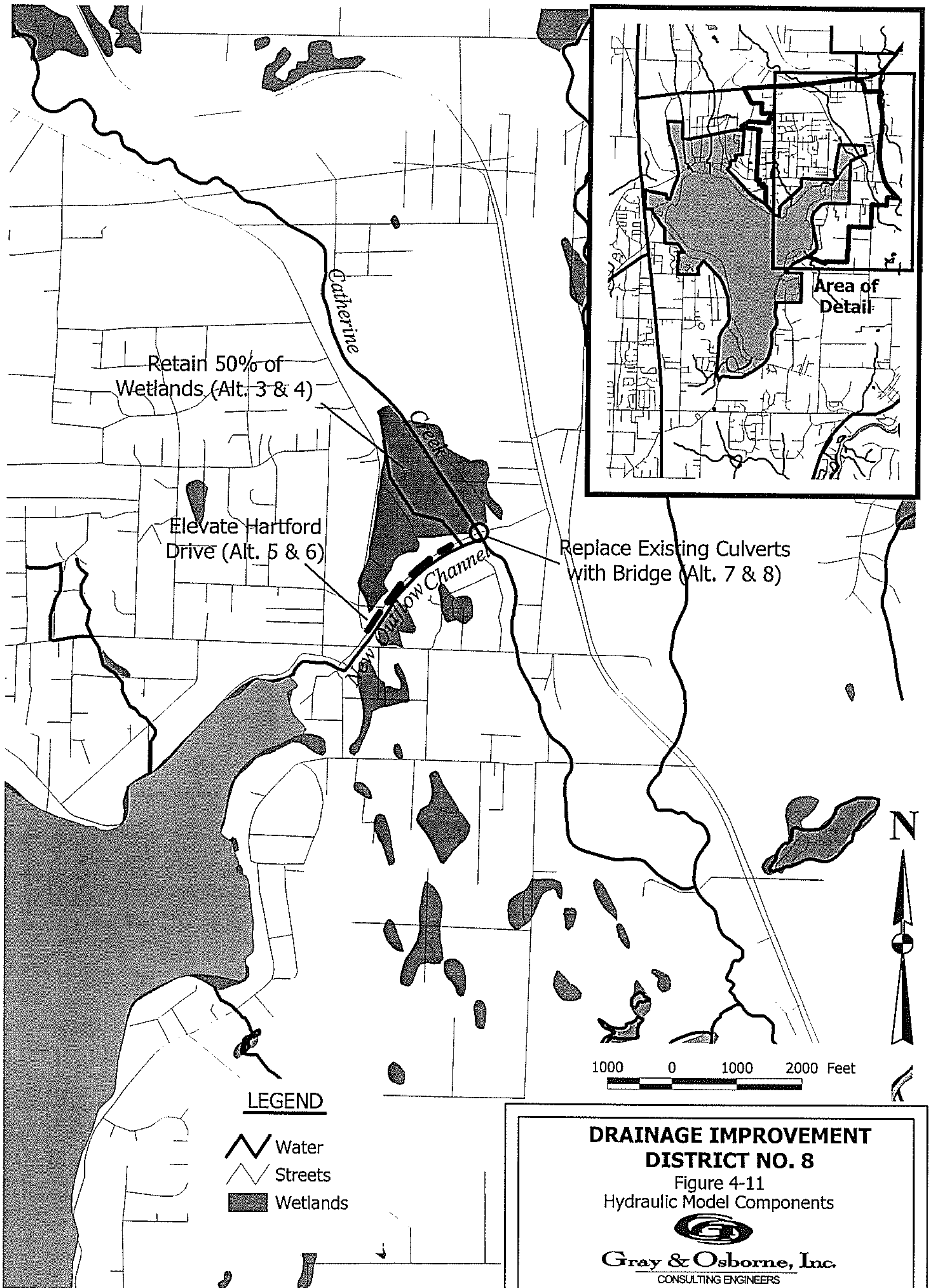
Figure 4-11 displays the location of the modeling scenarios listed above.

The filling of 50 percent of the flat pasture north of Hartford Drive was modeled with the assumptions that the Leavitt ditch would remain, but all land north of Hartford and west of the Leavitt residence will be raised to a minimum elevation of 214.0 feet, 2.6 feet above the level observed on January 1, 1997.

The FEQ results from five locations are reported. The following five locations can be found in Figure 4-12:

1. Lake Stevens outlet channel at Lake Stevens.
2. Lake Stevens outlet channel adjacent to the low spot on Hartford Drive.
3. Leavitt residence on the north side of Hartford Drive.
4. Catherine Creek immediately upstream of Hartford Drive.
5. Catherine Creek downstream of Hartford Drive at 20th Street N.E.

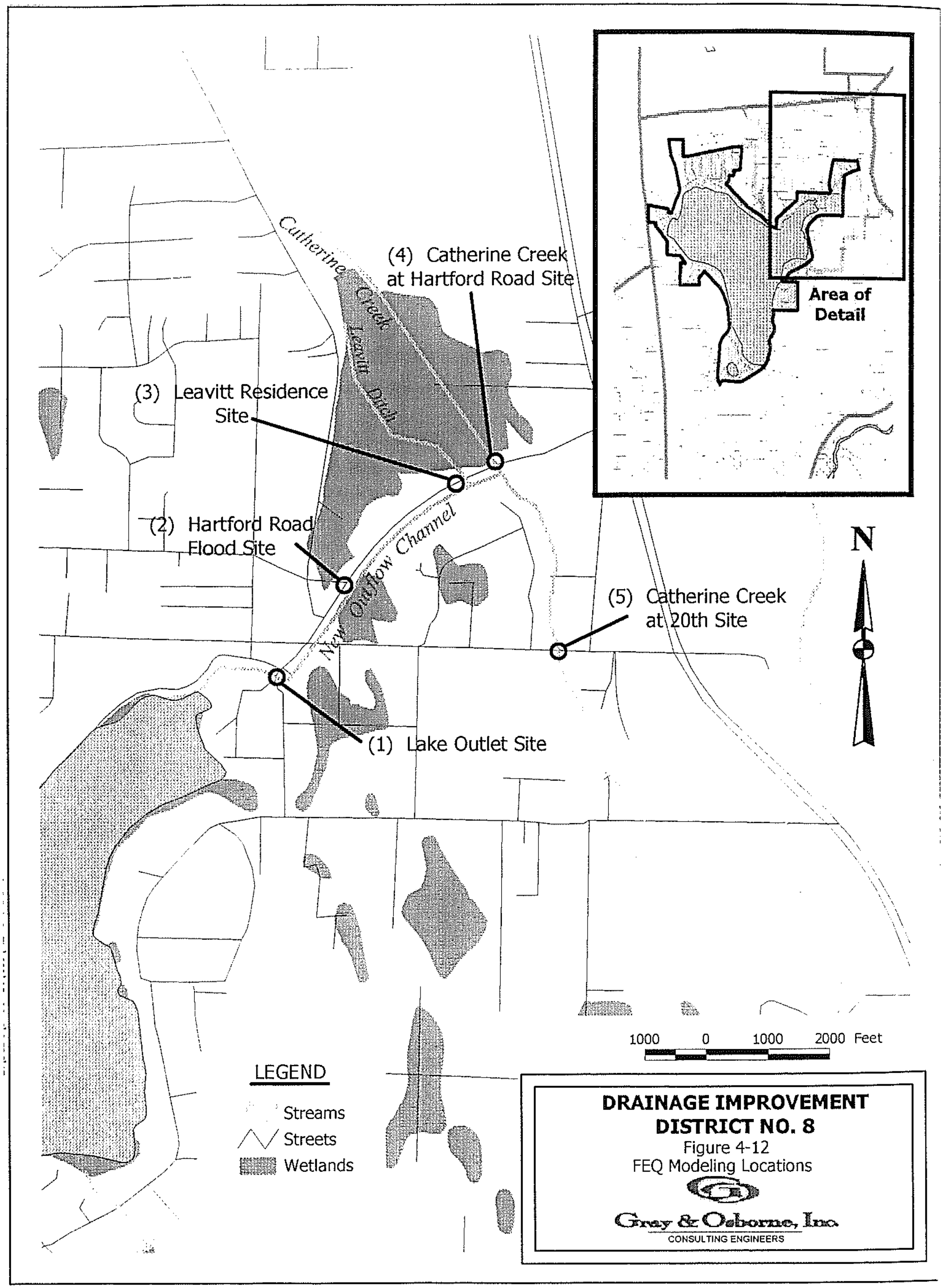
The hydraulic modeling results at the five locations listed above for the eight alternatives are summarized in Tables 4-11 through 4-12. These tables show the January 1, 1997 flood flows and water surface elevations for Alternatives 1 through 8 (Table 4-11), 2-year flood flows and water surface elevations for Alternatives 1 through 8 (Table 4-12).



DRAINAGE IMPROVEMENT DISTRICT NO. 8

Figure 4-11
Hydraulic Model Components

Gray & Osborne, Inc.
CONSULTING ENGINEERS



Catherine Creek
Leavitt Ditch
New Outflow Channel
(1) Lake Outlet Site
(2) Hartford Road Flood Site
(3) Leavitt Residence Site
(4) Catherine Creek at Hartford Road Site
(5) Catherine Creek at 20th Site
Area of Detail
N
1000 0 1000 2000 Feet
LEGEND
Streams
Streets
Wetlands
DRAINAGE IMPROVEMENT DISTRICT NO. 8
Figure 4-12
FEQ Modeling Locations
Gray & Osborne, Inc.
CONSULTING ENGINEERS

Table 4-11

January 1, 1997 Flood Flows and Water Surface Elevations (based on HSPF and FEQ)

Alternative:

1 Current with 100% wetland; existing Hartford Dr; existing Hartford culverts
2 Future with 100% wetland; existing Hartford Dr; existing Hartford culverts
3 Current with 50% wetland; existing Hartford Dr; existing Hartford culverts
4 Future with 50% wetland; existing Hartford Dr; exsting Hartford culverts
5 Current with 100% wetland; raised Hartford Dr; existing Hartford culverts
6 Future with 50% wetland; raised Hartford Dr; existing Hartford culverts
7 Current with 100% wetland; existing Hartford Dr; new Hartford bridge
8 Future with 50% wetland; existing Hartford Dr; new Hartford bridge

Flood Date	Location	Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5		Alternative 6		Alternative 7		Alternative 8	
		Current Land Use (cfs)	WS Elevation (ft)	Future Land Use (cfs)	WS Elevation (ft)	Current Land Use (cfs)	WS Elevation (ft)	Future Land Use (cfs)	WS Elevation (ft)	Current Land Use (cfs)	WS Elevation (ft)	Future Land Use (cfs)	WS Elevation (ft)	Current Land Use (cfs)	WS Elevation (ft)	Future Land Use (cfs)	WS Elevation (ft)
	lake outlet flood																
12/15/96 - 1/15/97	>100-yr	92	212.9	94	213.0	92	212.9	94	213.0	92	212.9	94	213.0	92	212.9	94	213.0
recorded		71	213.1														
	Hartford flood (TOR 209.2)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97	>100-yr	+31/-132	211.4	+40/-200	211.8	+0/-0	210.2	+0/-0	210.6	+0/-0	210.1	+0/-0	210.4	+31/-75	210.8	+0/-0	210.4
recorded		N/A	N/A														
	Leavitt Residence flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97	>100-yr	N/A	211.4	N/A	211.8	N/A	212.2	N/A	212.2	N/A	213.2	N/A	214.0	N/A	210.8	N/A	211.2
recorded		N/A	211.4														
	Catherine at Hartford flood (TOR 211.7)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97	>100-yr	136	211.4	141*	211.8	153*	212.1	151*	212.2	173*	213.2	183*	214.0	215	208.2	332	208.9
recorded		N/A	N/A														
	Catherine at 20th flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97	>100-yr	337	203.8	379	204.1	418	204.4	475	204.7	299	203.5	329	203.8	382	204.1	476	204.7
recorded		172	N/A														

* flow through culvert; does not include weir flow over top of road

Note:
TOR = top of road
at Hartford Dr low elev +31/-132 means that 31 cfs flowed from the lake outlet channel north across Hartford Dr and (later) 132 cfs flowed south from Catherine Creek across Hartford
50% flat pasture assumes all property west of Leavitt and north of Hartford raised to elev 214
raised Hartford Dr assumes to an elevation greater than overtopping
new Hartford bridge assumes no Catherine Creek channel constriction at road crossing

FEQ assumptions to calibrate to Leavitt HWM:
Leavitt culvert 90% blockage during peak flooding
Hartford culverts 35% blockage during peak flooding
Lake Stevens inflows 120% HSPF volumes

Table 4-12
2-Year Flood Flows and Water Surface Elevations (based on HSPF and FEQ)

Alternative:

1 Current with 100% wetland; existing Hartford Dr; existing Hartford culverts
2 Future with 100% wetland; existing Hartford Dr; existing Hartford culverts
3 Current with 50% wetland; existing Hartford Dr; existing Hartford culverts
4 Future with 50% wetland; existing Hartford Dr; exsting Hartford culverts
5 Current with 100% wetland; raised Hartford Dr; existing Hartford culverts
6 Future with 50% wetland; raised Hartford Dr; existing Hartford culverts
7 Current with 100% wetland; existing Hartford Dr; new Hartford bridge
8 Future with 50% wetland; existing Hartford Dr; new Hartford bridge

		Alternative 1		Alternative 2		Alternative 3		Alternative 4		Alternative 5		Alternative 6		Alternative 7		Alternative 8	
Flood Date	Location	Current Land Use	WS Elevation	Future Land Use	WS Elevation	Current Land Use	WS Elevation	Future Land Use	WS Elevation	Current Land Use	WS Elevation	Future Land Use	WS Elevation	Current Land Use	WS Elevation	Future Land Use	WS Elevation
12/05/84 - 12/22/84	lake outlet flood 2-yr	(cfs) 66	(ft) 212.4	(cfs) 67	(ft) 212.4	(cfs) 66	(ft) 212.4	(cfs) 67	(ft) 212.4	(cfs) 66	(ft) 212.4	(cfs) 67	(ft) 212.4	(cfs) 66	(ft) 212.4	(cfs) 67	(ft) 212.4
12/05/84 - 12/22/84	Hartford flood (TOR 209.2) 2-yr	(cfs) +6/-0	(ft) 209.4	(cfs) +9/-0	(ft) 209.5	(cfs) +0/-0	(ft) 209.6	(cfs) +0/-0	(ft) 209.7	(cfs) +0/-0	(ft) 209.6	(cfs) +0/-0	(ft) 209.7	(cfs) +6/-0	(ft) 209.4	(cfs) +0/-0	(ft) 209.7
12/05/84 - 12/22/84	Leavitt Residence flood 2-yr	(cfs) N/A	(ft) 207.6	(cfs) N/A	(ft) 208.0	(cfs) N/A	(ft) 207.5	(cfs) N/A	(ft) 207.6	(cfs) N/A	(ft) 207.0	(cfs) N/A	(ft) 207.5	(cfs) N/A	(ft) 207.6	(cfs) N/A	(ft) 207.7
12/05/84 - 12/22/84	Catherine at Hartford flood (TOR 211.7) 2-yr	(cfs) 96	(ft) 208.3	(cfs) 111	(ft) 208.8	(cfs) 96	(ft) 208.3	(cfs) 111	(ft) 208.8	(cfs) 96	(ft) 208.3	(cfs) 111	(ft) 208.8	(cfs) 96	(ft) 206.9	(cfs) 111	(ft) 207.1
12/05/84 - 12/22/84	Catherine at 20th flood 2-yr	(cfs) 186	(ft) 202.7	(cfs) 207	(ft) 202.9	(cfs) 189	(ft) 202.7	(cfs) 213	(ft) 202.9	(cfs) 187	(ft) 202.7	(cfs) 211	(ft) 202.9	(cfs) 186	(ft) 202.7	(cfs) 213	(ft) 202.9

Note:
TOR = top of road
at Hartford Dr low elev +6/-0 means that 6 cfs flowed from the lake outlet channel north across Hartford Dr and (later) 0 cfs flowed south from Catherine Creek across Hartford Dr
50% flat pasture assumes all property west of Leavitt and north of Hartford raised to elev 214
raised Hartford Dr assumes to an elevation greater than overtopping
new Hartford bridge assumes no Catherine Creek channel constriction at road crossing

FEQ assumptions:
Leavitt culvert 50% blockage during peak flooding
Hartford culverts 20% blockage during peak flooding
Lake Stevens inflows 120% HSPF volumes

100-YEAR FLOOD RESULTS

The results for the January 1, 1997 storm show that the entire lake outlet channel-in the Hartford Drive-Leavitt property-Catherine Creek area acts as a single large pond with the water everywhere at a similar elevation (Table 4-11). In contrast, the 2-year flood results (Table 4-11) show each of these floodprone areas acting independently and having a different water surface elevation.

The results further show that future land use conditions (Alternative 2) when compared to current conditions (Alternative 1) will increase flood flows and flood elevations at all locations. Larger floods on Catherine Creek cause greater overtopping of Hartford Drive and more water entering the outlet channel from road overtopping. This extra flow rejoins Catherine at the confluence and adds to the peak flows downstream at 20th (Station B). The Leavitt property will receive 0.4 feet of additional flood water for a storm of this magnitude. Catherine Creek at 20th peak flow elevations will increase by 0.3 feet beyond the current 100-year flood elevation.

Alternative 3 (current land use with only 50 percent wetlands retained) compared with Alternative 1 (current with 100 percent flat pasture) shows major increases in flood elevations. Filling of the land west of the Leavitt residence to an elevation of 214.0 feet (1929 NGVD) prevents overtopping of Hartford Drive, except in the vicinity of the Leavitt ditch culvert under Hartford Drive. The Leavitt property will receive 0.8 feet more water than Alternative 1; Catherine at 20th will increase by 0.6 feet.

Alternative 4 (future land use with only 50 percent flat pasture retained) compared with Alternative 1 (current with 100 percent flat pasture) shows similar results to the Alternative 3 comparison. Flood depths at the Leavitt residence do not change from Alternative 3. The largest change is at 20th where flood depths are increased another 0.3 feet above Alternative 3.

Alternatives 5 and 6 raise Hartford Drive to prevent overtopping by either the outlet channel or Catherine Creek. Alternative 5 (current land use) decreases flood flows and elevations in the lake outlet channel. This is because no Catherine flood water can overtop the road and flow into the outlet channel. The largest impact of raising Hartford Drive is increasing flood depths in the Catherine Creek wetlands north of Hartford Drive (to a flood elevation of 213.2). Downstream Catherine Creek flood flows decrease by 0.3 feet compared to Alternative 1. More water is stored in the flat pasture on the north side of Hartford Drive.

Alternative 6 (future land use; 50 percent flat pasture) increases flood flows and elevations everywhere compared to Alternative 5 (or Alternative 1). As with Alternative 5, there is some benefit to the downstream end of the outlet channel by preventing road overtopping. The Leavitt residence flood elevation rises to 214.0; 2.6 feet above the 1997 flood level (the 1997 high water mark is at 211.4). At Station B (20th) flood flows are very comparable to Alternative 1.

Removing the two Catherine Creek culverts under Hartford Drive and replacing them with a bridge (Alternatives 7 and 8) decreases but does not eliminate Catherine Creek flood waters overtopping Hartford Drive from both directions. The Leavitt residence flood elevation drops to 210.8 (Alternative 7). Catherine Creek flood elevations north of Hartford Drive are decreased by 3.2 feet. Catherine Creek downstream flood flows are increased. Without the Hartford Drive culverts to backup water into the flat pastures north of Hartford Drive, flood flows are unimpeded as they travel down Catherine Creek. For both the current conditions (Alternative 7) and the future conditions (Alternative 8) Catherine Creek flood flows are similar to Alternatives 3 and 4 (50 percent filling of flat pasture). Increased downstream flooding at Station B will result.

In summary, all of the alternatives (2 through 8) have some benefits and create some problems during a large flood. If the wetlands on the north side of Hartford Drive can be dedicated for flood storage (which will require either floodproofing or removal of the houses on the north side of Hartford Drive), raising Hartford Drive will provide the greatest benefits of the alternatives modeled. These benefits (decreased downstream flooding) could be further enhanced by additional restriction of Catherine Creek flood flows through the Hartford Drive culverts. Either total or partial blockage of one of the two culverts under Hartford Drive will assist in this goal.

TWO-YEAR FLOOD RESULTS

The 2-year flood results (Table 4-12) show some different trends compared to the 100-year flood. For this event, each of these floodprone areas acting independently and having a different water surface elevation as water, does not spill over Hartford Drive. Alternatives 1 (current land use with existing hydraulic conditions), 2 (future land use with existing conditions), and 7 (current with new Hartford bridge) show minor flooding (less than 0.3 feet of water) over Hartford Drive from the outlet channel. There is no flooding in the other direction (from Catherine Creek).

The maximum flood elevation on the Leavitt property is between 207.0 (Alternative 5) and 208.0 feet (Alternative 2). In the 2-year flood most of the water flooding the Leavitt property is from the local hillside runoff to the west; neither the lake outlet channel nor Catherine Creek contribute substantially to the flooding of this area.

Removal of the Catherine Creek culverts under Hartford Drive and replacing them with a bridge has little downstream impact at Station B during the 2-year flood. The culverts are large enough to handle the 2-year flood and do not significantly detain or reduce the peak flow in Catherine Creek.

During the 2-year flood each flow pathway (the lake outlet channel, Leavitt ditch, and Catherine Creek) contains and conveys its peak flows. And while all of this water eventually gets into Catherine Creek above Station B (20th Street NE), the timing and the size of the flood flows is not substantially altered by the different flow pathways. This is not true for the 100-year flood.

OUTLET CONFIGURATION ANALYSIS

Alternative lake outlet configurations were investigated to see if they can provide substantial downstream flood protection. Two scenarios were proposed. The first scenario operates the lake outlet based on the streamflow level in Catherine Creek at Station B. Boards are added to the lake outlet weir as the Catherine Creek streamflow increases above specified flow levels. The second scenario is to dredge the outlet channel between the lake and the weir. Figure 4-13 shows the locations of these two scenarios.

Both scenarios were modeled with FEQ for Alternatives 1 (current land use, 100 percent flat pasture, existing Hartford Drive, existing Catherine culverts) and 8 (future land use; 50 percent flat pasture, existing Hartford Dr., new Catherine bridge) for both the 100-year flood and the 2-year flood (See Tables 4-13 and 4-14).

The operation of the weir boards was based on Catherine Creek streamflow and used the following procedure for setting board height (elevation):

1. If Catherine flow at Station B is less than 132 cfs (2-year flood) then lake control elevation (at weir) is set to 210.4 feet.

2. If Catherine flow at Station B is greater than 132 cfs (2-year flood) and less than 150 cfs (10-year flood) then lake control elevation (at weir) is set to 211.4 feet.

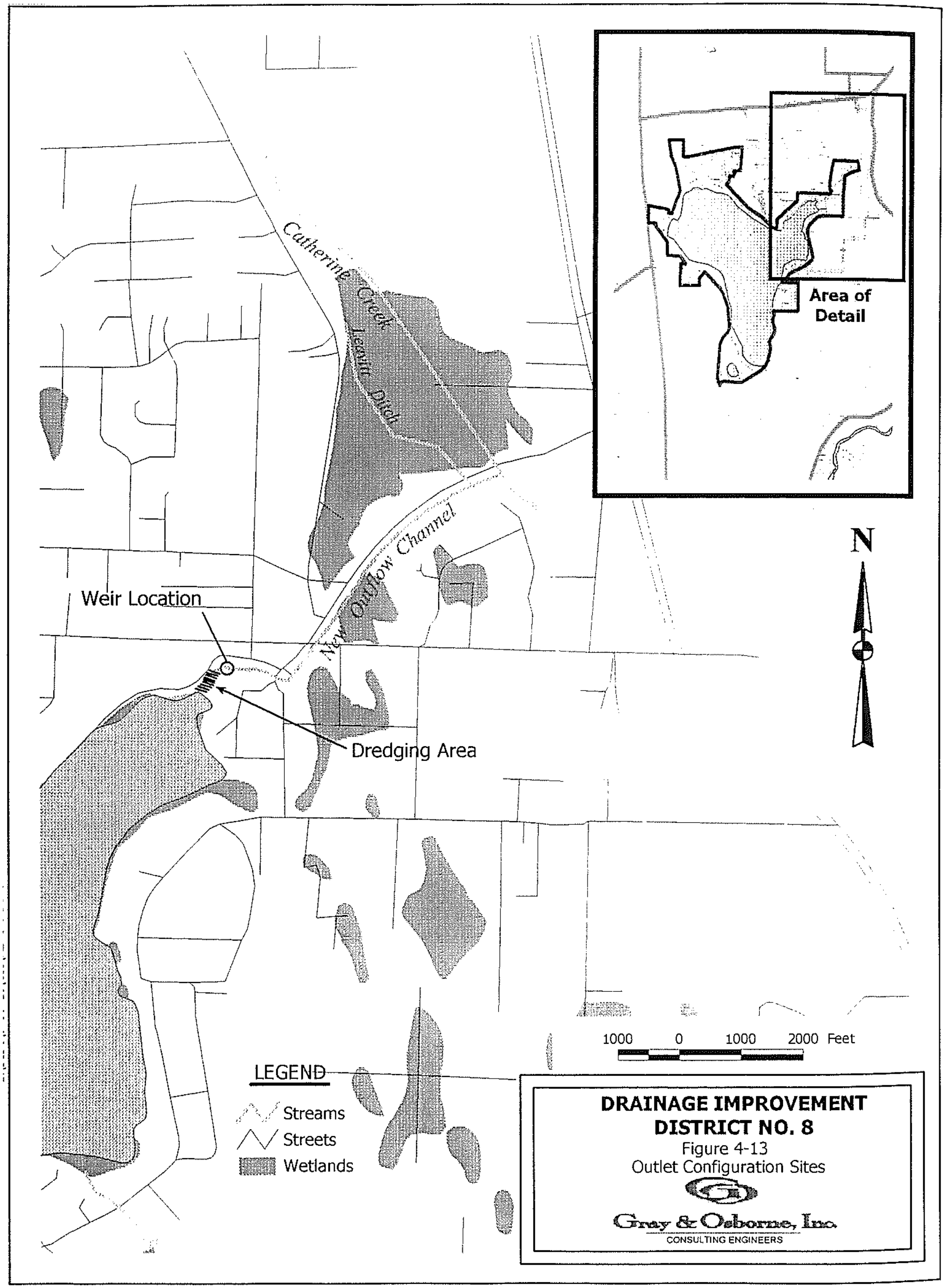
3. If Catherine flow at Station B > 150 cfs (10-year flood) then lake control elevation (at weir) is set to 212.4 feet.

The channel bottom at the outlet channel weir is at elevation 209.3 feet; the channel high spot upstream of weir is 210.4 feet (1929 NGVD). The channel high spot prevents water from flowing out of the lake and down the outlet channel when the lake level is below elevation 210.4.

The dredge scenario removes the 210.4 high spot upstream of the outlet control weir. As in the case described above, the dredge scenario also involved adding boards to the outlet weir based on Catherine Creek streamflow. The following operating rule was used:

1. If Catherine flow at Station B is less than 132 cfs (2-year flood) then lake control elevation (at weir) is set to 209.3 feet.

2. If Catherine flow at Station B is greater than 132 cfs (2-year flood) and less than 150 cfs (10-year flood) then lake control elevation (at weir) is set to 210.8 feet.



Catherine Creek
Leavitt Ditch
New Outflow Channel
Weir Location
Dredging Area
Area of Detail
N
1000 0 1000 2000 Feet
LEGEND
Streams
Streets
Wetlands
DRAINAGE IMPROVEMENT
DISTRICT NO. 8
Figure 4-13
Outlet Configuration Sites
Gray & Osborne, Inc.
CONSULTING ENGINEERS

Table 4-13
Simulated Flood Elevations Using the Lake for Flood Storage
January 1, 1997 Flows and Water Surface Elevations (based on HSPF and FEQ)

Alternative:

1 Current with 100% wetland; existing Hartford Dr; existing Hartford culverts
2 Future with 100% wetland; existing Hartford Dr; existing Hartford culverts
3 Current with 50% wetland; existing Hartford Dr; existing Hartford culverts
4 Future with 50% wetland; existing Hartford Dr; exsting Hartford culverts
5 Current with 100% wetland; raised Hartford Dr; existing Hartford culverts
6 Future with 50% wetland; raised Hartford Dr; existing Hartford culverts
7 Current with 100% wetland; existing Hartford Dr; new Hartford bridge
8 Future with 50% wetland; existing Hartford Dr; new Hartford bridge

Flood Date	Location		Alternative 1 Existing Current Land Use	Alternative 1 Existing WS Elevation	Alternative 1 Adjust boards Current Land Use	Alternative 1 Adjust boards WS Elevation	Alternative 1 Dredge and boards Current Land Use	Alternative 1 Dredge and boards WS Elevation	Alternative 8 Existing Future Land Use	Alternative 8 Existing WS Elevation	Alternative 8 Adjust boards Future Land Use	Alternative 8 Adjust boards WS Elevation	Alternative 8 Dredge and boards Future Land Use	Alternative 8 Dredge and boards WS Elevation
	lake outlet	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	92	212.9	109	213.5	115	213.4	94	213.0	109	213.5	115	213.5
recorded			71	213.1										
	Hartford (TOR 209.2)	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	+31/-132	211.4	+56/-120	210.8	+60/-120	210.8	+0/-0	210.4	+0/-0	210.4	+0/-0	210.5
recorded			N/A	N/A										
	Leavitt Residence	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	N/A	211.4	N/A	210.8	N/A	210.8	N/A	211.2	N/A	211.2	N/A	211.2
recorded			N/A	211.4										
	Catherine at Hartford (TOR 211.7)	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	136	211.4	135	210.8	135	210.8	332	208.9	331	208.7	331	208.7
recorded			N/A	N/A										
	Catherine at 20th	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	337	203.8	295	203.6	295	203.6	476	204.7	413	204.3	416	204.3
recorded			172	N/A										

Note: TOR = top of road
at Hartford Dr low elev +31/-132 means that 31 cfs flowed from the lake outlet channel north across Hartford Dr and (later) 132 cfs flowed south from Catherine Creek across Hartford
50% flat pasture assumes all property west of Leavitt and north of Hartford raised to elev 214
raised Hartford Dr assumes to an elevation greater than overtopping
new Hartford bridge assumes no Catherine Creek channel constriction at road crossing

FEQ assumptions to calibrate to Leavitt HWM
Leavitt culvert 90% blockage during peak flooding
Hartford culverts 35% blockage during peak flooding
Lake Stevens inflows 120% HSPF volumes

Table 4-14.
Simulated Flood Elevations Using the Lake for Flood Storage
2-Year Flows and Water Surface Elevations (based on HSPF and FEQ)

Alternative:

1 Current with 100% wetland; existing Hartford Dr; existing Hartford culverts
2 Future with 100% wetland; existing Hartford Dr; existing Hartford culverts
3 Current with 50% wetland; existing Hartford Dr; existing Hartford culverts
4 Future with 50% wetland; existing Hartford Dr; exsting Hartford culverts
5 Current with 100% wetland; raised Hartford Dr; existing Hartford culverts
6 Future with 50% wetland; raised Hartford Dr; existing Hartford culverts
7 Current with 100% wetland; existing Hartford Dr; new Hartford bridge
8 Future with 50% wetland; existing Hartford Dr; new Hartford bridge

Flood Date	Location		Alternative 1 Existing Current Land Use	Alternative 1 Existing WS Elevation	Alternative 1 Adjust boards Current Land Use	Alternative 1 Adjust boards WS Elevation	Alternative 1 Dredge and Boards Current Land Use	Alternative 1 Dredge and Boards WS Elevation	Alternative 8 Existing Future Land Use	Alternative 8 Existing WS Elevation	Alternative 8 Adjust boards Future Land Use	Alternative 8 Adjust boards WS Elevation	Alternative 8 Dredge and Boards Future Land Use	Alternative 8 Dredge and Boards WS Elevation
	lake outlet	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/05/84 - 12/22/84		2-yr	66	212.4	66	212.4	66	212.4	67	212.4	67	212.4	66	212.5
	Hartford (TOR 209.2)	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/05/84 - 12/22/84		2-yr	+6/-0	209.4	+7/-0	209.4	+7/-0	209.4	+0/-0	209.7	+0/-0	209.7	+0/-0	209.7
	Leavitt Residence	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/05/84 - 12/22/84		2-yr	N/A	207.6	N/A	207.4	N/A	207.4	N/A	207.7	N/A	207.6	N/A	207.6
	Catherine at Hartford (TOR 211.7)	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/05/84 - 12/22/84		2-yr	96	208.3	96	208.2	96	208.2	111	207.1	111	207.0	111	207.0
	Catherine at 20th	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/05/84 - 12/22/84		2-yr	186	202.7	172	202.5	172	202.5	213	202.9	172	202.5	202	202.8

Note:
TOR = top of road
at Hartford Dr low elev +6/-0 means that 6 cfs flowed from the lake outlet channel north across Hartford Dr and (later) 0 cfs flowed south from Catherine Creek across Hartford Dr
50% flat pasture assumes all property west of Leavitt and north of Hartford raised to elev 214
raised Hartford Dr assumes to an elevation greater than overtopping
new Hartford bridge assumes no Catherine Creek channel constriction at road crossing

FEQ assumptions:
Leavitt culvert 50% blockage during peak flooding
Hartford culverts 20% blockage during peak flooding
Lake Stevens inflows 120% HSPF volumes

3. If Catherine flow at Station B greater than 150 cfs (10-year flood) then lake control elevation (at weir) is set to 212.4 feet.

For the purposes of the dredge analysis and board combination, the dredged channel high spot upstream of the weir will be assumed to be lowered to 209.3 feet (1929 NGVD), which is the same elevation as the bottom of the outlet control weir. The model results for these scenarios for the 100-year flood are presented in Table 4-13.

The two scenarios produce essentially identical results for the 100-year flood. They increase the maximum lake surface water elevation by approximately 0.5 feet over the existing conditions due to the addition of boards at the weir during the flood event. The lake outlet channel along Hartford Drive, Leavitt property, and Catherine Creek at Hartford Drive flood elevations are decreased by 0.6 feet for Alternative 1 (current land use, existing conditions).

Alternative 8 (future land use, altered conditions) shows no measurable positive impact from either modifying the weir height or dredging the lake outlet channel. This is because filling the flat pastures north of Hartford Drive and replacing the Catherine culverts under Hartford with a bridge has more control over water levels than changing weir heights or dredging the channel.

The same analysis was conducted for the 2-year flood (see Table 4-14). These results show even less impact than for the 100-year flood. This is partially due to the small amount of time that boards are added to the weir during the 2-year flood.

Dredging shows no benefit for the 2-year flood (nor does it for the 100-year flood). This is because at these flood flows, the downstream control for the lake is not the high channel bottom of 210.4 between the lake and the weir structure but the weir structure itself. The channel at the weir structure is 9.5 feet wide and restricts water from the lake flowing down the outlet channel during periods of high lake levels.

One solution to this problem is to enlarge the entire downstream outlet channel to move more water down the channel to Catherine Creek without overtopping Hartford Drive. Otherwise, other factors (filling the wetlands, increasing the height of Hartford Drive, and replacing Catherine culverts with a bridge) play a larger role in the depth and location of downstream flooding than the operation of Lake Stevens board heights during floods or dredging the channel entrance.

TRAPEZOIDAL CHANNEL ANALYSIS

A new lake outlet channel was designed to evaluate how much of a difference it would make in terms of lowering 100-year flood elevations. A trapezoidal shape was selected for the designed channel. This shape, compared to the existing fairly rectangular shape, allows more water to flow out of the lake at lower lake elevations than does the existing channel. The trapezoidal shape is also cheaper to construct because of its sloping side walls that do not need expensive vertical pilings for wall stabilization.

The dimensions of the designed channel were selected as follows. The bottom width is 11 feet. The side slope is two feet horizontal to every one foot vertical. The maximum depth is 4 feet and the top width at this depth is 27 feet across.

The FEQ model was modified to represent this designed channel and the current 100-year flood was run through the model to compute the associated flooding. As shown in Table 4-15, the largest advantage of the designed channel is that the peak flood level in Lake Stevens is reduced by 0.7 feet. The designed channel also reduces flooding in the Leavitt ditch by 0.4 feet.

The designed channel does not prevent overtopping of Hartford Drive during the 100-year flood. In addition, Catherine Creek peak flows at 20th Street NE are increased in size. Another potential problem is the designed top width of 27 feet is wider than the current outlet channel. To widen the outlet channel would require reducing the paved width of Hartford Drive from 18 feet to 13 feet. This reduction in pavement width would probably require Hartford Drive to be designated as a single-lane, one-way road.

SUMMARY

HSPF was used to model the runoff from the surrounding watershed into Lake Stevens, Catherine Creek, the lake outlet channel, and the Leavitt ditch. Both current and future land use were modeled. Flood frequencies were computed for both sets of land use conditions.

Analysis of different flood solution alternatives was conducted using FEQ. The FEQ model results show that each alternative reduced flooding in some locations but increased flooding in others. Depending on the availability of the flat pasture to the north of Hartford Drive for flood storage, Catherine Creek downstream flood flows can be reduced by constructing a berm around the homes on the north side of Hartford Drive and reducing flow through the culverts under Hartford Drive.

Storing more flood water in Lake Stevens by adding boards to the outlet weir reduces downstream flooding. However, this is accomplished at the expense of more flooding around the perimeter of the lake.

Widening the outlet channel can reduce flooding in the lake and on the north side of Hartford Drive. But flood flows in Catherine Creek are increased and Hartford Drive is reduced to a single traffic lane.

Regardless of the proposed solution it must be recognized that the flood waters have to go somewhere and in doing so cause problems for someone. With future development these flood problems will increase in size, frequency of occurrence, and length of time.

Table 4-15

Design Channel

January 1, 1997 Flood Flows and Water Surface Elevations

Alternative:

1 Current with 100% flat pasture; existing Hartford Dr; existing Hartford culverts
2 Future with 100% flat pasture; existing Hartford Dr; existing Hartford culverts
3 Current with 50% flat pasture; existing Hartford Dr; existing Hartford culverts
4 Future with 50% flat pasture; existing Hartford Dr; exsting Hartford culverts
5 Current with 100% flat pasture; raised Hartford Dr; existing Hartford culverts
6 Future with 50% flat pasture; raised Hartford Dr; existing Hartford culverts
7 Current with 100% flat pasture; existing Hartford Dr; new Hartford bridge
8 Future with 50% flat pasture; existing Hartford Dr; new Hartford bridge

Flood Date	Location		Alternative 1 Existing		Alternative 1 Adjust Boards		Alternative 1 Design Channel	
			Current Land Use	WS Elevation	Current Land Use	WS Elevation	Current Land Use	WS Elevation
	lake outlet	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	92	212.9	109	213.5	100	212.2
recorded			71	213.1				
	Hartford (TOR 209.2)	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	+31/-132	211.4	+56/-120	210.8	+17/-136	211.0
recorded			N/A	N/A				
	Leavitt Residence	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	N/A	211.4	N/A	210.8	N/A	211.0
recorded			N/A	211.4				
	Catherine at Hartford (TOR 211.7)	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	136	211.4	135	210.8	132	211.0
recorded			N/A	N/A				
	Catherine at 20th	flood	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
12/15/96 - 1/15/97		>100-yr	337	203.8	295	203.6	356	204.0
recorded			172	N/A				

Note: TOR = top of road
at Hartford Dr low elev +31/-132 means that 31 cfs flowed from the lake outlet channel north across Hartford Dr and (later) 132 cfs flowed south from Catherine Creek across Hartford
50% flat pasture assumes all property west of Leavitt and north of Hartford raised to elev 214
raised Hartford Dr assumes to an elevation greater than overtopping
new Hartford bridge assumes no Catherine Creek channel constriction at road crossing

FEQ assumptions to calibrate to Leavitt HWM
Leavitt culvert 90% blockage during peak flooding
Hartford culverts 35% blockage during peak flooding
Lake Stevens inflows 120% HSPF volumes

CHAPTER 5

WATER QUALITY

INTRODUCTION

Non-point source pollution results from diffuse and diverse human activity. As water runoff flows over developed land, the water picks up a variety of pollutants such as hydrocarbons and metals from roadways, motor oil, household chemicals, fertilizers and pesticides. The combination of more runoff and the increased availability of pollutants in urban runoff creates a negative impact on the water quality and the associated aquatic habitat. (Table 5-1).

TABLE 5-1

Typical Pollutant Loadings (Lbs/Acre-Year) From Urban Land Uses[6]

LAND USE	TSS [1]	TP [2]	TKN [3]	Lead [4]	Zinc	Copper
Commercial	1,000	1.5	6.7	2.7	2.1	0.4
Parking Lot	400	0.7	5.1	0.8	0.7	0.04
High Density						
Residential	42	1	4.2	0.8	0.7	0.03
Low Density						
Residential	10	0.04	0.03	0.01	0.04	0.01
Freeway	880	0.9	7.9	4.5	2.1	0.37
Industrial	860	1.7	3.8	2.4	7.3	0.5
Park, Woodland	3	0.03	1.5	0.005	NA[5]	NA[5]
Construction	60,000	80		NA[5]	NA[5]	NA[5]

1 Total Suspended Solids.
2 TP = Total Phosphorus.
3 TKN = Total Kjeldahl Nitrogen.
4 Lead contamination has decreased since these data were collected with the reduced use of leaded gasoline.
5 NA = Not Available.
6 Source: Horner, et al., 1994.

The chemical and physical parameters in nonpoint source runoff are dependent upon factors such as: land use, best management practices, soil type, onsite water quality treatment and rainfall intensity. For example, in agricultural areas the stormwater runoff may contain elevated levels of pesticides, nutrients and fecal bacteria from animal waste. Runoff from industrial areas may contain high levels of metals and industrial contaminants. Runoff from construction sites may contain high levels of suspended solids as the soil may not be covered and stabilized and thus is susceptible to erosion.

While urban runoff is often not immediately disruptive or fatal to wildlife and vegetation, it can have a significant cumulative impact. The long-term effects on population and community structure can severely impact ecosystem functions and integrity. In assessing the impact of runoff on a suburban creek in the Pacific Northwest, Field and Pitt (1990) stated that:

The long-term aquatic life effects of urban runoff are probably more important than short-term effects associated with specific events. The long-term effects are probably related to the deposition and resuspension of toxic sediments, or the inability of aquatic organisms to adjust to repeated exposures to high concentrations of toxic materials or high flow rates. Long-term effects may only be expressed at great distances downstream from discharge locations, or in accumulating areas such as lakes and ponds.

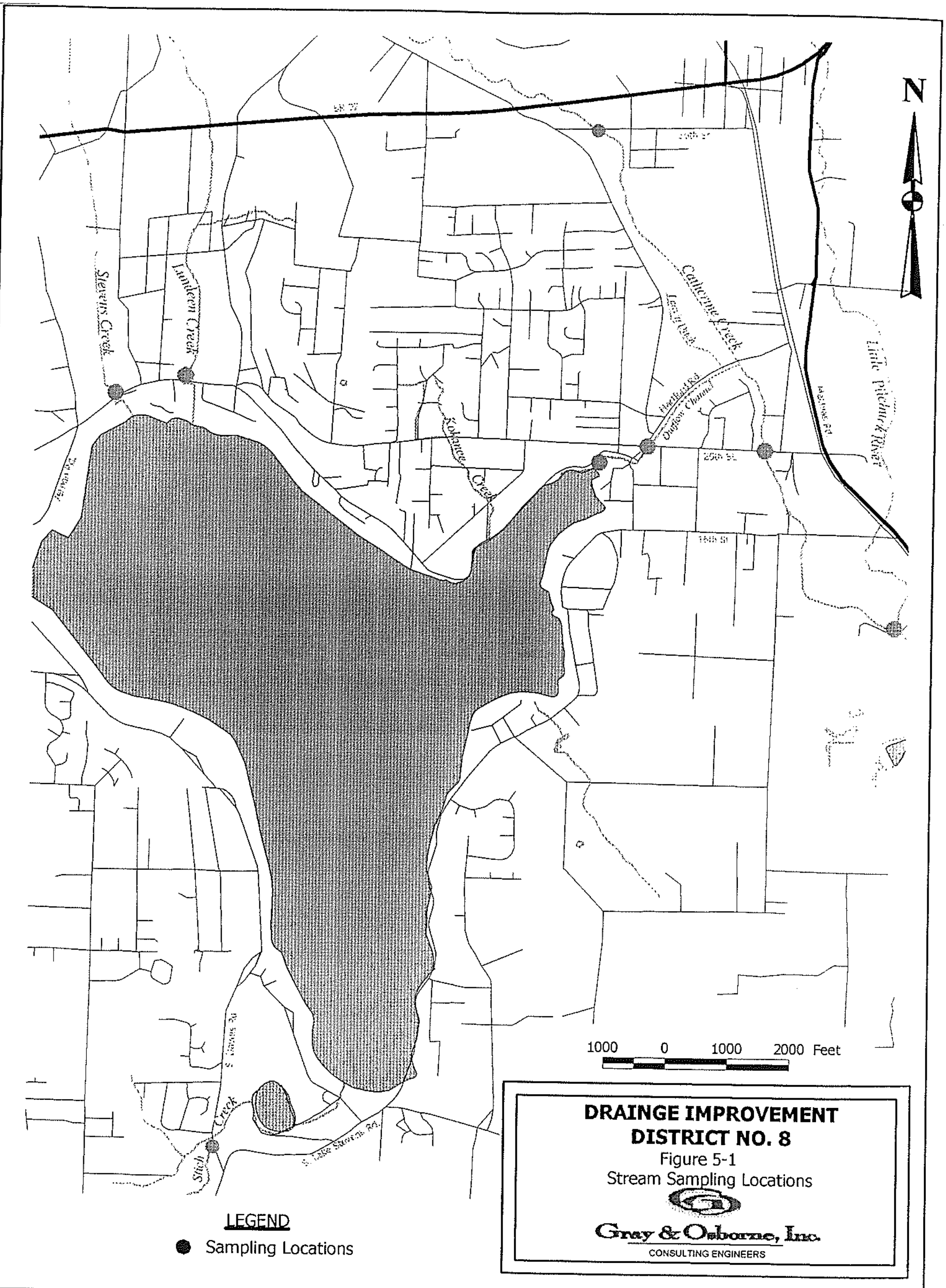
A study by Seager and Abrahams (1990) in the United Kingdom reveals that even diluted urban runoff can have adverse impacts on the biota. Using Simpson's Diversity Index (which factors in the number of species present in an area and their relative abundance within that area), researchers found that diversity 100 meters downstream from a combined sewer overflow (CSO) was significantly less than that 10 meters above the pollution source. The study concluded that "physio-chemical properties of habitats appeared to be altered in a way which tends to favor the proliferation of certain pollution-tolerant species and decrease the abundance of taxa intolerant of organic pollution."

LAKE STEVENS AND CATHERINE CREEK WATER QUALITY

This basin plan focuses on Catherine Creek and the major tributaries to Lake Stevens. It does not examine Lake Stevens itself as this has been covered in several reports (Reid Middleton, 1983; KCM, 1987; Gray & Osborne, 1998). Predicted long term impacts to the lake from storm water runoff are included but are based upon a "text book" model and do not take into account the unique nature of Lake Stevens. The specific streams evaluated in this basin plan are:

- Catherine Creek, from Lake Cassidy to confluence with the Little Pilchuck River.
- The Outlet Channel from Lake Stevens to confluence with Catherine Creek.
- Major tributaries to Lake Stevens: Stevens Creek, Lundeen Creek, Kokanee Creek, and Stitch Creek.

The locations of these creeks are shown in Figure 5-1.



DRAINGE IMPROVEMENT DISTRICT NO. 8

Figure 5-1

Stream Sampling Locations

Gray & Osborne, Inc.

CONSULTING ENGINEERS

WATER QUALITY SAMPLING

Depending on the creek, there are little or no existing data describing the water quality of the creeks of interest. Consequently, a program of data collection was carried out between September 1997, the beginning of the development of this basin plan, and September 1998. The Monitoring Plan is included in Appendix C. The locations of the sampling stations are shown in Figure 5-1.

The strategy to water quality sampling was to focus on the periods most critical to the fish species of interest, which are Kokanee (*Oncorhynchus Nerka*), Coho (*O. kisutch*), and Cutthroat Trout (*O. clarkii*). Kokanee spawn in Stevens, Kokanee (Mitchell), and Lundeen Creeks. Kokanee may spawn in Stitch Creek as well, however a survey in the fall of 1998 found no kokanee in Stitch creek below the Davies Road culvert. Four to six months after the adult spawn, Kokanee fry move down to Lake Stevens where they spend the remainder of their lives until they return to the creeks to spawn. Coho and Cutthroat Trout are present in all creeks evaluated in this basin plan. Coho will typically rear in the creek in the summer following their birth as well as the following winter. They then migrate out to the ocean. They must therefore survive two winters, including the winter of their birth, and one summer, in the creek of their birth. Habitat in the Lake Stevens and Catherine Creek basins is limited in part due to low flows in the streams during the latter part of the summer and early fall.

The periods considered most critical to these fish species were determined to be:

- February - March: fry emergence and/or early growth period for Coho and Kokanee.
- May - June: fry emergence and/or early growth period for Cutthroat Trout.
- July - September: summer rearing of Cutthroat Trout and Coho.

Emergence and the first few weeks of their life is the most sensitive period in the life of fish. Good water quality during these weeks is particularly important. The next most sensitive period is the summer. Although summer storms are fewer in number and smaller then winter storms, their impact on the water quality of the streams may be much more significant. Concentrations of toxicants can be higher in streams due to summer storms because there is less base flow in the streams to dilute the runoff. Additionally fish are more sensitive to toxicants because the warmer water increases their metabolic rates.

With the above strategy, the following field program was carried out:

- February - March: Examine water quality during dry-weather over the period of a week. Sample one storm.

- May - June: Examine water quality during dry-weather over a period of a week. Sample one storm.

- July - September: Examine water quality during dry-weather during two separate one-week periods, emphasizing sampling during periods of high ambient temperatures. Sample one storm. However, although the plan was to sample one storm, two were sampled in 1998. Partial sampling of a storm occurred in September 1997.

The dates of the sampling are summarized in Table 5-2 as well as pertinent information on the sampled storms. The parameters that were analyzed are presented in Table 5-3. As noted in Table 5-2, water quality of dry-weather flows was examined two ways, with grab samples and with dissolved oxygen meters. The meters recorded hourly data over the entire week, whereas the grab samples were taken at the beginning and end of the week with some mid-week grab samples. For storms, flow-weighted composite samples were analyzed. The composite samples were obtained by taking several individual samples during the storm. These individual samples were then composited based on the stream flow existing at the time of each individual sample. Each time an individual sample was taken, the flow was also taken using District staff gages.

TABLE 5-2

Water Quality Sampling Dates

SAMPLING PERIOD	FLOW CONDITION	CREEK	SAMPLING DATES
MARCH	Dry-weather	• Catherine Creek and Lake Stevens Outlet	• Grab samples on March 13 and 19, 1998. Meters installed March 13th to 19th.
		• Lundeen and Stevens Creek	• Grab samples on April 1, 6, and 9, 1998. Meters installed April 1st to 9th.
	Storm flows	• Catherine Creek and Lake Stevens Outlet	• Sampled March 22, 1998. Storm depth of 0.63 inches in 21 hours of which 0.48 inches occurred in 7 hours. Peak intensity of 0.15-inch/hour.
		• Lundeen and Stevens Creek	• Sampled March 22, 1998. Antecedent dry period 7 days.

SAMPLING PERIOD	FLOW CONDITION	CREEK	SAMPLING DATES
MAY/JUNE	Dry-weather Storm flows	• Catherine Creek and Lake Stevens Outlet • Lundeen and Stevens Creek • Catherine Creek and Lake Stevens Outlet • Lundeen and Stevens Creek	• Grab samples on May 29, June 2 and 5, 1998. Meters installed from 29th to 5th. • Grab samples on May 11, 14, and 19, 1998. Meters from installed 11th to 19th. • June 15, 1998. Storm depth of 0.50 inches over 5 hours. Peak intensity of 0.37inches/hour. • June 15, 1998. Antecedent dry period 5 days.
JULY/ SEPTEMBER	Dry-weather Storm flows	• Catherine Creek and Lake Stevens Outlet • Lundeen and Stevens Creek • Catherine Creek and Lake Stevens Outlet • Lundeen and Stevens Creek	• Grab samples July 22nd and 28thth. Meters installed from July 22nd to 28th. Grab samples September 4th, 8th, and 11th. Meters installed from September 4th to 11th. • No flow in either creek • September 18, 1998; storm depth of 0.49 inches over 5 hours. Peak intensity of 0.17 inches/hour. September 25, 1998; storm depth of 0.52 inches over 8 hours. Peak intensity of 0.19 inches/hour. • No samples at Station D on either date due to lack of storm flow. • No storm flows in either creek on 18th; no storm flow in Stevens on the 25th. Antecedent dry period prior to September 18th in excess of two weeks.

TABLE 5-3

Water Quality Parameters

SAMPLING	WATER QUALITY PARAMETERS
Dry-weather, meters	Temperature, dissolved oxygen, conductivity, pH, flow.
Dry-weather, grab samples	Ambient and water temperature, dissolved oxygen, conductivity, pH, fecal coliform, phosphorus, ammonia, nitrate, total kjeldahl nitrogen, flow.
Stormwater, flow-weight composite samples	Total suspended solids, total and dissolved zinc and copper, pH, dissolved oxygen, temperature, conductivity, hardness, phosphorus, ammonia, nitrate, total kjeldahl nitrogen, flow.

In the Lake Stevens basin, the sampling focused on Stevens and Lundeen Creeks because their combined watersheds represent about 65 percent of the area that drains to Lake Stevens through definable creeks.

As noted in Table 5-2, the storms that were sampled were of relative short duration with peak intensities that were typical, on the order of 0.15 to 0.20 inches/hour with the exception of the storm of June 15th in which the peak intensity of 0.37 inches/hour. The duration of the storms were shorter than the norm: the mean storm duration for western Washington is 20 hours. The March 22nd storm was in effect shorter than indicated in Table 5-2 because most of the rainfall occurred in seven hours, which was when the sampling was done.

The dry-weather sampling in Stevens and Lundeen Creek did not occur until early April, just outside the period of interest, because of faulty meters. However, it is believed that the quality would not differ significantly from what would have been observed in March. Data from grab samples collected during dry-weather are presented in Appendix D. Data from flow-weighted composite samples collected during storms are also presented in Appendix D.

The data indicate that the water quality of Catherine Creek and the Lake Stevens Outlet Channel is affected to a significant degree for some constituents by human activity. These constituents are discussed below.

Catherine Creek and the Outflow Channel are rated as Class A streams. All the creeks entering Lake Stevens are Class AA streams. Based upon the state criteria set forth in Tables 2-1 the stream standards differ slightly. Due to the different applicable standards, the two groups of streams are discussed separately.

EXISTING WATER QUALITY OF CATHERINE CREEK AND THE OUTFLOW CHANNEL

The water quality of Catherine Creek and the Outlet Channel is discussed separately from that of the streams entering Lake Stevens because of different water quality standards. The factors affecting the water quality of the two sets of creeks also differ.

WATER QUALITY DURING DRY-WEATHER

Summer Water Temperatures

Temperature data taken during dry-weather conditions are summarized in Table 5-4. High water temperatures occur during the summer months in the Outlet Channel and lower Catherine Creek, from its confluence with the Outlet Channel to the confluence with Little Pilchuck Creek. In late May and early June, the temperature in the Outlet Channel was above the standard of 18°C. It ranged from 18 to 19.5°C over the sampling period of seven days. It was 25 to 26°C in July and 20 to 22.5°C in early September. By late September in both 1997 and 1998, the temperature had decreased to more desirable levels. Data in Table 5-4 indicates that the temperature does not change significantly as water flows down Catherine Creek to the Little Pilchuck River.

TABLE 5-4

Temperature And Dissolved Oxygen Data - Dry Weather
Lake Stevens Outlet Channel And Lower Catherine Creek

	Water Temperature (°C)		Dissolved Oxygen (mg/L)	
Date	Outlet Channel in City of Lake Stevens	Upstream of Confluent with Lake Pilchuck	Outlet Channel in City of Lake Stevens[3]	Upstream of Confluent with Lake Pilchuck[3]
September 9, 1997	18.7	18.5[1]	6.2 (66%)[2]	8.1(86%)[1]
September 11, 1997		16[1]		5.3(54%)[1,2]
September 24, 1997	22.8[2]	15.3	9.8 (113%)	9.65 (96%)
March 13, 1998	9.5	11	11 (96%)	11 (100%)
March 19, 1998	9	9.5	14 (122%)	11 (100%)
May 29, 1998	18	14	10 (105%)	8.8 (85%)
June 2, 1998	19.5	18.5	11 (120%)	8.3 (88%)
June 5, 1998	19	18	10 (108%)	8.6 (91%)
July 22, 1998	25	23	8.5 (103%)	7.4 (86%)[2]
July 28, 1998	26	24	7.3 (90%)[2]	7.4 (88%)[2]
September 4, 1998	22.5	21	8.4 (99%)	7.5 (84%)[2]
September 8, 1998	21	18	7.5 (84%)[2]	8.6 (91%)

Date	Water Temperature (°C)		Dissolved Oxygen (mg/L)	
	Outlet Channel in City of Lake Stevens	Upstream of Confluent with Lake Pilchuck	Outlet Channel in City of Lake Stevens[3]	Upstream of Confluent with Lake Pilchuck[3]
September 11, 1998	18	16	8 (88%)	8.8 (89%)
September 25, 1998	16	13	6.3 (64%)[2]	7.5 (71%)[2]

1 These data were taken in Catherine Creek at the 20th Street Bridge.
2 Does not meet Ecology standard of ≥ 0.8 mg/l.
3 Number in parentheses is the saturation percentage

It is noticed that high water temperatures occurred in Lake Stevens during the warm summer months. As the high temperatures are not due to human activity, they do not constitute a violation of Ecology standards (Table 2-1). Nonetheless, the high temperatures are not desirable for fish and likely reduce fish production from the lake outlet to the Little Pilchuck River. High temperatures also increase the sensitivity of fish to the toxic effects of metals and other pollutants that enter the stream during summer storms. In response to these high temperatures, it is likely that Cutthroat Trout and Coho move down Catherine Creek into the Little Pilchuck during the summer (Chamlin, personal communication).

Summer Dissolved Oxygen

Dissolved oxygen data, presented in Table 5-4, were obtained concurrently with the temperature data. Temperature affects the amount of dissolved oxygen that can be retained by the water. The lower the temperature, the more oxygen that can be retained in the water.

In early September 1997, the dissolved oxygen was very low, similar to the situation in late September 1998. Two interrelated factors appear to cause the low dissolved oxygen; low flow in the channel and stream late in the summer, and organic debris on the bottom. Flow in the Outlet Channel and Lower Catherine Creek was very low in early 1997, less than 1 cfs. Similarly, by late September 1998, the flow had decreased to less than 1 cfs (it was about 4 cfs in early September). The flow was so low that the Outlet Channel and lower Catherine Creek were essentially a string of shallow pools with negligible flow from pool to pool.

During very low flows, the dissolved oxygen is also very low because of its consumption by bacteria feeding on organic material on the channel bottom. These periods of bacterial degradation of the organic material on the bottom is sufficient enough to significantly depress the dissolved oxygen. However, the effect on dissolved oxygen is apparently not as noticeable when flows are higher as the water is not in contact with the bottom sediments for as long a period.

The dissolved oxygen increased in late September 1997. Storms occurred between September 11th and September 24th that raised the water level of Lake Stevens and therefore the dry-weather flow in the Outlet Channel, to about 1 cfs. The storms also apparently stimulated an algal bloom in the lake as the dissolved oxygen on September 24th exceeded 100 percent saturation. However, in 1998, the first significant storms did not occur until mid-October. Consequently, the situation in the Outlet Channel and lower Catherine Creek will vary from year to year depending upon the water level in Lake Stevens and storm patterns in September and October.

A similar situation exists in upper Catherine Creek where, in 1998, the flow was very low by early June. There was essentially no flow by mid-July. The effect of the low flow on dissolved oxygen varies throughout upper Catherine Creek, depending on shading by streamside vegetation and localized groundwater inflows. Where the shading is poor, as is the case along much of the creek between SR 92nd and Lake Cassidy, and where there is little to no groundwater inflow, the dissolved oxygen likely becomes very low.

Data were not taken in upper Catherine Creek because of its inaccessibility except at 36th Street N.E. In early June the dissolved oxygen in a pool beneath the bridge was 9 mg/L. The temperature ranged from 16 to 18°C. In late July, the temperature was 19°C and the dissolved oxygen had decreased to 7 mg/L. In late September the temperature was 16°C but the dissolved oxygen was only 6 mg/L. The stream was well shaded at this point and the groundwater inflow was modest.

In spring 1998, the saturation level exceeded 100 percent in the Outlet Channel presumably due to algal activity in Lake Stevens. During the spring, algal activity during daylight hours produces oxygen causing the water to become supersaturated with oxygen. By the time the water reaches the Little Pilchuck River, the oxygen level drops to at or below saturation.

During the summer, the dissolved oxygen levels decreased in response to the increase in the water temperatures. Again, as with temperature, the dissolved oxygen concentration does not meet the Ecology standard. However, as this is not due to human activity, it does not constitute a violation. Table 5-4 indicates that the dissolved oxygen concentration is slightly below saturation until late September when the saturation level dropped significantly.

Bacteria

Both the existing standard for Fecal Coliform bacteria and the proposed standard for Enterococci were exceeded in one or more of the samples for all stations sampled. The data are summarized in Table 5-5. The geometric means for each station are shown in Table 5-5 for each station. Both bacteria standards were exceeded at the two stations in Catherine Creek. The sources of bacteria pollution are not known, but are likely to be either failing septic tanks and/or domestic livestock. During a survey of Catherine Creek, livestock or evidence of livestock were found in Catherine Creek, a few hundred yards upstream of the confluence with the Little Pilchuck River, and along the creek north of SR 92. Given the setback distances of the houses along Catherine Creek, livestock is the likely cause as opposed to failing septic systems.

TABLE 5-5

Bacteria Data During Dry Weather
Lake Stevens Outlet Channel And Catherine Creek

	Fecal Coliform[1]			Enterococci[1]		
Date	Outlet Channel in City of Lake Stevens	Catherine Creek at 36th N.E.	Upstream of confluence at Lake Pilchuck	Outlet Channel in City of Lake Stevens	Catherine Creek at 36th N.E.	Upstream of confluence at Lake Pilchuck
March 13, 1998	20	30	<32	10	43[2]	53
March 19, 1998	38	73	82	9	55	29
May 29, 1998	140	200	240	24	690	480
June 2, 1998	14	76	200	5	180	57
June 5, 1998	31	180	2,400	4	42	47
July 22, 1998	31	600	140	53	88	85
July 28, 1998	43	580	200	320	360	30
Sept 4, 1998	23	no flow	60	-	no flow	-
Sept 8, 1998	140	no flow	64	300	no flow	43
Sept 11, 1998	19	no flow	72	67	no flow	140
Geometric mean	36	154	128	29	121	68
Exceeds 10% Criteria?	no	yes	yes	na	na	na

1 Count per 100 mls.
2 Numbers exceed Ecology standard.

Phosphorus

There is no standard for phosphorus. A guideline of 0.100 mg/L has been proposed for creeks that are not entering lakes (USEPA, 1986). At Station D at 36th Street N.E., the guideline was reached once in the seven samples taken in March, June and July 1998 (there was no flow in September). The concentrations ranged from 0.054 to 0.100 mg/L with an average of 0.080 mg/L. In contrast, the phosphorus concentration of samples from the Outlet Channel averaged 0.025 mg/L. As a comparison, the concentration of phosphorus in a stream that is unaffected by urban or agricultural activities is on the order of 0.010 mg/L. It is therefore clear that human activities are introducing significant quantities of phosphorus to Catherine Creek.

pH

On several occasions the pH exceeded 8.5 units in the Outlet Channel. However, this was a natural phenomena caused by algal activity in Lake Stevens.

Flow

Flow is not a water quality parameter. Nonetheless it can have a significant impact on water quality. Its effect on dissolved oxygen in the Outlet Channel was previously discussed. By August, there was essentially no flow in upper Catherine Creek from Lake Cassidy to Hartford Drive. As previously discussed, the flow was low in the Outlet Channel by June and extremely low by mid-September.

WATER QUALITY DURING STORMS

As noted in Table 5-2, four storms were sampled: March 22, June 15, September 18, and September 25, 1998. Partial sampling was done on September 11 and 25, 1997 to obtain some sense of the conditions in the Outlet Channel.

Experience with other streams in urban western Washington has established that water quality will be adversely affected during storms. This notion held true for the Outlet Channel and Catherine Creek with the exception of temperature and dissolved oxygen. During the storms sampled in June, July and September, the temperatures decreased and the dissolved oxygen increased. These outcomes occurred because the stormwater coming from the land surfaces is cooler with higher concentrations of dissolved oxygen than the base flows in the Outlet Channel and Catherine Creek. As anticipated, the highest concentrations of pollutants generally occurred in the two September storms, due primarily to the very low base flows of less than 1 cfs. Almost all of the water in the Outlet Channel during each storm was stormwater from the land area draining into the channel as lake level did not respond to the two storms. The peak flows during the two late September storms on the 18th and the 24th were 7 and 10 cfs, respectively.

Metals

The most notable change in water quality during storms, in comparison to dry-weather, is the increase in the concentrations of metals. While only zinc and copper were evaluated, experience with other streams in urban western Washington has established that the concentrations of other metals like cadmium, nickel, and lead will also increase. Presented in Table 5-6 are the ranges in concentrations observed at the four sampling stations. The dry-weather flow samples were not analyzed for metals. Rather, the stormwater samples at the outlet of Lake Stevens were considered to be reasonably representative of what would be expected during dry weather because of the treatment effect of the lake.

TABLE 5-6

Ranges Of Metals Concentrations During Storms Lake Stevens Outlet Channel And Catherine Creek

Station	Zinc (mg/L)		Cooper (mg/L)	
	Total	Dissolved	Total	Dissolved
Outlet Channel at Lake	<0.004 - 0.009	<0.004 - 0.012	<0.002	<0.002
Outlet Channel at 20th N.E.	0.005 - 0.071	<0.004 - 0.032	<0.002 - 0.007	<0.002 - 0.004
Catherine Creek at 36th N.E.	0.007 - 0.008	<0.004 - 0.008	0.002 - 0.004	0.003
Catherine Creek at 20th N.E.	0.007 - 0.012	<0.004 - 0.006	0.002	<0.002 - 0.002

The average total zinc concentration increased from an average of 0.005 mg/L at the lake outlet to 0.044 mg/L at 20th N.E. in the outflow channel in downtown Lake Stevens, nearly a ten fold increase. Copper did not increase as significantly. Despite the significant increase, the Ecology standards were not violated at 20th N.E. Concentrations of other toxic pollutants such as oil and grease, polyaromatic hydrocarbons (PAHs), and pesticides probably increased during storms as well.

The highest metal concentrations occurred during the two storms in September when the pre-storm flow was at its lowest in the Outlet Channel. In the two events, total zinc at 20th N.E. was 0.070 and 0.071 mg/L, a twenty fold increase over the concentration at the outlet of Lake Stevens.

Metals concentrations at the two stations in Catherine Creek, upstream at 36th N.E. and at 20th N.E. were similar to those observed at the lake outlet, even though the latter station is downstream of downtown Lake Stevens. The lower concentration was due to dilution by less polluted water that enters the Outlet Channel downstream of the business and residential areas.

Bacteria

Bacteria counts in the Outlet Channel and Catherine Creek increased significantly during storms in comparison to dry-weather. The counts that were found for the three storms in which bacteria were evaluated are presented in Table 5-7. The counts are not unusual for stormwater but nonetheless exceed the Ecology standards.

TABLE 5-7

Bacteria Counts During Storms[1] Lake Stevens Outlet Channel And Catherine Creek

STATION	FECAL COLIFORM[2]	ENTEROCOCCI[2]
Outlet Channel at Lake	13, 680, 1,300	9, 860, 3,500
Outlet Channel at 20th N.E.	500, 4,800, TNTC[3]	290,3,500, 7,100
Catherine Creek at 36th N.E.	1,800[4]	290
Catherine Creek at 20th N.E.	480, 1,800, TNTC	380, 3,000, 4,800

1 One storm in June and two in September
2 Count per 100 mls
3 TNTC = "too numerous to count"
4 Only the June storm was sampled at this station. There was no flow during the September storms.

Other Pollutants

Phosphorus concentrations in the Outlet Channel at 20th N.E. averaged 0.094 mg/L, in comparison to 0.025 mg/L during dry-weather. Ammonia concentrations were slightly higher but nitrate concentrations were generally lower during storms, in comparison to dry-weather flows.

EXISTING WATER QUALITY OF CREEKS ENTERING LAKE STEVENS

As previously indicated, water quality sampling focused on Stevens and Lundeen Creeks because their combined watersheds represent about 65 percent of the area that drains to Lake Stevens through definable creeks.

WATER QUALITY DURING DRY-WEATHER

Dry-weather flow data were obtained in early April and mid-May. By July, Stevens Creek was dry and Lundeen Creek was only a "trickle". Water quality was generally good with exceptions. In Lundeen Creek, the counts for fecal coliform and enterococci exceeded the standard in all six samples, ranging from 93 to 2,400 and 36 to 2,100 counts/100 mls, respectively. In Stevens Creek, the fecal coliform standard was exceeded in four of the six samples. The proposed enterococci standard was exceeded in three of the six samples. The ranges were 20 to 1,100 and 5 to 3,000 count/100 mls, respectively. Nitrate concentrations were high in the April sampling, 1.5 to 3.1 mg/L in the two creeks but relatively low (less than 1 mg/L) in May. In streams relatively unaffected by human activity, nitrate concentrations should be less than 0.25 mg/L. The water quality guideline is 10 mg/L.

Possible causes of the high nitrate and bacteria concentrations are failing septic tanks, livestock that have access to the streams and poor animal waste management practices. A chicken farm located in the Stevens Creek watershed was recently cited by the Department of Ecology (Wright, personal communication). Nitrate concentrations were highest in the April samples while the bacteria counts were found to be at their lowest. The opposite occurred in the May samples. That is, the bacteria and nitrate were not consistent in the two sampling periods. A fourth possible source of bacteria is waterfowl in the wetlands situated immediately upstream of each sampling station.

A dissolved oxygen meter was placed in Stevens Creek for one week in early April and two weeks in late May. The meter was placed immediately upstream of the culvert at Lundeen Parkway. In April, the dissolved oxygen was consistently above 10 mg/L. However, in May, the dissolved oxygen was consistently below the standard of 9.5 mg/L, measuring as low as 6.2 mg/L. The decrease in the dissolved oxygen is most likely natural. It is possibly a reflection of the wetland immediately north of Lundeen Parkway where the combination of the organic material on the bottom and shallow, slow moving water reduced the dissolved oxygen. Lundeen Creek similarly drains through a wetland. It produced a similar but less pronounced effect on dissolved oxygen which dropped below 9 mg/L for a portion of the week monitored in May.

The guideline for phosphorus in streams entering lakes is 0.050 mg/L (USEPA, 1986), unless a lake restoration plan has a different concentration for the lake. A guideline has not been established for Lake Stevens. The average phosphorus concentrations in Lundeen and Stevens Creek were 0.070 and 0.098 mg/L, respectively; exceeding the general stream guidelines. As noted previously with Catherine Creek, the concentration of phosphorus in a stream that is unaffected by urban or agricultural activities is on the order of 0.05 to 0.010 mg/L. The data indicate that human activities are introducing significant quantities of phosphorus to both creeks. Given current land use, the potential sources are livestock and septic tanks.

The above average concentrations found for Lundeen and Stevens Creek are higher than observed in 1994 (KCM, 1995) when the average concentrations were on the order of 0.035 mg/L. Nitrate concentrations were similar to those observed in 1998, ranging from about 0.4 to 2.6 mg/L in Lundeen Creek and about 0.5 to 1.3 mg/L in Stevens Creek.

No sampling was conducted on Kokanee (or Mitchell) Creek in this study. Kokanee Creek was monitored in 1994 (KCM, 1995). The concentration of phosphorus in Kokanee Creek was considerably lower than in Stevens and Lundeen Creeks, averaging about 0.008 mg/L. Nitrate concentrations ranged between about 0.2 and 0.7 mg/L. The concentrations of both constituents are low for an urbanized watershed, in particular the phosphorus (Metro, 1994). The low concentration of phosphate and nitrogen may be explained by the absence of septic tanks and livestock in the Kokanee watershed. Sampling of Stitch Creek occurred in 1994 (KCM, 1995). The concentrations of phosphorus and nitrate at this time ranged from 0.011 to 0.059 mg/L (average about 0.035 mg/L) and 0.4 to 3.2 mg/L (average about 2.2 mg/L).

WATER QUALITY DURING STORMS

With the exception of bacteria, the existing water quality of Lundeen and Stevens Creek is noticeably better than the Outlet Channel, a reflection of the lower level of development in the two watersheds. Of the four storms sampled in this project, only two produced samples for Stevens Creek: March 22nd and June 15th. Samples were obtained from Lundeen Creek during these two storms and on September 25th. Samples were not obtained for the other events because the rainfall was insufficient to generate stream flows.

While water quality was degraded during the storms, the degradation was not particularly notable with the exception of bacteria. On Stevens Creek, the two events produced zinc concentrations of only 0.009 and 0.012 mg/L. Copper was just slightly above the detection limit. Similar results were found with Lundeen Creek except in one of the three events, the total zinc was 0.045 mg/L. The relative low zinc concentrations reflect, in part, the low level of development but may possibly experience removal by the wetlands. Phosphorus concentrations were high in all three events sampled in Lundeen Creek ranging from 0.23 to 0.49 mg/L. Nitrate was on occasion high in both creeks: a maximum of 1.8 mg/L in Lundeen Creek and 4.2 mg/L in Stevens Creek. Ammonia concentrations were low.

Bacteria counts were elevated during storms, above that observed in dry-weather flows. However, these counts are not unusual for storm flows in urban areas. The data are presented in Table 5-8. The higher nitrate concentrations in addition to the bacteria suggest that the source of the bacteria is failing septic tanks and/or livestock. Representatives of the Lake Stevens Sewer District have indicated that there are failing septic systems near Lundeen Creek on 101st Avenue.

TABLE 5-8

Bacteria Counts During Storms Stevens And Lundeen Creeks

STATION	FECAL COLIFORM[1]	ENTEROCOCCI[1]
Lundeen Creek[2]	5,100, TNTC[3]	4,000, TNTC
Stevens Creek[4]	1,800	1,800

1 Count per 100 mls
2 One storm in June, one in September
3 TNTC means "too numerous to count"
4 No flow in Stevens Creek during the September storms.

SOURCES OF POLLUTION

Summaries are provided for each potential pollution source with regard to what was observed in this study. As noted in Table 5-9 as well as in the discussion of the existing water quality, the streams are currently affected adversely by various activities in the rural areas, in particular livestock in the streams and the removal of streamside vegetation. It is likely that fish habitat is already significantly and negatively affected. Preventing or reducing urbanization will not in itself provide significant benefits to the fisheries. Other positive actions are needed if the community expects to have what would be considered effective fish habitat.

Table 5-10 presents a comprehensive list of likely pollution sources and how these might change in the future in the watersheds of Catherine Creek and Lake Stevens.

Statements made with regard to the "Future" are highly dependent upon what actions may be taken to mitigate the effects of the change in land use. The statements in Table 5-9 assume that current policies and programs will continue without change. Land development projects are currently required to control soil erosion during construction and must install detention and treatment systems. However, as discussed in this chapter, these controls, as currently specified, are not completely effective.

URBAN RUNOFF

Urban runoff from developed land and construction sites are two of the major contributors of nonpoint pollution in the Puget Sound area. Natural erosion rates from forested areas varies from 0.01 to 1.0 ton per acre per year. Construction sites lacking effective erosion and sedimentation control measures eroded soils at the rate of 50 to 500 tons per acre per year (WDOE, 1988). In addition to the sediment load, the phosphorus input to streams and lakes from uncontrolled construction sites has been estimated at 10 to 20 times that of a forested area and 5 to 10 times that of a developed residential area (Perkins, 1995).

CONSTRUCTION SITE EROSION

Construction practices are subject to inspection by either the County or City depending upon the location. Major construction is anticipated in the near future with a population increase of up to 14,000 people expected within the UGA by 2012 (Alternative 6). Assuming an occupancy of 2.5 people per unit and six units per acre, approximately 1,000 acres of land will be cleared for 5,600 new homes. This area is equivalent to 15 percent of the UGA area or the surface area of Lake Stevens itself. Assuming a sediment erosion rate from construction sites of 200 tons per acre, potentially 200,000 tons of sediment (300,000 cubic yards) could move into the streams and lake from construction sites unless strict erosion control measures at construction sites are implemented.

TABLE 5-9

Possible Causes Of Degraded Water Quality

POTENTIAL POLLUTION SOURCE	POSSIBLE POLLUTANTS OR EFFECTS	FINDINGS IN THIS STUDY	THE FUTURE
Loss of streamside vegetation through clearing by owners of property that abuts the stream	Increase in water temperature which increases the toxic effects of metals and other toxicants	Walking of the streams and/or aerial photography indicates that significant sections of each creek are exposed to the sun because of inadequate vegetation in both the urban and rural areas.	Loss will increase with increasing development as streamside buffers will be abused by unknowing property owners.
Accelerated erosion of stream channels and banks	Sediment, phosphorus	Currently, erosion due to urbanization is not readily apparent in each creek but it is not possible to know what the channel dimensions were prior to this study due to the lack of data.	Increased flows from new development will increase sediment generation.
Excessive erosion of residential and commercial sites under development	Sediment, phosphorus	Sediment in stormwater runoff has been observed from construction sites. During this study construction sites have been shut down by the county because of the lack of adequate erosion and sediment control BMPs.	With each new development sediment will be generated during the construction period even with effective implementation of BMPs.
Residential and commercial developments	Metals, phosphorus, nitrogen, oil and grease, PAHs, pesticides and herbicides, bacteria	The data gathered in this study is consistent with other field studies in western Washington that have found that urban development results in a significant increase in the concentrations and loadings of various pollutants.	Will increase significantly particularly in Lundeen, Stevens, Stitch, and Catherine Creeks.
Failing septic tank drain fields	Bacteria, ammonia, nitrate, organic nitrogen	The level of bacteria and nitrate in Stevens, Lundeen, and upper Catherine Creek indicate that septic tanks should be considered as a possible source.	Could decrease with time as unsewered areas are sewered with the increase in housing densities
Livestock accessing streams	Bacteria, phosphorus, nitrogen	A ground survey of Catherine Creek found that livestock have access to portions of both upper and lower Catherine Creek. Manure was found within a few feet of the stream in upper Catherine Creek.	Will not change with development as the livestock are north of SR 92 unless actions are taken by livestock owners to prevent access.
Degraded pasture land	Sediment, phosphorus, nitrogen, and bacteria if livestock present.	Aerial surveys indicated many pasture areas where vegetation appears to be thin.	Will not necessarily change as these lands are north of SR 92nd.
Chicken farms in Lundeen and Stevens Creek	Bacteria, phosphorus, nitrogen	Chicken waste and stormwater exposed to chicken waste was reaching the streams.	Field visits are required to ascertain the magnitude of this source of pollution.
Low flow	Higher temperatures and lower dissolved oxygen during dry-weather	Observations during this and previous studies indicate flows become very low during the summer, and that water quality degrades.	The length of little or no flow each year will increase with increasing development.
Improper disposal of solid waste, and littering	Aesthetic impacts. Wildlife may be adversely affected. May contribute toxics as they deteriorate.	Careless tossing of packaging materials and other debris accumulates in streams.	Will increase as population densities increase in the Growth Management Boundary

TABLE 5-10

Estimated Change In Pollutant Loadings During Storms From Land Surfaces

Watershed	TSS[1]			Phosphorus[2]			Zinc[2]		
Loading Point	Exist	Future w/o treat lbs/(% change)	Future w/ treat lbs/(% change)	Exist	Future w/o treat lbs/(% change)	Future w/ treat lbs/(% change)	Exist	Future w/o treat lbs (% change)	Future w/ treat lbs (% change)
CATHERINE CREEK WATERSHED									
Catherine Creek at Hartford Drive	121	136 (12%)	98 -(19%)	558	734 (33%)	555 (0%)	177	465 (163%)	348 (97%)
Outlet Channel at 20th N.E.	21	26 (24%)	22 (5%)	120	144 (20%)	129 (11%)	79	101 (28%)	86 (9%)
Outlet Channel at Catherine Creek	54	94 (74%)	58 (7%)	288	554 (92%)	373 (30%)	165	358 (117%)	246 (49%)
Catherine Creek at Lake Pilchuck	192	267 (39%)	174 (-9%)	933	1,500 (61%)	1,047 (12%)	375	955 (155%)	673 (79%)
LAKE STEVENS WATERSHED									
Stevens Creek	60	77 (28%)	55 (-8%)	265	416 (57%)	286 (8%)	57	251 (340%)	171 (207%)
Lundeen Creek	46	73 (59%)	42 (-9%)	214	422 (97%)	269 (26%)	67	257 (200%)	167 (107%)
Kokanee/Mitchell Creek	35	39 (11%)	35 (0%)	199	226 (14%)	203 (2%)	123	146 (19%)	132 (7%)
Stitch Creek	45	75 (67%)	39 (-13%)	232	445 (92%)	271 (17%)	119	299 (151%)	195 (64%)
Total to Lake Stevens	272	432 (59%)	242 (-11%)	1,340	2,516 (88%)	1,584 (18%)	576	1,616 (181%)	1,061 (84%)

1 Tons per year
2 Pounds per year

AGRICULTURAL NONPOINT SOURCES

Agricultural activities can be broadly defined into two groups; crop production and animal keeping. For the most part, in the Lake Stevens and Catherine Creek watersheds, commercial crop production is minimal. However there are many small hobby farms with large livestock. Runoff from animal keeping includes sediment, pathogens, organic material, fecal coliform bacteria and pesticides. Nonpoint source pollution can become a problem from farms if the animals are not restricted from entering creeks, if the land is overgrazed leading to poor soil cover or if proper waste management is not practiced.

There are also a few chicken farms in the region. The commercial chicken farm located on the western branch of Stevens Creek was recently shut down by the State Department of Ecology. One sample obtained from the farm found 22,000 fecal coliform units per 100 ml of water. This far exceeds the state standard of 100 units/100ml of water. At the time of this report, the farm owner was fined $21,500 by DOE and if he does not comply with the EPA's regulations within 10 days, he could be fined up to $27,500 per day.

If wastes are spread on the land, care must be taken to prevent both storm water runoff and ground water contamination. Nitrates, a byproduct of animal waste, is mobile in the ground water system and has been known to create contamination problems in wells. Fecal coliform was found in both Stevens and Lundeen Creeks at concentrations exceeding water quality standards.

FUTURE WATER QUALITY

THE EFFECT OF NEW DEVELOPMENT

Continued urban development will impact future water quality. To evaluate the impacts consideration was given to:

1. The effect of growth on annual pollutant loadings.
2. The change in water quality caused by the change in annual pollutant loadings.

Pollutant Loading

Pollutant loading has a long term impact on the water quality of Lake Stevens whereas changes in water quality in the streams can have an immediate impact on the biota in the streams. The possible effects of continued urbanization are evaluated by first estimating the existing and future annual loading of key pollutants. Loading refers to the total pounds of a pollutant that are washed into a stream or lake over an average year. The second step, described in the next section, is to translate the change in pollutant loadings to water quality in the streams.

Loading estimates were made for three conditions:

Condition #1: Loading from land use under existing conditions
Condition #2: Loading when development in the basins has reached essentially saturation as defined by the Snohomish County land use plan, but without treatment systems installed in each new development
Condition #3: The same as Condition #2, but with treatment systems installed in each new development following the current requirements of Snohomish County.

Estimates in the change in pollutant loadings with the urbanization of the planning area are derived from a loading simulation model (Appendix E). The modeled area covers the entire watersheds of Catherine Creek and Lake Stevens, and uses the same basin and subbasin delineation that was used for the HSPF hydrologic model analysis (Figure 4-4). The estimates of the various types of land use (for example, multifamily residential) also used the same data base as that used for the HSPF stormwater modeling. The complete procedure that was followed in preparing these loading estimates as well as the detailed calculations are presented in Appendix E.

The results of the loading analysis are presented in Table 5-10. The total quantities of pollutants at key points of interest in the two watersheds are shown. The percentage increases in each pollutant at the same points of interest are displayed as well. Three pollutants were modeled: totals suspended solids (TSS) or sediment, phosphorus and zinc. TSS was selected as it represents sediment and is the primary parameter for judging the effectiveness of stormwater treatment systems.

Phosphorus represents nutrients and is of particular concern to Lake Stevens. Zinc represents metals and other potentially toxic pollutants.

There are several observations to draw from the information provided in Table 5-10. The effect of development is most easily understood by comparing the percentage changes in loading. There are about 7,000 acres in the two watersheds, excluding the surface areas of the lakes. About 1,000 acres have been developed to-date into medium to high density residential, parks and government, and commercial or industrial land uses. At build-out, according to the current land use plan, about 2,400 more acres will be urbanized, an increase of 240 percent.

Sediment entry into streams may differ between urban and rural land use. Sediment washes from developed urban land in all storms, and in comparison to runoff from pasture lands, may vary less with respect to concentration. In contrast, sediment from pastures may enter streams primarily during large but less frequent storms. The effect on the stream may therefore differ with respect to an urban stream. It is also important to recognize the considerably greater uncertainty in the estimates of sediment loss from pastures. Finally, the sediment estimates in Table 5-10 do not include two other significant sources in urban areas: sediment from construction sites and sediment for accelerated erosion of stream channels. These two sources are discussed later in this chapter.

For most subbasins the loading of sediment or TSS from developed land surfaces may decrease with urban development. This is because much of the land conversion will be from pasture to urban land uses, or from pasture to low-density residential in which land owners may allow a portion of their land to return to forest cover. Pastures can generate sediment loads similar to loads from pavement in urban areas. With treatment in new developments, the overall sediment coming from the land surfaces may decrease.

With urbanization, loadings of phosphorus increase. However, with treatment in new developments, the increase in the phosphorus loading from developed land surfaces may be modest, from 2 to 30 percent depending on the basin in Table 5-10. The modest increase is due in part to the fact that pastures that will be replaced by urbanization contribute phosphorus. The stream data collected in this study tend to confirm this observation.

The most significant change will be with zinc and other pollutants that can be toxic to the aquatic community. Even with treatment in new developments, loading of zinc is estimated to increase by as much as 207 percent.

The change in the loading to Kokanee (Mitchell Creek) is very modest because this basin is essentially developed. This is also the case for the Outlet Channel in downtown Lake Stevens.

In contrast, loadings of phosphorus but, more significantly, zinc increase substantially in Stevens, Lundeen, Stitch and Catherine Creeks because of the greater amount of land within each watershed that will be converted to urban use. The increases are not consistent between the basins because of the differences in the types of land conversion that occur in each basin.

Requiring stormwater treatment in new developments is important to reduce pollutant loadings. However, higher levels of treatment may be necessary to control toxicants like metals, and phosphorus, particularly for those basins that drain to Lake Stevens. Proper maintenance of the treatment systems is important as the removal efficiencies judgmentally assumed in the preparation of Table 5-10 assumes that maintenance will occur.

To the above estimates of sediment and phosphorus must be added two additional sources: construction sites and accelerated erosion of stream channels. Estimates for these sources are summarized in Tables 5-11A and 5-11B (Appendix G). Two estimates are provided for each constituent: low and high. The extremes of the range reflect differing assumptions as explained in Appendix G. For construction, two factors are considered: the period over which all of the construction occurs, assumed to be 10 and 20 years, and the type and effectiveness of soil erosion and control BMPs. The estimates of sediment for channel erosion are based on the anticipated increase in the cross-sectional area of the channel due to the expected increase in the flows of the 2-year storm (Table 4-8). The channel adjustments are assumed to occur over a period of 50 years.

TABLE 5-11A

Sediment And Phosphorus From Construction And Stream Channel Erosion From Construction Sites

Watershed	Sediment (tons/year)		Phosphorus (lbs/year)	
Loading Point	Low	High	Low	High
CATHERINE CREEK WATERSHED				
Catherine Creek at Hartford Drive	6	59	35	350
Outlet Channel at 20th N.E.	<1	<1	<1	<1
Outlet Channel at Hartford Drive	4	45	26	267
Catherine Creek at Little Pilchuck River	13	127	75	760
LAKE STEVENS WATERSHED				
Stevens Creek	4	44	27	267
Lundeen Creek	5	54	32	314
Kokanee/Mitchell Creek	1	8	5	50
Stitch Creek	7	75	45	448
Total to Lake Stevens	15	149	89	893

TABLE 5-11B

Sediment And Phosphorus From Construction And Stream Channel Erosion From Stream Channel Erosion

Watershed	Sediment (tons/year)		Phosphorus (lbs/year)	
Loading Point	Low	High	Low	High
CATHERINE CREEK WATERSHED				
Catherine Creek at Hartford Drive	10	20	60	120
Outlet Channel at 20th N.E.	<1	<1	<1	<1
Outlet Channel at Hartford Drive	<1	<1	<1	<1
Catherine Creek at Lake Pilchuck	30	45	190	270
LAKE STEVENS WATERSHED				
Stevens Creek	20	40	120	240
Lundeen Creek	10	20	60	120
Kokanee/Mitchell Creek	<1	<1	3	5
Stitch Creek	5	10	30	60
Total to Lake Stevens	35	70	211	423

The estimates of channel erosion for lower Catherine Creek assume that the large wetland north of Hartford Drive will remain intact. However, as noted in Table 4-8, should the wetland be reduced by 50 percent, the effect on flows as well as channel erosion will be significant. A reduction of the wetland by 50 percent would increase the estimates of accelerated channel erosion in Table 5-11 by almost 50 percent.

The estimates in Table 5-11 indicate that the amount of sediment and phosphorus from either erosion at construction sites or of stream beds can be significant, possibly on the order of what is washed from developed land, in those subbasins that are undergoing significant development. The two types of sediment have different effects however. Sediment from erosion can adversely affect fisheries by the smothering of spawning areas. Sediments from developed lands can be toxic in addition to smothering the spawning gravels.

Water Quality Of The Streams

Water quality during dry-weather may not change significantly with urbanization. The water quality of Stevens and Lundeen Creeks is already degraded particularly with respect to bacteria, phosphorus and nitrate. The water quality of Kokanee Creek and the Outlet Channel in downtown Lake Stevens will not likely change as the land that drains to these receiving waters are essentially developed. However, the Outlet Channel downstream of 20th N.E. may degrade because much of the land draining to this section of the channel remains to be developed.

Water quality of the creeks during storms will continue to degrade with urbanization. The two exceptions may be Kokanee Creek and the Outlet Channel in downtown Lake Stevens, for the reason given above with regard to dry-weather flows. For the other creeks, it can be expected that urbanization will increase the concentrations of metals, petroleum products like oil and polyaromatic compounds (PAHs), and sediments. However, the concentrations will not necessarily increase in direct proportion to the increase in the loadings presented in Tables 5-10 and 5-11. This is because the amount of stormwater will also increase with urbanization. Judging from Table 5-10 and the fact that phosphorus is already elevated in all of the creeks except the Outlet Channel (owing to the removal of phosphorus in the lake), phosphorus concentrations may not increase significantly. A likely exception is the Outlet Channel downstream of 20th N.E. as land that drains through the Leavitt ditch north of Hartford Drive develops.

Table 5-10 indicates that the concentrations of zinc, and by extension other metals and toxicants, will increase significantly, on the order of 50 to 100 percent depending on the stream. Particularly significant increases will occur in Catherine, Stevens and Lundeen Creeks. It can be expected based on experience with urban streams elsewhere in Puget Sound that some metals, in particular zinc and copper, will frequently exceed the Ecology standards during storms.

An effect of urbanization which is very important and must not be overlooked is the increase in the number of rainfall events that produce runoff. For example, the two storms that were sampled in September did not produce flows in Lundeen, Stevens or upper Catherine Creek (north of Hartford Drive) even though the depth of each storm was about 0.50 inches. With urbanization, storm depths as low as 0.10 inches will produce runoff that will enter the stream. Although water quality standards specify only concentrations, research has shown that adverse affects on fish are also directly related to the frequency and the duration of exposure to elevated levels of pollutants. Urbanization increases the number of storms that expose the fish to toxicants and the duration of elevated levels of pollutants (Booth, 1990).

IMPACTS OF NONPOINT SOURCE RUNOFF ON LAKE STEVENS

The Vollenweider model was used to evaluate long term impacts on phosphorus concentrations in the lake due to increased storm water runoff. The model estimates long term total phosphorus on an annual average basis. The model does not account for seasonal changes in the water quality of the lake.

$TP = L/z(\rho+\sigma)$

TP= average annual TP concentration (µg/L)
L = loading in (mg/m^2-yr)
z = mean depth in meters
ρ = flushing rate (1/yr)
σ = sedimentation rate (approximately equal to $\rho^{0.5}$) (Welch, 1992)

The loading was shown in Table 5-10. Current total phosphorus loading is estimated at 1,340 lb/yr (609 kg/yr). Future loading is estimated at 2,516 lb/yr (1,143 kg/yr) without treatment and 1,584 (720 kg/yr) pounds per year with treatment.

Total phosphorus loading to the lake per unit area is calculated as the total mass divided by the surface area. The lake surface area is approximately 1,060 acres (4,240,000 m^2).

$$L_{existing} = 609 \text{ X}10^6 / 4.24 \text{ X}10^6 = 143 \text{ mg/m}^2\text{-yr}$$
$$L_{future\ w/out\ treat} = 1{,}143 \text{ X}10^6 / 4.24 \text{ X}10^6 = 269 \text{ mg/m}^2\text{-yr}$$
$$L_{future\ w/treat} = 720 \text{ X}10^6 / 4.24 \text{ X}10^6 = 170 \text{ mg/m}^2\text{-yr}$$

The detention time of the lake is about seven years. The flushing rate is 1/detention time or 1/7 1/yr. The mean depth of the lake (volume/surface area) is approximately 20 meters. The solution to the model is given below using the parameters given above.

$$TP_{existing} = L/z(\rho+\sigma) = L/z(\rho+\rho^{0.5}) = 143/(20*(1/7+(1/7)^{0.5})) = 143/(20*0.52) = 14 \ \mu g/L$$
$$TP_{future\ without\ treat} = L/z(\rho+\sigma) = L/z(\rho+\rho^{0.5}) = 269/(20*(1/7+(1/7)^{0.5})) = 26 \ \mu g/L$$
$$TP_{future\ with\ treat} = L/z(\rho+\sigma) = L/z(\rho+\rho^{0.5}) = 170/(20*(1/7+(1/7)^{0.5})) = 16 \ \mu g/L$$

The model compares well with the observed data. The mean annual volume weighted total phosphorus concentration in Lake Stevens in 1997 was 14.8 µg/L. If development occurs without treatment the total phosphorus concentrations in the lake are predicted to double. The Phase IIa Restoration Study (KCM, 1987) presents phosphorus data which indicates the annual average total phosphorus concentration in 1986 through 1987 was 22 µg/L. Algae blooms, both frequency and duration are positively correlated to increased total phosphorus concentrations. Based upon projected loadings, unless stormwater runoff treatment occurs, the phosphorus concentration in the lake will increase to concentrations greater than those that existed prior to the aerator restoration project. With increased phosphorus concentrations will come increased algae concentrations and increased algae blooms. As stated in the KCM (1987) report, "Without watershed improvements all in-lake restoration efforts will in time be overcome by the phosphorus loading from the lake basin."

CHAPTER 6
FISHERIES

INTRODUCTION

The specific streams evaluated in this plan are:

- Catherine Creek, from Lake Cassidy to its confluence with the Little Pilchuck River.
- The outlet channel from Lake Stevens to its confluence with Catherine Creek.
- Major tributaries to Lake Stevens: Stevens, Lundeen, Kokanee, and Stitch creeks.

The locations of these creeks are shown in Figure 5-1.

The habitat questions addressed in this chapter include:

- What is the quantity and quality of the existing stream habitat?
- What is the status of the existing water quality related to fish requirements?
- What is the future stream habitat likely to be under buildout conditions?
- How might stream habitat be affected by the alternative flood control solutions considered in this basin plan?
- What are the possible actions that could be taken to improve stream habitat and/or reduce the affects of future development?

HISTORICAL FISH USAGE

The Pilchuck River has been an important system for the spawning, rearing and migration of coho (*Oncorhynchus kisutch*), chinook (*O. tshawytscha*), chum (*O.* keta) and pink (*O. gorbuscha*) salmon, and steelhead (*O. mykiss*) and cutthroat trout (*O. clarkii*). Coho salmon historically spawned and reared in all accessible tributaries of the Pilchuck River system including Little Pilchuck Creek, Catherine Creek and Stevens Creek. Steelhead and cutthroat trout also utilize these streams.

Other species of fish in this system include sculpin (*Cottus sp.*), sunfish (*Lepomis sp.*), three-spined stickleback (*Gasterosteus aculeatus*), and Western brook lamprey (*Lampetra richardsoni*).

In the mid-1920's, Lake Stevens and Lake Cassidy were noted for their large populations of coho salmon and cutthroat trout, respectively. Lake Stevens was always a very popular resort lake, even in the early days. As early as 1925, Lake Stevens had already been stocked with an assortment of fishes to supply the demands of recreational anglers, including rainbow trout, lake trout, spiny-rays, and kokanee (*O. nerka*) of Whatcom Lake origin (Anon. 1925). The introduced kokanee established a spawning population and did very well for a number of years. The old Washington Department of Game even operated an egg-taking station for kokanee at Lake Stevens during the 1930's and 1940's; this operation was phased out in the 1950's (Crawford 1979).

There is anecdotal information about native kokanee being in Lake Stevens as well. These stories, however, could not be verified. While Lake Stevens is now stocked, self-sustaining populations of salmonids likely remain in tributaries to the lake. Unfortunately, the native lake-dwelling cutthroat of Lake Cassidy were overfished and disappeared.

Lake Stevens is a deep, rich lake, and kokanee, as well as the other species of fish within the lake, grow very well. Kokanee as large as 20 inches in length are routinely reported by anglers. Spawning habitat appears to be a major limiting factor for kokanee in Lake Stevens.

Catherine, Stevens and the other adjacent streams investigated have, and continue to support, populations of resident and anadromous salmonids and other fish. In particular, coho salmon, kokanee and sea-run cutthroat trout in these tributaries make an important contribution to the total fish production in Lake Stevens and the Pilchuck River system.

FISH LIFE HISTORY INFORMATION

Kokanee spawn in Stevens, Kokanee (Mitchell), and Lundeen Creeks in late October through December. One hundred to two hundred days after the eggs have been laid, kokanee fry emerge from the gravel and migrate downstream to Lake Stevens. Young kokanee remain in the lake until they return to the streams to spawn.

Coho and cutthroat trout are present in all of the creeks evaluated in this basin plan. Similar to the kokanee described above, coho fry will remain in the gravel for a similar period. After emergence, the young fry will typically remain in the creek during the summer and the next winter before migrating to the ocean. Coho must therefore survive at least two winters and one summer in the stream.

The cutthroat trout have two distinct life forms: resident fish and sea-run fish. Early life stages for both fish are the same and are similar to those of coho. The difference between the two life forms is that resident fish will remain in the stream their entire life. After rearing for a year or more, sea-run cutthroat will then migrate to salt water, and after a year or more, then return to freshwater to spawn.

SUMMARY OF THE FIELD INVESTIGATIONS

Fish Sampling

As part of previous investigations, four sites were sampled for the presence or absence of fish on May 31, 1995. The sites sampled were the Outflow Channel near its confluence with Catherine Creek, Catherine Creek at 36th Street, Catherine Creek at 54th Street, and Stitch Creek at Vernon Road. Salmonids were captured at three of the four sites; no fish were captured at Catherine Creek in 54th Street.

Of the four sites sampled, the Outflow Channel had the most flow (estimated at two to three cubic feet per second [cfs]). In the sampling area, where the channel flows adjacent to Hartford Drive, there is limited overhead cover and instream cover, and a substrate of small gravel and sand. The fish at this site were captured in glide habitat.

In May of 1995, Catherine Creek at 36th Street had very limited flow—estimated at a few gallons per minute—most of which was flowing through the gravel. The riparian corridor was well vegetated with nearly complete canopy closure. The substrate was large gravel and small cobble. The fish at this site were captured from water left in pools along the creek.

Catherine Creek at 54th Street was mostly standing water with little velocity. The flow at this site was constrained by a downstream beaver dam. The substrate consisted of organic material; visibility in the dark, tannic water was very limited.

In Stitch Creek, the fish were captured in a plunge pool downstream of the culvert crossing under Vernon Road. The flow in Stitch Creek, while more than Catherine Creek at 36th Street, was also limited. The riparian corridor was well vegetated; the substrate consisted of small gravel and sand. Stitch Creek was also sampled upstream of the culvert; because no fish were captured in this area, it appears that this culvert may be a barrier to upstream migration of fish.

Of the six species of fish captured at these sites, juvenile coho were most common (Table 1). Other species of fish include cutthroat trout, sculpin (*Cottus sp.*), sunfish (*Lepomis sp.*), three-spined stickleback (*Gasterosteus aculeatus*), and a Western brook lamprey (*Lampetra richardsoni*).

The juvenile coho captured in the Outflow Channel and Catherine Creek were very similar in size (median length = 53 mm for each stream). These fish were likely young-of-the-year fish (i.e., born in late 1994—early 1995). The juvenile coho in Stitch Creek, which were larger (median length = 65 mm), may also be young-of-the-year or possible holdovers from 1994.

The only cutthroat trout captured were in Stitch Creek. Because of the larger size (median length = 120 mm), these fish appear to be mostly one or two-year old fish. A summary of the fish sampling data is presented in table 6-1.

TABLE 6-1

Summary of fish sampling data collected on May 31, 1995 at four sites in the Lake Stevens basin.

	Species of Fish (size in mm)			
Location	Coho	Cutthroat	Sculpin	Other
Stevens Creek	39, 43, 43, 44, 45, 45, 51, 54, 55, 58, 65, 75, 76, 81		79, 89, 90, 91	Sunfish - 47 Western Brook Lamprey - 120
Catherine Creek at 36th St.	39, 46, 47, 50, 52, 54, 56, 61, 64, 64,			Stickleback - 45
Catherine Creek at 54th St.	No fish captured			
Stitch Creek	50, 51, 64, 65, 65, 65, 72, 75, 81	55, 105, 120, 120, 130, 130		

Invertebrate sampling
The invertebrate population is a important indicator of stream health inasmuch as they are the food source for fish. In this context, health is determined by the types and variety of species, and the total number of individuals. Samples were obtained in late September 1998 at the locations shown in Figure 6.2. The procedures used and the detailed results are presented in Appendix F.

Refuge habitat
Fish require refuge areas for protection from the high flows of winter storms. The initial general survey of Catherine Creek and the Outlet Channel indicated that lower Catherine Creek, from 16th NE to the creek's confluence with the Little Pilchuck was least affected by human activities(the lower half of Reach 1). Hence, it was decided that the focus of the refuge survey would be in this section inasmuch as poorer conditions would be found elsewhere. The survey was conducted in early October, 1998. The analysis is presented in Appendix G and discussed later in this chapter.

EXISTING STREAM HABITAT

OUTFLOW CHANNEL TO CONFLUENCE WITH CATHERINE CREEK

This stream has a low gradient (<0.5 to 1.0 percent), mostly trapezoidal channel with high, steep banks. The stream averages 12 feet in width through most of the reach (range: 10 to 22 feet). Within the City of Lake Stevens, the stream banks are nearly vertical and reinforced with riprap. Downstream, there are high banks (10-15 feet) that are covered with grass, vines and occasional willows. The overhead canopy is limited to nonexistent.

The habitat is primarily glide with short riffle stretches under the bridges. The substrate in the upstream portion of this reach is gravel; further downstream, the substrate is silt and sand. There is limited instream complexity. For example, there is no large woody debris in the channel or off-channel or eddy areas for high flow protection. Because of this limited complexity, there is also limited refuge habitat. Bridges and streambank with vegetation on the right side provides shade. The riparian vegetation consists of blackberries and other brush.

The stream banks consist of non-cohesive coarse sand and gravel; there are few signs of erosion. There is some road slope failure that appears due to saturated banks rather than toe erosion. There are a few stretches of recently placed bank protection.

CATHERINE CREEK

Reach 1: Confluence with the Little Pilchuck Creek to 20th Street NE.

In this reach, which has the least disturbed habitat, the stream slope varies from 1.0 to1.5 percent. The substrate consists of small to medium gravel that is tightly embedded by sand. The habitat consists mostly of riffle and mid-channel pools. There is a moderate amount of large woody debris with few small debris jams that cross the stream.

There are floodways on both sides with clear signs that at high discharge, the stream flows between successive bends through side channels and vegetated, low elevated areas. There is a considerable amount of off-stream refuge in and along these channels.

The low stream banks (one to three feet high) consist of a semi-cohesive to non-cohesive sand and gravel that is well rooted by willows or protected by large woody debris. There were no obvious signs of excessive erosion or mass wasting. The canopy closure varies from 50—100 percent. The vegetation along banks consists of thick willows with some larger firs.

Reach 2: 20th Street NE to Hartford Drive

The stream has been channelized with high banks that are densely covered with blackberries and other brush. The stream slope varies from 0 to 0.5 percent and channel width averages 13 feet (range: 10 to 18 feet). The instream habitat consists primarily of glides (95 percent) with limited large woody debris and a substrate of silt and sand with a few areas of gravel. There is limited overhead canopy and limited woody debris, off-channel or eddy areas that provide refuge habitat.

Reach 3: Hartford Drive. upstream 2,514 feet

The stream flows through an open field that used to be a farm in a straight, deeply entrenched channel. The riparian vegetation is mostly reed canary grass; the habitat consists primarily of one long glide with no large woody debris.

Reach 4: 2,514—4,341 feet upstream of Hartford Drive
The stream in this reach has a very gentle slope (<0.5 to 0.5 percent). The channel averages 11 feet in width (range: 9 to 18 feet) along with a very wide floodway area. The substrate consists of loose, small gravel throughout the reach. The habitat consists of riffles, shallow glides, and shallow, short mid-channel pools. The large woody debris is limited to tangles of small, wood debris across the channel.

Reach 5: 4,341 feet upstream of Hartford Drive to 36th Street NE.
The stream is channelized with a slope of 0.5 percent. The channel width averages eight feet (range: 7' to 9') with banks that are 3 to 10 feet high. The stream banks consist of unconsolidated course sand. The instream habitat, which consists of riffles and glides, has very little complexity. The substrate is small to medium loose gravel. The canopy closure ranges from 25 to 50 percent.

Reach 6: Stream Distance 10,791 feet to SR92
The stream, with a slope of 0.5 percent, is much more sinuous than other downstream reaches. The channel width varies from 8 to 18 feet. Banks range from low levels to five feet high; semi-cohesive to non-cohesive bank material. Habitat consists mostly of glides with very little large woody debris in the stream channel but there is some channel complexity. The substrate is primarily gravel.

Reach 7: Hwy 92 to 1718 feet upstream. Upstream of Highway 92, the stream is very "natural," with diverse habitat, gravel substrate, and large conifers along both banks. With a slope of 0.5 to 0.75 percent, the stream in this reach meanders frequently. Channel width average 12 feet (range: 8 to 18 feet) with floodways and side channels through thick vegetation. The stream banks vary from one to five feet in height and consist of semi-cohesive to non-cohesive material. There are no areas of significant erosion or mass wasting.

The habitat consists of glides, riffles and some shallow mid-channel pools. Compared with other reaches, there is considerable complexity along the stream edges, particularly along the first 600 feet.

Reach 8: 1718 feet upstream of Highway 92 to end of inventory. This reach of Catherine Creek is surrounded by pasture and wetland. The channel is well-defined, relatively deep and narrow with very little overhead cover or instream woody debris. At the upstream end of the reach, stream banks are covered with dense brush and sparse trees.

The stream has a slope of 0.5 percent with an average channel width of 12 feet (range: 6 to 35 feet). The stream flows through an open, grassed area where cattle graze on both sides of channel and are able to enter creek. There is no overhead canopy. The low banks and grassed channel bottom suggest much of this reach is dry during the late summer.

Habitat consists of glides interspersed with shallow mid-channel pools. There is little channel complexity and no large woody debris.

WATER QUALITY

WATER TEMPERATURE

Salmonids are cold water fish with definite water temperature requirements. Water temperatures influences the metabolism, behavior, and mortality of fish and other organisms in their environment. Although fish may survive at temperatures near the extremes of the suitable range, growth is reduced at high temperatures because most or all of the food must be used for maintenance. Many salmonids change behavior with increases in temperature.

The preferred water temperatures of the various salmonids rearing in the Catherine Creek system are very similar to each other (Table 6-2). The upper lethal water temperatures are also very similar. Water temperatures that exceed state standards can stress fish, making them susceptible to predators or disease.

TABLE 6-2

Salmonid Preferred and upper lethal water temperatures (°C)

Species	Preferred Temperature	Upper Lethal Temperature
Coho Salmon	12-14	26-29
Sockeye Salmon	12-14	26
Steelhead Trout	10-13	24
Cutthroat Trout		23

Source: Bjornn and Reiser 1991.

In small streams where daily maximum water temperatures approach lethal levels, salmonids can thrive if the temperature is high for only a short time and then declines well into the optimum range. Many populations of native salmonids respond to natural temperature patterns in streams by moving upstream or downstream when water temperature becomes unsuitable (Bjornn and Reiser 1991).

High water temperatures were recorded during the summer months in the outlet channel and lower Catherine Creek (from its confluence with the outlet channel to its confluence with Little Pilchuck Creek). In late May and early June, the water temperatures were sufficiently high enough to stress fish. The water temperatures in July and early September were near the upper lethal limits for cutthroat and steelhead trout.

The high water temperatures in Catherine Creek (see Table 5.4) most likely reduce fish production from the lake outlet to the Little Pilchuck River. High temperatures also increase the sensitivity of fish to the toxic effects of metals and other pollutants that enter the stream during summer storms. In response to these high water temperatures, it is likely that cutthroat trout and coho migrate out of Catherine Creek to the Little Pilchuck during the summer.

Dissolved Oxygen

Salmonids may be able to survive when DO concentrations are relatively low (less than 5.0 mg/l), but growth, food conversion efficiency, and swimming performance will be adversely affected. High water, which reduces oxygen solubility, can compound the stress on fish caused by marginal DO concentrations.

Bjornn and Reiser (1991) report that salmonids would not be impaired at concentrations near 8 mg/l (76 to 93 percent saturation). As seen in table 6-3, they further state that initial symptoms of DO deprivation would occur at about 6 mg/l (57 to 72 percent saturation).

TABLE 6-3

Response of freshwater salmonid populations to dissolved oxygen.

	Dissolved Oxygen (mg/l)	Percent saturation at Temperature (°C)					
		0	5	10	15	20	25
Function without impairment	7.75	76	76	76	76	85	93
Initial distress symptoms	6.00	57	57	57	59	65	72
Most fish affected by lack of oxygen	4.25	38	38	38	42	46	51

(Source: Bjornn and Reiser 1991).

Of the 12 sampling dates (see Table 5.4), there were no dissolved oxygen concentrations less than 6.0 mg/l reported. For these same samples, the percent saturation was greater than 64 percent.

SUMMARY OF EXISTING CONDITIONS

QUALITY OF THE INSTREAM HABITAT

Space suitable for salmonids in streams is a function of flow, channel shape, gradient, and various forms of instream or riparian cover. Suitable space for each life stage has water of sufficient depth and quality flowing at appropriate velocities. The amount of space needed by fish increases with age and size.

Some features that provide cover for fish are water depth, water turbulence, overhanging riparian vegetation, large woody debris, and aquatic vegetation. The addition of cover (extra depth, preferred substrates, woody debris, etc.) increases the complexity of the space and usually the carrying capacity. The addition of certain types of cover (e.g., overhead) may make some areas in streams suitable for fish that would not otherwise be used. Salmonids, especially the juveniles, also use the space available in side channels for rearing.

Much of the channel of Catherine Creek and its tributaries has limited diversity. There is scarce large woody debris and high flow refuge. In long reaches, the riparian zone provides little overhead cover. These conditions all contribute to limiting the fish production in this system.

Water quality

In general, the water quality is excellent with the sole but notable exception of temperature during the summer months in the Outlet Channel and lower Catherine Creek. Low flows in these creek sections contribute to low dissolved oxygen during the summer as well. However, while less than optimum, the low values do not pose an unacceptable condition.

Sediment

The substrates of salmonid streams are important habitats for incubating embryos and aquatic invertebrates that provide much of the food of salmonids, and they provide cover for fish in summer and winter. Silt and sand substrates have little or no value as cover for fish (Bjornn and Reiser 1991).

The quality of the substrate for fish depends on the amount of fines in the gravel at the end of spawning and the amount of fines that settle on to the eggs (redds) and surrounding substrate during incubation. The quantity of fines affects the rate of water interchange between the stream and redds, the amount of oxygen available to the embryos, the concentration of embryo wastes, and the emergence of the fry from the gravel.

There are substantial areas of this stream system where the stream substrate consists of, or have been degraded by the addition of, sand and silt. The stream banks in many areas consist of unconsolidated sands that could further degrade existing salmonid spawning gravels.

Stream Flows and Velocity

Stream flow is obviously one of the basic determinants of the amount of space available for fish. The relation between stream flow and carrying capacity varies with channel geometry and surrounding landuse. As stated by Bjornn and Reiser (1991), the relation must start at the origin (no flow, no fish), increase (perhaps not uniformly) with increases in flow up to a point, and then level off or decline if flows become excessive.

By August, there was little flow in upper Catherine Creek (from Lake Cassidy to Hartford Drive). As previously discussed, the flow was low in the outlet channel by June and extremely low by mid-September. There was no flow in either Stevens or Lundeen Creeks from the latter part of August until the fall rains began.

Given flow in a stream, velocity is probably the next most important factor in determining the amount of suitable space for rearing salmonids. Coho salmon shift in the winter to sites with low velocity (deep pools, undercuts, debris jams, side sloughs, velocity less than 1.0 ft/s) and good cover. Juvenile coho salmon often move into side-channel pools for the winter.

Estimated changes in maximum water velocity in lower Catherine Creek at two different characteristic flows are minor (Table 6-4). There is a difference of 1.0 fps between the lowest and highest values between approximate current bankfull flow and an extreme flow (100+-year).

TABLE 6-4

Predicted Maximum Discharge and Velocity at 20th Street Bridge

	Max Flow (cfs)	Max Velocity (fps)
Current 2-year	186	3.3
Future 2-year (Alternative 2)	207	3.4
Future 2-year (Alternative 8)	213	3.5
Current 100+-year	337	4.0
Future 100+-year (Alternative 2)	379	4.1
Future 100+-year (Alternative 8)	476	4.3

While the changes in maximum water velocity are minimal, it illustrates the significance of high flow refuge areas for salmonids. Table 6-5 contains the sustained and prolonged swimming speeds for adult coho salmon. Sustained swimming speeds are defined as those that are the normal range of that species i.e., do not result in fatigue. Prolonged swimming speeds are those activities lasting from 15 seconds to 200 minutes that result in fatigue.

TABLE 6-5

Swimming speeds for average-size adult coho salmon

Swimming Speed (fps)	
Sustained	Prolonged
0—3.4	3.4—10.6

Source: Bell (1973)

As can be seen in comparing Tables 6-4 and 6-5, the estimated maximum water velocities are very close to the upper sustained speeds for adult coho. The sustained speeds for juvenile fish or smaller fish such as trout would be much less than those for adult fish. If refuge areas are limited, the high water velocities that occur during storm flows could result in fish fatigue. With limited areas to rest, the fish would likely be swept from the stream.

The hydraulic diversity created by and maintained around channel obstructions enhances species diversity by providing habitat space for a variety of species and age classes. The lack of channel complexity may be one of several limiting factors identified in the Catherine Creek stream system.

Invertebrates

The invertebrate data collected in this study were evaluated to generate an index of the invertebrate condition, called the Benthic Index of Biological Integrity (B-IBC). The B-IBC values for the sampled stations are presented in Table 6-6.

As noted in Table 6-6, the index could not be calculated at four of the six stations because the number of individuals was too small. This situation might suggest pollution but given the level of development of the watershed, this is highly unlikely. The reason for the very low numbers was the extremely low flow of water in both the Outlet Channel and Catherine Creek. At these low flows, the total numbers or mass of invertebrates drops significantly. As noted in Chapter 5, this condition is typical in late summer.

It was possible to calculate the index at two stations: D and F. The first station is in the Outlet Channel. The second was in Catherine Creek just upstream of its confluence with the Little Pilchuck River. The values of 13 and 17, respectively, are very low. For western Washington a score of approximately 25 to 35 would be expected given the level of development of the watershed. A score of approximately 30 to 45 would be expected in an undeveloped watershed (May, 1996). The scores found in this study, 13 and 17, are similar to streams in heavily developed urban watersheds. The invertebrate data suggest less than optimal conditions for the fish with regard to food resources.

The essential conclusion of the invertebrate sampling is that the numbers of invertebrates are very low in Catherine Creek in the late summer because the flow in the creek is very low; a reflection of the water levels in Lake Stevens and Lake Cassidy. Hence, invertebrate populations as a food source may be limiting. The samples from the Lake Outlet Channel indicate the effects of urbanization: species intolerant to poorer water quality are absent.

TABLE 6-6

Biological Index from Invertebrate Data

STATION	LOCATION	B-IBC
A	On Catherine Creek about 150' upstream from SR92	Too few individuals to calculate index
B	On Catherine Creek about 50' upstream from 36th	Too few individuals to calculate index
C	On Catherine Creek about 150' upstream from its confluence with the Little Pilchuck36th	Too few individuals to calculate index
D	Immediately downstream of Main Street on the Lake Stevens Outlet Channel	13
E	In the Lake Stevens Outlet Channel just upstream of the weir near the lake outlet	Too few individuals to calculate index
F	On Catherine Creek about 150' downstream from 20th	17

Refuge from high flows

Refuge from the high velocities of storm flows is essentially for fish. In streams relatively unaffected by the activities of humans, these refuge areas are downstream of boulders, eddy areas behind logs and other woody debris, pools, and backwater areas.

There is little refuge in lower Catherine Creek. There is somewhere on the order of 7% of the creek surface area. As a comparison, about 20 to 30% of the creek sections of streams in forested watersheds met the requirements of refuge habitat during high flows according to research studies (Appendix G). Lower Catherine Creek has little refuge habitat because it lacks the appropriate pools of adequate depth and cover, as well as eddy areas and side pools. The stream banks lack the complexity of a stream that is unaffected by urban development and the encroachment of housing that is provided by rooted areas or root wads, large logs, and boulders.

IMPLICATIONS OF THE ENDANGERED SPECIES ACT

The proposal to list chinook and bull trout as "threatened" under the Endangered Species Act (ESA) implies that existing construction practices, as well as management and conservation measures, have failed to protect the species. Jeopardy, as defined by federal regulation (50 CFR 402.02), is *"...to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species"*. A critical element in this definition related to this project is the notion that actions, directly or indirectly, could reduce the *recovery* of a listed species. This has been interpreted to include human activities that transform freshwater spawning or rearing habitat to an unproductive state or *human intervention that prevents natural disturbances from creating or maintaining habitat that is important for salmon production.*

Once a species is listed under the ESA, additional prohibitions are initiated to further protect the species. Under Section 9 of the ESA, a variety of actions, including "take", are prohibited for species listed as endangered and may be prohibited, under Section 4(d) for species listed as threatened. Section 3 of the ESA defines "take" as *"to harass, harm, pursue, hunt, shoot, wound, trap, collect or attempt to engage in any such action"*. Some believe "takes" for Chinook currently exist within this region and could possibly expand to include other salmonids. Specifically, this means it will no longer be acceptable for projects to provide mitigation at a level that compensates only for identified project impacts. To satisfy the ESA, projects must not only neutralize any adverse project impacts, but must also take substantial steps to promote the recovery of the species.

All major river systems in our region have been subjected to the alteration and removal of riparian vegetation, modification and simplification of natural bank conditions, and elimination of woody debris. These actions, which have contributed significantly to the decline of salmonids in the Pacific Northwest, should serve as a focal point in future recovery activities.

CHAPTER 7

ALTERNATIVE ACTIONS

There are many actions that can maintain the existing water quality and habitat as well as actions to improve them. As urbanization increases in the watershed so will the pressures on the existing ecological system. Preservation of the existing ecological system is both possible and cost effective and should be the focus of future efforts. The general degradation of the water quality due to urbanization can be slowed or stopped through the implementation of both non-structural and structural methods and through increased maintenance of the existing facilities. The analysis of existing water quality indicates that the focus of future actions should be on mitigating:

- High bacteria and phosphorus concentrations during dry-weather.
- Metals and toxicants during storms.
- High summer temperatures, currently in the Outlet Channel and Catherine Creek, and potentially in creeks entering Lake Stevens.
- Low summer flows in Outlet Channel and lower Catherine Creek.
- Low dissolved oxygen during the summer in the Outlet Channel and Catherine Creek.
- Sediments from construction sites
- Sediments from accelerated erosion of stream channels from increased flows.

Presented in Table 7-1 are water quality concerns and alternative actions that address each concern. Presented in Table 7-2 is a matrix of quality constituents and the affect of each alternative action. Table 7-3, located at the end of this chapter, describes various Best Management Practices (BMPs) available for solving many of the problems listed above.

Table 7-1

Actions to Correct Water Quality Problems

FOCUS	POSSIBLE ACTIONS
Bacteria and phosphorus	Reduce phosphorus loading from fertilizer through education. Reduce the use of pesticides and herbicides through education. Eliminate failed septic systems by extending sanitary sewers or requiring rehabilitation of septic systems. Increase maintenance to include: 1) high efficiency street sweeping, 2) routine catch basin cleanout and 3)Roadside ditch maintenance to remove accumulated sediment and promote the growth of grasses. Work with livestock owners to prevent animal access to streams Conduct DNA testing to determine if human sources are present
Metals and toxicants	Implement current regulations for treatment in new developments Increase requirements for treatment in new developments Retrofit existing detention basins to include stormwater treatment Install regional treatment systems Sweep curbed streets Clean catch basin sumps Modify the land use plan to protect key wetlands Community education Maintain ditches and road shoulders to enhance pollutant retention
Summer temperatures	Implement current regulations for retention of stream buffers Work with owners of property that abut streams on care of riparian buffers.
Low summer flows	Alter management of water levels in Lake Stevens
Low dissolved oxygen	Alter management of water levels in Lake Stevens Implement current regulations for retention of stream buffers Work with owners of property that abut streams on care of riparian buffers.
Construction sediments	Enforce regulations for sediment control at construction sites Use polymers for enhanced sediment control
Stream channels sediments	Implement current regulations for detention in new developments Watershed tree planting program Establish a large woody debris maintenance program Install regional detention where appropriate Enforce regulations concerning wetland preservation

Table 7-2

Parameters Affected by Actions

ACTION	Cat [1]	Temp	Bact	DO	Metals	Phos [2]	Sed [3]	Habitat	Flow
Set Water Quality Goals	NS		X	X		X	X		
Create Sensitive Lake Development Standards	NS		X	X		X	X		
Education	NS					X	X	X	
Property Acquisition	NS	X	X	X	X	X	X	X	X
Littoral (lakeshore) planting	NS					X	X	X	
New development detention/treatment	NS				X	X	X		X
Site design	NS				X	X	X		X
Stream buffer retention	NS	X	X	X				X	X
Stream buffer improvement	NS	X	X	X				X	X
Forest Management	NS					X	X	X	X
Lake Stevens water level management	S/NS			X				X	X
Construction erosion	M/NS					X	X	X	
Farm management	NS/M		X			X			
Lawn care	NS/M					X		X	
Regional detention/treatment	S						X	X	X
Retrofit stormwater systems	S				X	X	X		
Increase fish passage	S								
Woody Debris management	S						X	X	
Facility maintenance	M				X	X	X		X
Street sweeping	M				X	X	X		
Sump cleaning	M				X	X	X		
Septic tank management	M		X			X			

1. Category - S = Structural, NS = Non-Structural, M = Maintenance
2. Phos – Phosphorus
3. Sed - Sediment

WATER QUALITY GOALS AND SENSITIVE LAKE STANDARDS

Much work has been done in the past to improve and maintain the water quality in Lake Stevens. However despite this work there have been no water quality goals set by the local governments. If goals were set then the evaluation of whether or not various water quality improvements measures are necessary would be facilitated. The management of lake water quality is subjective. The intensity and frequency of algae blooms may be acceptable to one person and not to the next. Without numerical standards or goals to measure against, the necessity of particular water quality measure is unclear. Currently there are no standards for phosphorus in lakes, although Ecology is proposing standards. However, based upon the proposed standards, 20 ug/L in the epilimnion in the summer, the water quality in Lake Stevens could deteriorate significantly and still comply. Current summer epilimnion concentrations are approximately 10 ug/L. Phosphorus is the nutrient that limits algae growth in Lake Stevens as it is in the shortest supply.

EDUCATION

Education could be used to increase the understanding of lakefront owners, as well as those that live in the watershed, in terms of the impact that their actions have on water quality. Education could be geared towards children in the schools, community leaders and residents. During this project there was interest expressed in creating a video discussing the local kokanee salmon and the impacts of non-point source pollution on them. This video could be utilized in the schools. Other mechanisms include flyers that are distributed through routine mailings, a booth at Aquafest, volunteer work parties and interfacing with the community through the watershed steward.

PROPERTY ACQUISITION

Public acquisition of property for open space is arguably the most effective method to eliminate the impacts of development. The difficulty, in addition to funding, is to prioritize the various properties. Wetland acquisition and the associated cost and preservation must be weighed against the protection afforded wetlands through the various regulations set out to protect them.

Both Snohomish County and the City of Lake Stevens protect wetlands through their Critical Area Ordinances. Key wetlands shown in Figure 7-1 are located on land that is zoned for high density, commercial or multifamily use. The District was given 18 acres of wetland in the lower portion of Stevens Creek in December 1998. For the remaining two wetlands, changing the zoning to a lower use intensity would help to preserve them. Alternatively, the land or a conservation easement could be purchased to retain the treatment, habitat and detention benefits of the wetlands. It might be argued that because the County and the City already protect wetlands, there is no reason to take further action. However given the designated zoning, development will likely encroach on these areas and will result in the loss of portions of each wetland. To compensate for the down zoning of these wetland areas, other areas within the Growth Management Boundary could be modified to commercial and multifamily in equal amounts.

Natural wetlands provide many environmental benefits that are not completely replaced by either engineered detention, wetland, or treatment facilities. Wetlands function as detention basins to reduce the impacts of floods by retaining water over an extended period. Existing wetlands can provide stormwater treatment although they are not allowed to be used for this purpose in lieu of an engineered system. Preservation of wetlands particularly those that immediately abut, or are an intimate element of the stream, provide water quality benefits, habitat diversity and attenuation of flood flows. While all wetlands are important, those identified in Figure 7-1 are particularly important given their size and location in relationship to the particular creeks.

Upland areas are less protected from development by regulations. They too however, are an integral part of the watershed. The benefits derived from the purchase of different types of properties are varied and divergent.

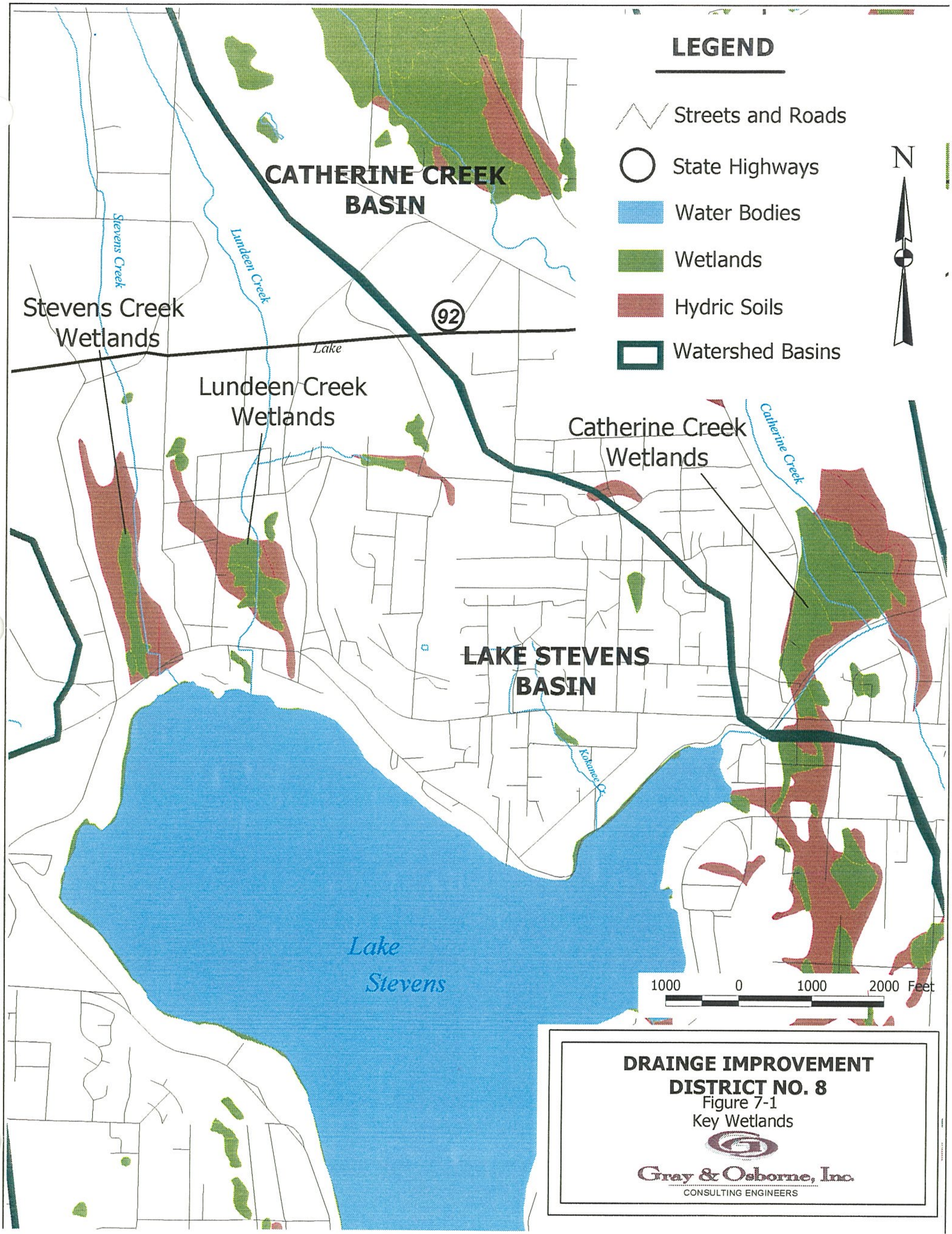
IMPROVE LITTORAL PLANT COMMUNITY

The water quality and diversity of the aquatic community could be helped through the establishment of a healthy plant community in the littoral zone (edges of the lake). A healthy plant community would reduce the turbulence created along the shore by water coming in from storm drainage pipes and from streams. The plants would also reduce the rebounding of motor boat wake off of bulkhead walls. In addition to the physical benefits on water quality, the plants would allow for uptake of pollutants as they enter the lake and potentially reduce the stormwater impacts to the lake water quality (Bozek, M.).

TREATMENT AND DETENTION IN NEW DEVELOPMENTS

Snohomish County and the City of Lake Stevens require new developments to install stormwater detention and treatment systems. The detention systems will moderate flows thereby reducing the impacts of development on stream channel erosion. Estimates of future loadings for zinc and by extension, other toxic pollutants, suggests that the current methods of stormwater treatment are inadequate and that higher levels of treatment are needed to prevent future impacts on the environment from increased urbanization. There are several options to improve treatment efficiency.

One way is to promote the use of treatment systems that remove both particulate and dissolved pollutants. A significant percentage of pollutants are in the dissolved form. Dissolved pollutants are more difficult to remove from non-point source runoff than particulate pollutants. Extended detention, filtration, constructed wetlands and large buffers are treatment systems that have been adopted by King County to reduce the impacts of development.



DRAINGE IMPROVEMENT DISTRICT NO. 8
Figure 7-1
Key Wetlands

Gray & Osborne, Inc.
CONSULTING ENGINEERS

SITE DESIGN

A new approach to site design is under development in recognition of the limits to mitigation that can be provided by on-site detention and treatment systems (Center for Watershed Protection, 1995; Center for Urban Water Resources Management, 1995). Elements of the new design approach focus primarily on reducing the amount of impervious surface (Olympia, 1994). It includes reducing street widths, sidewalks on only one side of the road, hammerhead rather than circular cul-de-sacs, and clustering housing on the site while leaving the remainder of the site in its original cover. Routing roof and driveway drainage to grassed areas for infiltration and treatment, rather than directly to the stormwater pipes, can reduce both the storm volume and pollutant levels. The incorporation of organic soil amendments when laying the lawn areas provides significant benefits (Chollak, 1998). A manual concerning these issues for western Washington has been prepared by the City of Redmond (City of Redmond, 1998).

RIPARIAN BUFFERS

Both the City and the County require buffers on the development of land that abuts streams and wetlands. Both jurisdictions allow what is known as "averaging"; that is, the buffer can be less than required in a portion of the development if other portions are greater than required. This is only allowed if the overall average buffer size meets the standards.

Johnson and Ryba (1992) conducted an extensive review of the technical literature on buffer widths. They concluded that the *minimum* buffer width needed to achieve the multiple needs of urban streams is on the order of 50 to 100 feet. Based on an extensive examination of 25 streams in western Washington with varying levels of urban development, May (1996) concluded that the buffer width needs to be at least 300 feet to avoid significant impacts to the stream. Based upon these studies the current City requirement of 50 feet is the absolute minimum that should be allowed and that a greater buffer width is desirable. The County has recently increased its buffer requirements to 150 feet. Although this is less than that recommended in the May study the impacts of this buffer increase should have a positive effect on the stream systems.

The survey of Catherine Creek (Chapter 6) found that owners of property that abut the stream have in many instances removed trees and riparian vegetation. This affects water quality in several ways. It increases water temperatures in the summer, frequently to unacceptable levels as noted previously. Higher water temperatures in turn, lower the dissolved oxygen. Accelerated stream channel erosion occurs along banks exposed by the removal of vegetation and large logs that protect the toes of banks. Quality riparian vegetation should be encouraged and in some cases may be used to eliminate livestock access to streams.

The Snohomish Conservation District could work with cooperative property owners to improve riparian areas along each creek. Property owners need to be aware of the significance of their actions and develop planting schemes that improve the vegetation while still allowing for visual and physical access to the stream as desired by the particular property owner.

FOREST MANAGEMENT

In many watersheds in western Washington, the conversion from forest cover to pasture has an effect on stream flows that is as significant as the conversion of pasture to urban development. Hence, conversion of pasture back to forest or even the integration of trees into what remains essentially a pasture can significantly benefit the water balance of a stream. About 1,000 acres, or approximately 30%, of the upper watersheds of Lundeen, Stevens and Catherine Creeks are pasture. Property owners could be provided educational materials on the importance of trees and forested areas. Given the detention benefits of forests, the County should consider tax policies that would encourage the retention of forests over conversion to pastures, as well as conversion of pastures back to forests.

LAKE STEVENS WATER LEVEL CONTROL

The current minimum water level in Lake Stevens, although weather dependent, is generally about 210.5 feet and occurs in September and October. This is approximately the same elevation as the sand bar located upstream of the control weir. Removal of the sand and deposits would allow the water level to be lowered an additional foot. This additional lake level drawdown should provide about 1,000 acre-feet of additional water for the outflow stream. With this additional water, the flow in the Outlet Channel and lower Catherine Creek could be maintained at approximately 5 cfs, during the months of September and October which would significantly improve the conditions for fish. This action would provide perhaps the most significant benefit of all possible actions to improve conditions in Catherine Creek. There may be some lakeside residents impacted by the lower lake level, particularly those residents in the northwest portion of the lake. Those residents may have difficulty launching their boats from their private docks during the low lake level period.

CONSTRUCTION SITE EROSION CONTROL

Construction site erosion control measures work only if maintenance is performed on a routine basis. Strict enforcement of current erosion control regulations is important to ensure proper maintenance. However, even with strict enforcement, sediment from construction sites may still be significant because of the limited ability of current BMPs to control sediments. A new technology utilizing polymer-assisted clarification of the stormwater has been shown to be very economic as well as very effective, particularly for larger sites (Minton and Benedict, in press). The stormwater is captured in the temporary sediment pond and then treated using polymers that are commonly used in municipal water treatment plants to produce potable water. The approach is routinely used in Redmond where it was first demonstrated and is now being used elsewhere in the Puget Sound watershed on a limited basis. In comparison to standard BMPs which reduce turbidity to a range of 100 to 500 NTU, depending on site conditions, polymer-assisted clarification typically reduces the turbidity to as low as 5 NTU. Snohomish County and the City of Lake Stevens could identify this new BMP as a method to reduce sediment from construction sites.

FARM MANAGEMENT

Ground and aerial surveys of Catherine Creek found that large livestock have access to the stream at several locations. Livestock are a probable contributor to the elevated bacterial counts and nutrient concentrations noted in Chapter 5. The Snohomish Conservation District needs to work with livestock owners to take the appropriate actions to keep their livestock out of the creek.

In addition to the large livestock, chicken farms are located on Stevens and Lundeen Creeks. In the winter of 1998 – 1999 one of these farms was found to be leaching chicken waste into Stevens Creek. This farm went out of business shortly after the discharge was identified. Other chicken farms have been identified as potential pollution sources. Careful management of these farms is required to prevent release of waste products into the streams.

LAWN CARE

Lawns and lawn care appear to be significant contributors of pollutants to urban streams. The most common pollutants are phosphorus, nitrogen, and herbicides and pesticides. These pollutants appear to reach the stream indirectly via groundwater and surface runoff during storms. Regional data (Metro, 1994) indicates that phosphorus concentrations in dry-weather base flows are commonly 10 to 20 times that found in forested streams.

Educational materials could be used to inform the public of the deleterious effects of lawn care when not done carefully, and methods by which attractive lawns can be kept while still protecting water quality. The City of Seattle has prepared a program embodying the concept of ecologically sound lawn care (McDonald, D., pers. comm.). A brochure has been prepared through a cooperative effort of local cities, counties and water utilities of western Washington (Anonymous, undated).

REGIONAL DETENTION AND/OR TREATMENT

As discussed in Chapter 4, regional public, detention facilities may be necessary to properly mitigate the effect of urbanization. Detention facilities will help water quality by reducing the amount of stream channel erosion that otherwise would occur. Additionally, regional detention facilities would most likely be large structures. Water quality gains would be achieved through the settling of sediment which would particularly occur in large detention facilities.

Existing outfalls can be retrofitted with treatment systems where there is sufficient land. One site where this condition appears to be met is the outfall that discharges into the Outlet Channel at NE 123rd. The watershed of this outfall is about 120 acres. The stormwater from this outfall enters the Outlet Channel in downtown Lake Stevens. With treatment of stormwater from this outfall, the water quality of the Outlet Channel could be improved significantly. To reduce cost impacts, the treatment facility could be sized to provide high levels of treatment of summer storms, but a lower level of treatment during the larger winter storms. For example, water quality treatment might target the one-month storm instead of the usual six-month storm.

RETROFIT EXISTING STORMWATER SYSTEMS

Retrofit of existing detention ponds in the Lake Stevens and Catherine Creek watersheds is possible when space permits. As discussed in Chapter 3, a survey of the existing detention facilities indicated that the space surrounding the detention facilities is too small for retrofitting the existing systems. One location, adjacent to the outflow channel, may provide opportunity for water quality treatment and is discussed in Chapter 8.

INCREASE FISH PASSAGE

A few of the streams have limited fish habitat because of fish blockages. The availability of habitat to fish could be increased by the removal of these blockages. Specific projects are discussed in Chapter 8.

MANAGEMENT OF LARGE WOODY DEBRIS (LWD)

A companion to improving the riparian zone along the stream bank is the protection of large logs and trees in the creek channel (May, 1996). Large logs, dead trees, and debris dams all provide good habitat for salmonids. The stripping of large woody debris (LWD) from stream channels has contributed to the degradation of salmon and trout populations through the elimination of natural riverine features. A common belief by property owners is that all large logs and trees must be removed from the stream channel to protect the banks from erosion and flooding. However, in many instances large logs and trees reduce bank erosion by protecting the toe of the bank. At the same time woody debris can provide critical habitat without significantly increasing flood water elevations. Property owners need to be made aware of the need to leave large logs and trees in the creek, and to be shown the adverse effects of removing the material. However, any efforts to protect LWD must be matched by a commitment by local government to reduce the adverse effects of urban development on stream flows. Failure to do so may result in excessive flows which in turn will motivate streamside property owners to, with justification, remove the LWD.

STREAM DEBRIS CLEANOUT

During the fish habitat survey of Catherine Creek, significant quantities of plastic bottles, tires, and other types of debris were found in lower Catherine Creek and the Outlet Channel. An annual cleanup, perhaps done in association with Aquafest by citizen volunteers, would be beneficial. It would also provide the opportunity to increase the awareness of local residents of the creeks, and the value of the streams.

FACILITY MAINTENANCE

To function properly, both on-site and regional detention or treatment facilities must be maintained at appropriate intervals. Few jurisdictions in the Puget Sound watershed have fully implemented facility maintenance programs, despite it being a requirement of the Department of Ecology. The City of Lake Stevens performs maintenance on detention systems within its jurisdiction on an as needed basis. The future level of maintenance is currently being evaluated as part of a parallel but separate cooperative project by the County, City and District (Storm And Surface Water Advisory Committee).

STREET SWEEPING AND CATCH BASIN SUMP CLEANOUT

New developments in sweeping technology have significantly improved the potential for this BMP. Known as "high-efficiency sweeping", limited studies (Sutherland, et al., 1998) suggest that frequent sweeping will significantly reduce pollutant loads. The sumps of catch basins provide some benefits in pollutant reduction if they are cleaned at least twice annually.

SEPTIC TANK MANAGEMENT

Given the observed levels of bacteria and nitrates, and their potential risks to human health, attention needs to be devoted to the potential for stream contamination by septic tanks. Some homes located near the major creeks are still served by septic systems. These homes may be contributing nutrients and pathogens to the creek through failing septic systems. DNA testing of water samples from each creek could be used to determine if effluent from the septic systems is reaching the creek. The method has been successfully used on several creeks in western Washington. The testing can specify the species of animal whether it be dog, cat, cattle, human, etc.

Table 7-3

Best Management Practices

BMP	Description	Type	Pollutants Removed
Detention Pond	Impoundment designed to slowly release floodwaters to surface water.	Structural.	Sediments; reduces flooding.
Retention (Wet) Pond	Excavation designed to store and treat runoff by allowing sediments to settle. Surrounding vegetation removes some pollutants.	Structural; may have some vegetative components.	Sediments; pathogens; nutrients; reduces flooding.
Grassed Swale	Designs vary, generally a vegetated drainage channel which filters runoff allowing infiltration and sedimentation.	Vegetative.	Reduces erosion by reducing runoff velocity; nutrients; pathogens.
Catch Basins	Underground retention systems in areas of high vehicle traffic or petroleum storage.	Structural.	Trash; oil/grease; organic debris (mainly leaves/grass); sediments; metals.
Street Sweeping	Specialized sweeping vehicles used in urban areas.	Management	Trash; oil/grease; sediments; organic debris (mainly leaves/grass).
Haybales or Sediment Screens	Primarily used to control erosion during disturbances such as construction or forestry.	Structural.	Sediments.
Infiltration Basins	Impoundment facility over permeable soils.	Structural.	Pathogens; Nutrients.

CHAPTER 8

RECOMMENDED ALTERNATIVES

INTRODUCTION

The alternatives presented in Chapter 7 provided a variety of solutions to problems within the Catherine Creek and Lake Stevens watersheds. The alternatives recommended were both non-structural and structural. Non-structural recommendations are targeted towards basin wide institutional activities that can improve or slow the rate of degradation of water quality. The major premise underlying the non-structural recommendations is that it is more cost effective to prevent degradation of the natural environment than to try to restore it at a later date. Structural solutions are those targeted towards specific areas where some repair or restoration structure should improve water quality, improve fish habitat, or reduce flooding. As with any list of solutions, alternatives will vary in terms of both productivity and cost.

RANKING THE ALTERNATIVES

To determine the effectiveness of the alternatives, each potential project was graded on a ranking system based on three categories: water quality, fish habitat and hydraulics. Within each of these categories, each alternative was ranked individually on a scale from zero to three with three being the highest score. After determining each alternative's individual category score, the three scores were added together using a weighted average system. For this plan, water quality was determined to be the most important goal followed by habitat and then hydraulics (flood control). Therefore, the water quality score consisted of 60% of the total score, habitat consisted of 30% of the total score and the hydraulic score composed 10% of the final score. The following is a sample calculation demonstrating the nature of this ranking system.

Alternative:	Enforce and Protect Buffer Requirements
Water Quality Score:	**1.5**
Habitat Score:	**2**
Hydraulic Score:	**2**

Total Score: (0.6 x **1.5**) + (0.3 x **2**) + (0.1 x **2**) = <u>1.7</u>

The ranks within each of the three categories were determined based on effectiveness and area of impact. For instance, water quality took into consideration the number of damaging effects that would be decreased by implementing that particular alternative. These include phosphorus, nitrogen, bacteria, metals, dissolved oxygen, TSS, and oil and grease. For habitat, a stream restoration project that is targeted toward creating habitat in a high resource area would receive a high score of three due to its impact on a habitat intensive area. As with water quality and habitat, hydraulic rankings were based on the size of the area affected as well as potential minimization of damage and/or cost to property within the vicinity. One example of this involves increasing the detention requirements. This could potentially affect all areas within the watershed and therefore, would receive a high score of three. The results of these rankings can be found in Table 8-1. If a particular project was deemed to have no impact on a particular parameter it was given a zero. For example, improving the habitat at the Stitch Creek culvert on Davies Road has no impact on the water quality or the hydraulics but does impact the habitat. This project received a score of zero for water quality and hydraulics.

The project rankings are specific to this project, which was funded through the Centennial Clean Water Fund. Projects that only address flood control issues, although they may be worthy projects, did not receive a high score due to the focus of this plan.

TABLE 8-1

Alternative Rankings

	Benefit			
Project	Water Quality	Habitat	Hydraulic	Total Weighted Score
Non-Structural				
Create Sensitive Lake Basin Standards	3	2	2	**2.6**
Set Water Quality Goals For Lake	3	2	1.5	**2.6**
Maintenance	2.5	2.5	2.5	**2.5**
Education through Watershed Keeper	2.5	2.5	2	**2.5**
Detention Requirements - Increase Standards, Enforcement through Inspectors	2.5	2	3	**2.4**
Wetland Acquisition - Lundeen Creek, Stevens Creek, Stitch Lake, Cedar Cove, Kokanee Creek	2.5	2.5	1.5	**2.4**
Forest Tax Credit	2.5	2	2.5	**2.4**
Zoning Requirements - Cluster Devel. W/ Open Space Requirements	2.5	2	2.5	**2.4**
Wetland Acquisition - Lake Cassidy	2	2.5	3	**2.3**
Lakefront Restoration	2.5	2	0	**2.2**
Buffer Requirements - Enforcement and Protection though Watershed Keeper	1.5	2	2	**1.7**
Construction Site BMPs – Polymers	2	1	0	**1.5**

Project	Benefit			Total Weighted Score
	Water Quality	Habitat	Hydraulic	
Structural				
Regional Detention Facilities for Lundeen and Stevens Creeks	2.5	2	2	**2.3**
Stream Habitat Restoration – Large, woody debris	1.5	2.5	1.5	**1.8**
Alum Sealing of Stitch Lake	2.5	1	0	**1.8**
Acquire properties and wetlands on north side of Hartford Drive, Culvert Replacement, Outlet Channel Realignment	1.5	2	2.5	**1.8**
Regional Detention Facilities for Catherine Creek	2	1	2	**1.7**
Route Lundeen Creek away from 101st	1	1.5	2.5	**1.3**
Install CDS storm treatment system in City	1.5	1	0	**1.2**
Habitat on Stitch Creek at Davies Road	.5	2.5	0.5	**0.8**
Increase weir board and/or dredge Outlet Channel	0.5	2	1	**0.7**
Habitat improvement for Eagle Park	0.5	2	0.5	**0.6**
Widen channel at Rabin-Calles	1	1	1.5	**0.5**
House raising for Clough/Leavitt	0.5	0.5	2.5	**0.3**

Scores ranked from 0 to 3 with 3 being high.

SUMMARY OF RECOMMENDATIONS

SET WATER QUALITY GOALS

Remediation and mitigation measures designed to improve the water quality in Lake Stevens have been installed and others are recommended in this plan. There are however no water quality goals set for the lake. Until water quality goals are set, evaluating whether additional remediation or mitigation measures should be instituted, or whether existing measures should continue, is difficult. As an example of water quality goals, a citizens task force determined water quality goals for Lake Sammamish in 1996. These goals are based upon total phosphorus, chlorophyll *a* and transparency. These goals were used as justification to institute Sensitive Lake Basin Standards for the Lake Sammamish Basin. For Lake Stevens the water quality goals may simply be no decrease in water quality from current levels. Water quality could be evaluated using total phosphorus, chlorophyll *a*, transparency or a combination of these parameters. For the past two years these parameters have been collected regularly. The annual or summer values could be used to establish water quality goals.

CREATE SENSITIVE LAKE BASIN STANDARDS

Creation of Sensitive Lake Basin Standards should provide additional protection of the water quality in Lake Stevens. Sensitive lake standards, recently adopted in King County, attempt to remove 50% of the phosphorus from storm water runoff. Phosphorus stimulates algal growth in the lake.

MAINTENANCE

Maintenance is key to the effectiveness of any project. At the current a task force comprised of representatives from the City, County and District are meeting to determine the level of service appropriate for the watershed. Each agency currently operates independently with its own funding source. Because higher levels of service inherently cost more, determining an appropriate level of service is a critical decision and impacts the amount of money available for capital improvements.

EDUCATION

Education can make the public aware of the impacts of their actions. A watershed keeper is a good vehicle to educate the citizens with local and regional issues that affect water quality and habitat.

DETENTION REQUIREMENTS

Increasing detention requirements will help to mitigate the increased stormwater runoff that occurs with urbanization. As stated earlier in this report the current Department of Ecology standards, which have been adopted by the City, and the Snohomish County standards, which are similar to the Ecology standards, do not fully mitigate the increased runoff from developed areas. The jurisdictions should consider increasing the detention requirements. King County recently updated their requirements through the use of the "Runoff Time Series Model."

WETLANDS ACQUISITION

Purchasing of wetlands by public agencies provides added security that there will be no net loss of wetlands in the future. Snohomish County and the City of Lake Stevens both provide for the protection of wetlands through their Critical Areas Ordinances. However both jurisdictions also allow limited development in wetlands if the wetlands prohibit the economically viable use of the property and if mitigation occurs. Purchasing of wetlands effectively removes them from the pressures of development.

FOREST TAX CREDIT

Providing a "Forest Tax Credit" creates a mechanism whereby the County or City can reward a property owner for leaving a property in a forested condition. In the Lake Sammamish basin if a property is more than 75% forested it is assumed to have minimal impact on the storm water runoff. A tax credit could be applied at this threshold with the amount of the credit based upon the "avoided cost" of not having to build regional detention systems.

ZONING REQUIREMENTS

Under current zoning and proposed land use the vast majority of the Lake Stevens and Catherine Creek basins will be used for single family residences (see Chapter 2). As an alternative to this type of land use, planners have considered denser development with larger amounts of open space to offset the increased density. An example is the use of townhouses surrounded by large amounts of open space.

LAKEFRONT RESTORATION

Currently only minor portions of the lakeshore have significant stands of emergent vegetation, (plants that have roots in the lake bottom but flower above the water surface). Twenty foot wide plots could be established on many lakefront properties without significantly interfering with either boat use or swimming. Emergent vegetation provides additional habitat for aquatic animals and will help to dampen boat wakes that currently rebound off concrete bulkheads around the lake.

BUFFER REQUIREMENTS

A review of the existing buffers along the streams revealed that there are many cases where buffers have either been altered or destroyed. The local jurisdictions should enforce the current buffer requirements and consider eliminating buffer averaging.

CONSTRUCTION SITE BMPS – POLYMERS

As discussed in Chapter 2 Best Management Practices are not always adequately applied at construction sites. Best Management Practices to control temporary erosion should always be applied. In addition to BMPs currently approved by the County and the Department of Ecology consideration should be given the to the use of polymers to control erosion and the movement of sediment offsite at construction sites. This BMP is still considered experimental by Ecology. Polymer use at construction sites in Redmond has been successful at controlling the movement and release of soils. The cost of polymers has averaged about 1% of the total construction cost.

REGIONAL DETENTION FACILITES

Regional detention facilities could be constructed to mitigate the increased flows that occur as a result of development. An advantage to regional facilities over private detention facilities is that their design will incorporate the entire basin upstream of the detention facility rather than a particular development. This generally leads to more effective designs than those that are targeted to a specific development (Beyerlein, personal communication).

STREAM HABITAT RESTORATION

Analysis of the stream habitat as part of this project indicates that the streams lack diversity. The habitat of the streams could be improved by the installation of large woody debris. The intent of any structure placed for habitat is to increase the hydraulic diversity of the streams and give aquatic life a diverse habitat for refuge, passage and rearing.

ALUM SEALING OF STITCH LAKE

Stitch Creek has been identified as a major source of phosphorus input to Lake Stevens contributing over 10% of the total annual load to the lake. Alum sealing of the bottom sediments can eliminate the transfer of phosphorus from the bottom sediments to the water column. This would reduce the concentration of phosphorus flowing out of Stitch Lake and into Lake Stevens.

OUTLET CHANNEL REALIGNMENT

This project would reestablish the old outflow channel through the City of Lake Stevens and continuing north of Hartford Drive (Figure 2-1). Completion of this project will require the purchase of several properties and most likely cannot be completed with out the assistance of outside sources of funding. The complete project will provide additional fisheries habitat and provide for additional flood control protection in lower Catherine Creek by retaining floodwaters north of Hartford Drive.

ROUTE LUNDEEN CREEK AWAY FROM 101ST AVE NE

The purpose of routing Lundeen Creek away form 101st Ave is twofold. First, if the creek were moved away from the road a riparian habitat could be established. Second, by moving the creek away from the road there will be a reduction in flooding. In particular flooding will reduced near the southerly end of 101st where the creek currently has an abrupt 90 degree bend.

CDS STORM TREATMENT SYSTEM

CDS ™ stormwater treatment system is capable of treating a wide range of flows. The system works by inducing low velocities as the stormwater is routed through a screen. The low velocities allow material to settle rather than get pushed against the screen. Maintenance is largely associated with removal of accumulated sediment and trash from the sump, which is built into the treatment system. Although the system is still considered experimental technology, they have been used in Australia with success. One of the CDS systems could be installed to treat runoff from the heavily populated area north of the outlet channel from Lake Stevens.

STITCH CREEK AT DAVIES ROAD

Downstream of the Stitch Creek culvert under Davies Road the channel has been eroded and currently is a fish blockage. Channel reconstruction could once again allow fish passage. The culvert itself would also need to be reconstructed to allow for fish passage through the culvert. The current slope and lack of refuge within the culvert creates shallow flow high velocity conditions making fish passage through the culvert difficult. Refuge could be created within the culvert through the use of baffles. However baffles would result in the loss of some hydraulic capacity.

LAKE LEVEL MANAGEMENT, WEIR BOARDS AND OUTLET DREDGING

Dredging of the gravel bar upstream of the current outlet weir would allow the lake to drawdown approximately one foot further in the late summer and early fall. This additional drawdown would supply much needed baseflow, on the order of 5 CFS for an additional month, to the Outflow Channel and lower Catherine Creek. The disadvantage is that some users may be restricted in the use of their docks and boat launches for this portion of the year due to the lower water levels. Additionally, more water could be stored in the lake for release later in the summer by raising the springtime and early summer operating level approximately ½ -foot above where it has been maintained in the past.

EAGLE CREEK/PARK HABITAT IMPROVEMENT

Eagle Creek flows out of Eagle Park on the north side of Lundeen Parkway at Route 9. The Creek flows to the southeast disappearing into a storm drainage catch basin west of the Bayliner facility. The creek then flows through a series of pipes, under Vernon Road and discharges into the lake at the southeast corner of the Bayliner facility. The Lake Stevens Sewer District is proposing to build a sewer lift station adjacent to the Bayliner facility. Site plans could incorporate daylighting the creek to Vernon Road and installation of a culvert under Vernon Road that would allow fish passage. The headwaters of Eagle Creek are protected by the City purchase of Eagle Park two years ago.

RABIN CALLES PROPERTY

The properties at the mouth of Stevens Creek have been subjected to flood events. Purchase of either the Rabin or Calles property would allow for channel widening resulting on flood mitigation and establishment of off channel refuge areas for fish.

HOUSE RAISING CLOUGH/LEAVITT

Houses along Hartford Drive have been flooded in recent years. Elevating the two homes at the easterly end of Hartford Drive, which are also the highest, would minimize the impacts of flooding on these two homes. The Leavitt home is the easterly most houses, is brick and has a basement. The basement of this home has flooded but water has not entered the main floor. Floodwaters are predicted to rise with development placing these houses at increased risk.

CAPITAL IMPROVEMENT SCHEDULE

The Six-Year Capital Improvement Plan (CIP) is a combination of structural and non-structural projects. The projects selected were based upon their rankings. At the current time, the City, County and District are working towards a cost sharing arrangement for maintenance and capital improvement projects as part of the Storm and Surface Water Advisory Committee. This plan does not identify or recommend a cost sharing arrangement. This plan assumes that the CIP will be funded through rates with a $2.00 monthly charge per Equivalent Residential Unit (ERU). A 4% increase in total revenue income per year is assumed, which could be allotted either to growth or increased rates. Additionally, if funds are left over from any year, a 4% interest is applied to the balance and added to the budget for the following year. All project costs are estimated in year 1999 dollars with a 3% per year inflation rate applied to projects scheduled after 2000.

TABLE 8-2
Cost Analysis

Catherine Creek/Lake Stevens Improvement Plan Financing

	Project	2000	2001	2002	2003	2004	2005	
	Non-Structural							
1	Create sensitive lake basin standards #	$23,000						
2	Set water quality goals for Lake #	$23,000						
3	Maintenance	Cost currently being developed as part of SASWAC						
4	Education through Watershed Keeper	$38,000	$39,140	$40,314	$41,524	$42,769	$44,052	
5	Detention requirements - Increase Standards, Enforcement through Inspectors	$53,000						
6	Wetlands Acquisition(2) - Lundeen Creek, Stevens Creek, Stitch Lake, Cedar Cove, Kokanee Creek	$25,000	$30,000	$45,000	$50,000	$55,000	$60,000	
7	Lakefront Restoration	$20,000	$30,000	$30,000	$30,000	$30,000	$30,000	
8	Buffer Requirements - Enforcement and Protection through Watershed Keeper		$39,140	$40,314	$41,524	$42,769	$44,052	
	Structural							
1	Stream Habitat Restoration - Large, woody debris	$6,000	$6,000	$3,000	$3,000	$3,000	$3,000	
2	Alum Sealing of Stitch Lake		$21,000					
3	Outlet Channel Realignment *	This project will require grant funding and has not been included in the cost summary.						
4	Route Lundeen Creek away from 101st			$54,106	.			
5	Install CDS storm treatment system in City [1]					$22,200	$22,200	Continues to 2023
6	Habitat on Stitch Creek - Davies Road & Stitch Road		$14,000					
7	Increase weir board and/or dredge Outlet Channel		$19,000					
8	Habitat improvement for Eagle Park					$35,000	$35,000	
	Amount Available at the Beginning of the Year:	$193,000	$205,920	$216,694	$221,217	$283,160	$289,332	
	Yearly Subtotal:	$188,000	$198,280	$212,734	$166,047	$230,739	$238,305	
	Reserve (Includes 4% interest):	$5,200	$7,946	$4,119	$57,377	$54,518	$53,068	

Assumes a year 2000 Project budget of $193,000 which grows at 4% per year
Inflation : 3%

Interest/Growth Rate: 4%

Estimated startup costs, does not include ongoing annual costs as they would be included under O&M.

* Acquire properties and wetlands on north side of Hartford Drive, Culvert Replacement, Outlet Channel Realignment

1. Assumes a 20-year bond at 5%
2. Assumes approximately 6 acres of wetlands purchased per year

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Only ERUs within the Lake Stevens and Catherine Creek Watersheds are considered.
Roads are not considered in this analysis as contributing ERUs.

ERUs in the City (Sewer ERUs)	1980	
ERUs in DID 8 but not in City (from Assessment Role)	1033	
ERUs in County but not in City or DID8, or CC basin above SR 92	4400	
ERUs in County in CC basin above SR 92	635	
Total ERUs	8048	
Yearly cost per ERU	$23.98	=$200,000/8048 ERU
Monthly cost per ERU (1999 dollars)	$2.00	

APPENDIX A

1997 Lake Stevens Report

Project No. 9713-01

12 June 1997

LAKE STEVENS REPORT

by D.C. Beyerlein, P.E., and J.T. Brascher

for

Meg Moorehead

SNOHOMISH COUNTY

EVERETT, WASHINGTON

INTRODUCTION

As part of Snohomish County's study of the Lake Stevens Urban Growth Area, the EPA HSPF (Hydrological Simulation Program - FORTRAN) model (Bicknell et al, 1991) was used to simulate the hydrology of the study areas. Information resulting from this computer simulation effort can be used to evaluate the hydrologic impacts of urbanization in the watershed.

The report is divided into two main sections:

Calibration

Long term simulations

CALIBRATION

Observed Data

There are six streamflow gages and one lake stage gage located in the Lake Stevens watershed. Data for the streamflow gages has collected by Gray and Osborne. Data for the lake stage gage has been collected by Drainage District #8. AQUA TERRA Consultants have obtained this data for use in the calibration of the Lake Stevens HSPF watershed model. Listed in the table below is the gage site, the length of available data, the rating equation used to convert the raw stage data to flow (cfs), and the maximum recorded flow for each location.

Location	Description	Formula	Maximum Measured Stage(ft)	Maximum Measured Flow(cfs)	Maximum Recorded Stage(ft)	Maximum Calculated Flow(cfs)
Site A	Lake Stevens Outlet	-9.949x^3 + 37.336x^2 - 2.9058x	2.32	71	2.39	70.5
Site B	Catherine Creek at 20th Street Bridge	(y/.0407)^1.1236	2.84	97	3.98	172.3
Site C	Stitch Creek at N. Davies Rd.	x=(y-.3511)/.0556	1.1	12.98	1.3	17.07
Site D	Catherine Creek at 36th Street Bridge	27.44x^2 - 13.088x - 0.9974	1.8	65	2.73	167.78
Site E	Lake Stevens	Lake Stage Data				
Site F	Lundeen Creek	Only one data point no equation could be generated	0.78	3.14	N/A	N/A
Site G	Stevens Creek at Lundeen Pkwy	(y/1.1383)^3.968254	3.9	60.12	5.99	727.42

The maximum field measured streamflow at the Site A is 71 cfs which corresponds to a stage of 2.32 feet. Using the 14 field measured flows, a rating equation has been generated. The highest recorded stage is 2.39 feet. Using the rating equation, a stage of 2.39 feet produces a flow of

70.5 cfs. Because the field measured stage and the highest recorded stage are nearly the same this yields a fairly high confidence level for the recorded streamflow data at Site A for steamflows below 75 cfs. The simulated versus observed streamflow at Site A is shown in Figure 1.

The maximum field measured streamflow at the Site B is 97 cfs which corresponds to a stage of 2.84 feet. Using the five field measured flows, a rating equation has been generated. The highest recorded stage is 3.98 feet. Using the rating equation, a stage of 3.98 feet produces a flow of 172.3 cfs. Because the field measured stage is over a foot lower than the highest recorded stage this introduces some uncertainty for all of the recorded stages above the highest measured stage. The simulated versus observed streamflow at Site B is shown in Figure 2.

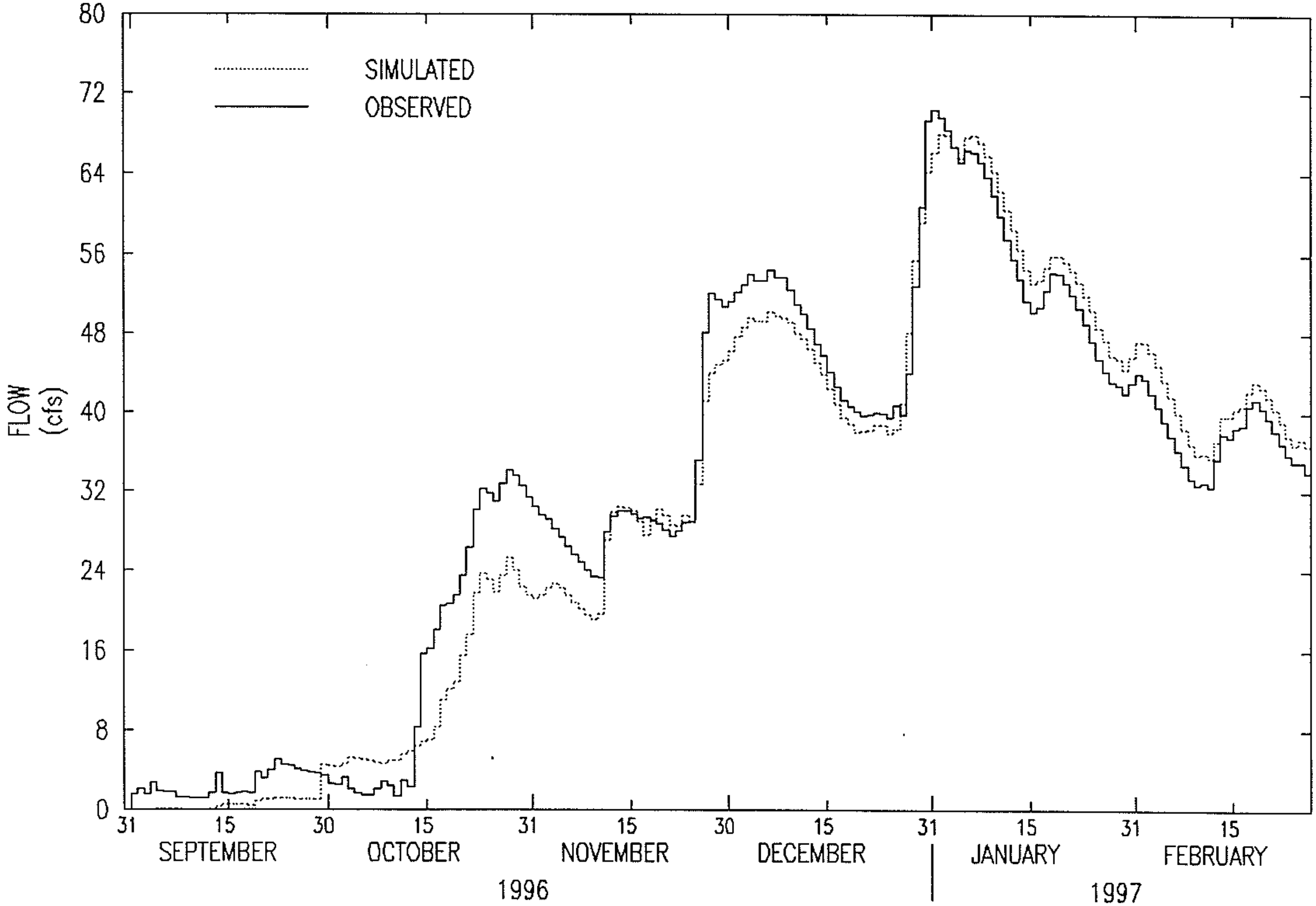
The maximum field measured streamflow at the Site C is 12.98 cfs which corresponds to a stage of 1.1 feet. Using the five field measured flows, a rating equation has been generated. The highest recorded stage is 1.3 feet. Using the rating equation, a stage of 1.3 feet produces a flow of 17.07 cfs. Because the field measured stage and the highest recorded stage are nearly the same this yields a fairly high confidence level for the recorded streamflow data at Site C for streamflows below 20 cfs. The simulated versus observed streamflow at Site C is shown in Figure 3.

The maximum field measured streamflow at the Site D is 65 cfs which corresponds to a stage of 1.8 feet. Using the five field measured flows, a rating equation has been generated. The highest recorded stage is 2.73 feet. Using the rating equation, a stage of 2.73 feet produces a flow of 167.8 cfs. Because the field measured stage is almost a foot lower than the highest recorded stage this introduces some uncertainty for all of the recorded stages above the highest measured stage. The simulated versus observed streamflow at Site D is shown in Figure 4.

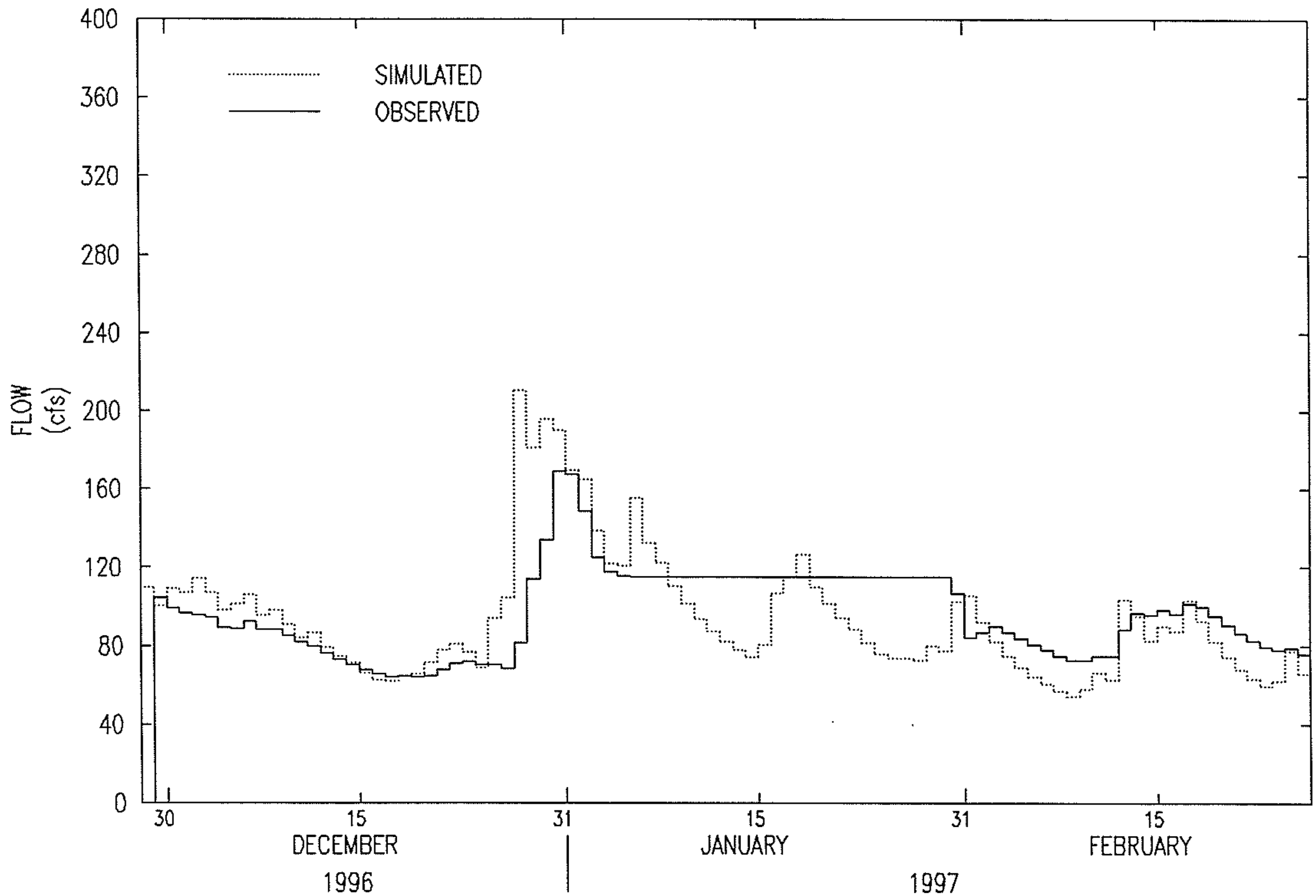
The maximum field measured streamflow at the Site G is 60.12 cfs which corresponds to a stage of 3.9 feet. Using the nine field measured flows, a rating equation has been generated. The highest recorded stage is 5.99 feet. Using the rating equation, a stage of 5.99 feet produces a flow of 727.42 cfs. Because the field measured stage is over a two feet lower than the highest recorded stage this introduces high level of uncertainty for all of the recorded stages above the highest measured stage. In fact it is highly unlikely that flows in the range of 700 cfs have ever occurred at this location. It is more likely that the rating equation does not represent the proper relationship for streamflows above a stage of four feet. The simulated versus observed streamflow at Site G is shown in Figure 5.

Precipitation Record

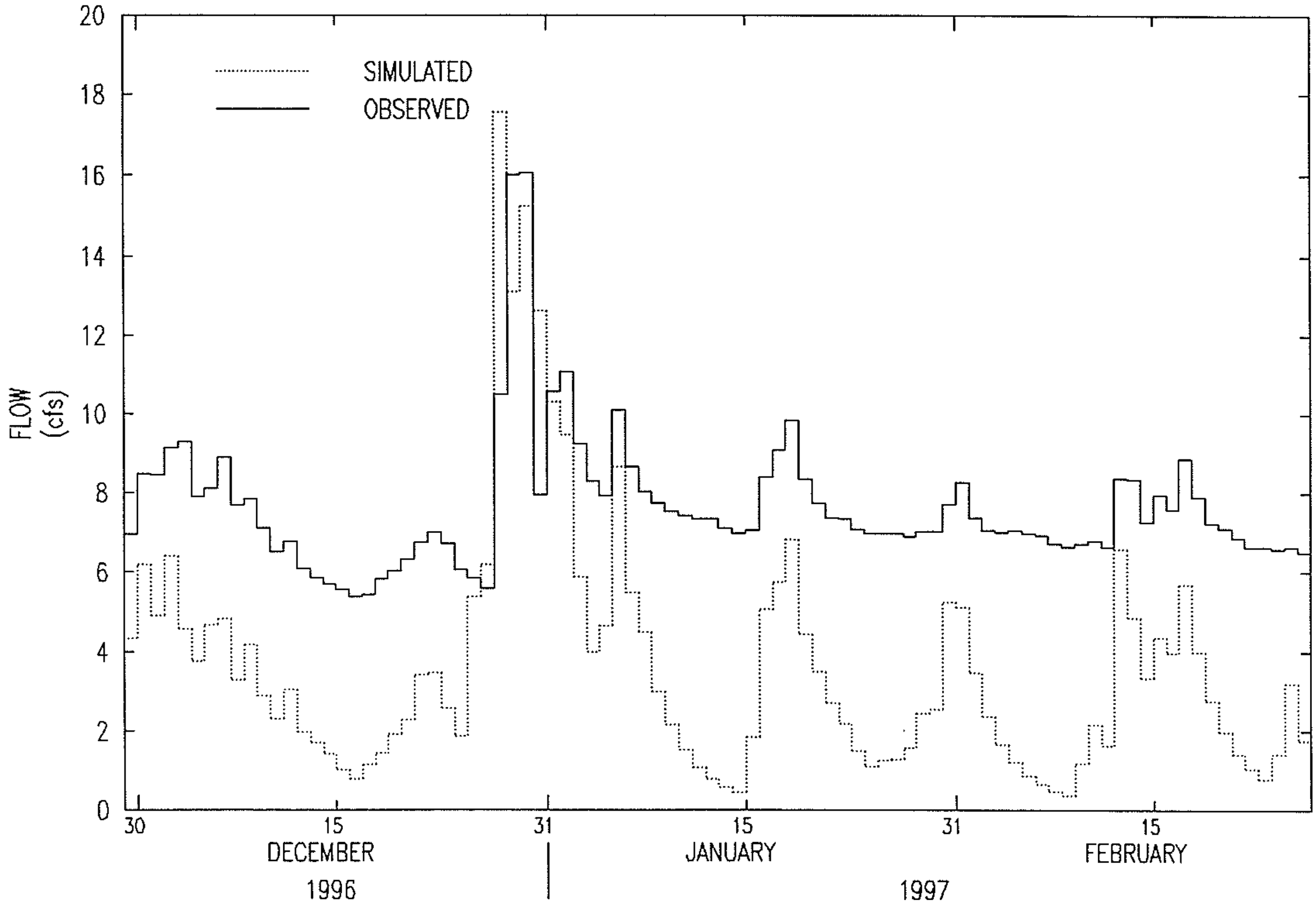
Precipitation data for the period of 10/1/92 - 2/28/97 at the Hewlet Packard gage site has been provided by Snohomish County Stormwater Management. This data was used for the calibration of the Lake Stevens watershed. A 49-year precipitation record was constructed by adding the Hewlet Packard data to the long-term Everett precipitation data. The Everett gage data and the Hewlet Packard gage data have less than two years of overlapping data. This does not provide enough information to determine a multiplication factor for converting the Everett precipitation volumes to match the Hewlett Packard precipitation volumes. For this reason no conversion factor was applied.



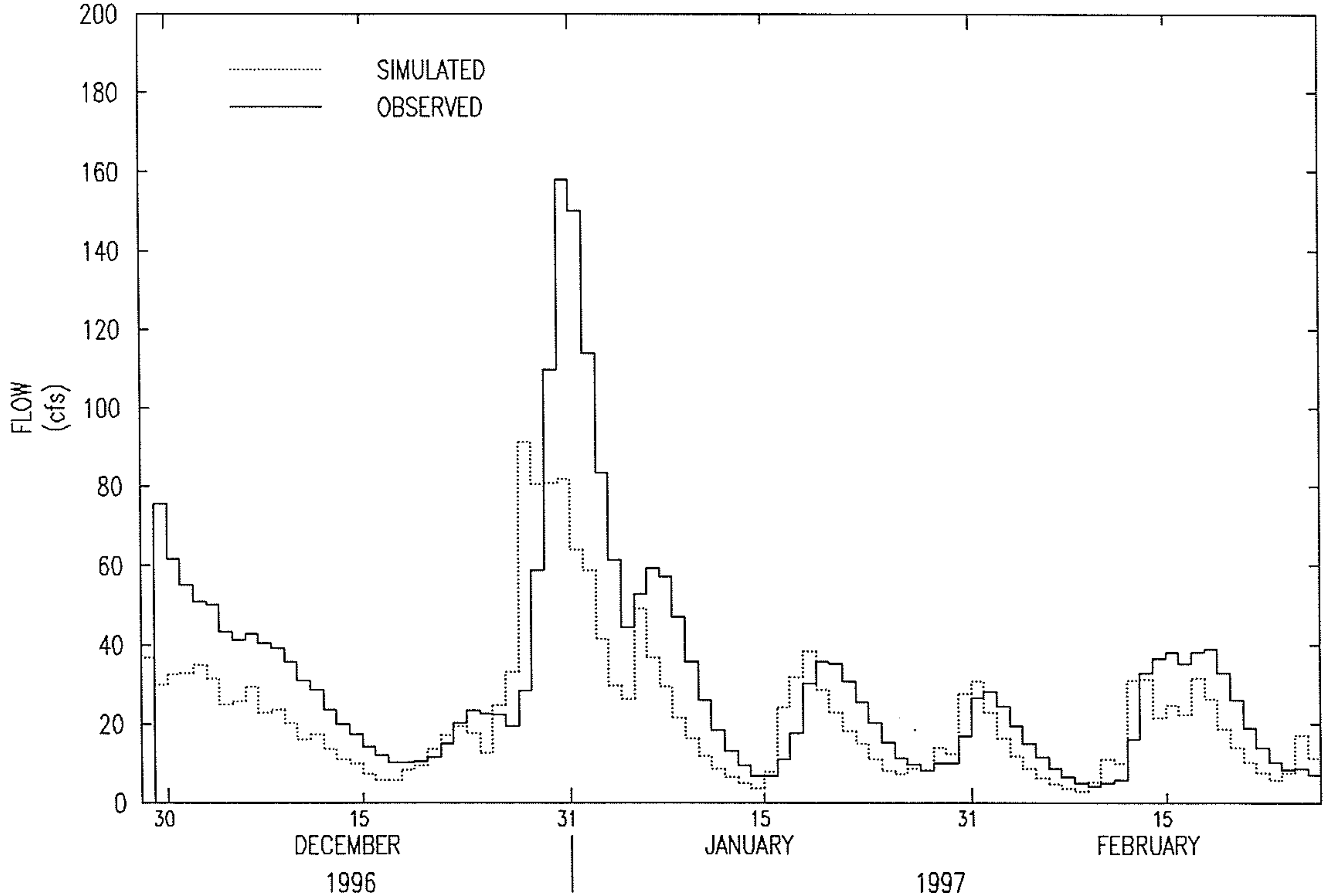
LAKE STEVENS OUTLET SITE A
5/18/97
FIGURE 1



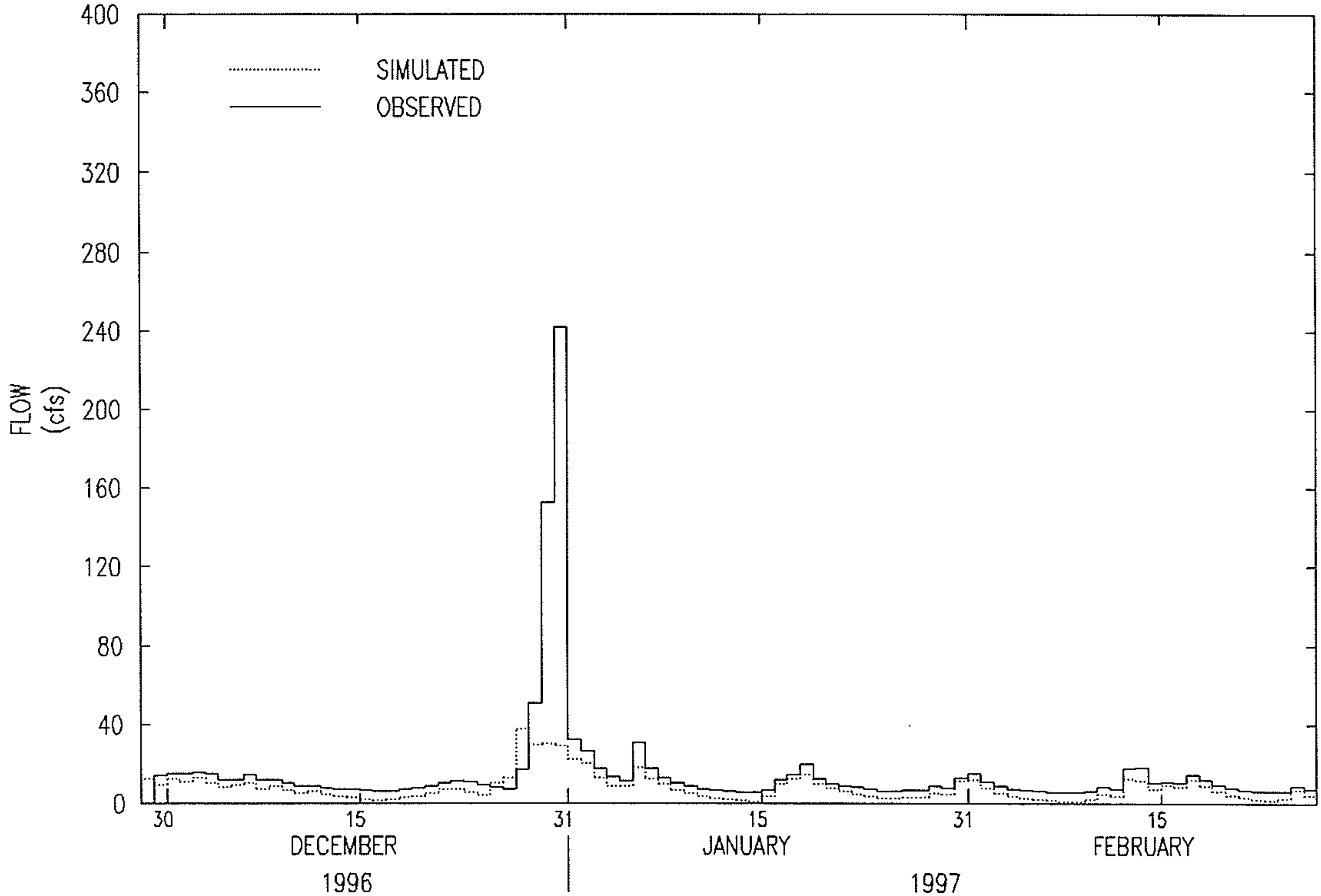
SITE B
5/18/97
FIGURE 2



SITE C
5/18/97
FIGURE 3



SITE D
5/18/97
FIGURE 4



SITE G
5/18/97
FIGURE 5

Model Parameters

The HSPF regional parameters were used as a starting point for the calibration of the Lake Stevens watershed model. Based upon our professional judgment, changes were made to the following PERLND parameters to better reflect the hydrology of the watershed. For a complete listing of the HSPF model parameters see Table 1.

Table 1

PERLND Parameter Values: Lake Stevens

PERLND #	PERLND Type	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC	INFEXP	INFILD	DEEPFR	BASETP	AGWETP	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
11	TFF	2.0	0.08	400	0.05	0.5	0.9	2	2	0	0	0.0	0.20	0.50	0.35	3	0.7	0.70
12	TFM	2.0	0.08	400	0.11	0.5	0.9	2	2	0	0	0.0	0.20	0.25	0.35	6	0.5	0.70
13	TFS	2.0	0.08	200	0.20	0.5	0.9	2	2	0	0	0.0	0.20	0.15	0.35	7	0.3	0.70
21	TPF	2.0	0.06	400	0.05	0.5	0.9	2	2	0	0	0.0	0.15	0.40	0.30	3	0.7	0.50
22	TPM	2.0	0.06	400	0.11	0.5	0.9	2	2	0	0	0.0	0.15	0.20	0.30	6	0.5	0.50
23	TPS	2.0	0.06	200	0.20	0.5	0.9	2	2	0	0	0.0	0.15	0.12	0.30	7	0.3	0.50
31	TLF	2.0	0.03	400	0.05	0.5	0.9	2	2	0	0	0.0	0.10	0.25	0.25	3	0.7	0.25
32	TLM	2.0	0.03	400	0.10	0.5	0.9	2	2	0	0	0.0	0.10	0.12	0.25	6	0.5	0.25
33	TLS	2.0	0.03	200	0.20	0.5	0.9	2	2	0	0	0.0	0.10	0.07	0.25	7	0.3	0.25
41	OF	2.5	2.00	400	0.05	0.3	0.9	2	2	0	0	0.0	0.20	0.25	0.35	0	0.7	0.70
42	OP	2.5	1.50	400	0.05	0.3	0.9	2	2	0	0	0.0	0.15	0.25	0.30	0	0.7	0.50
43	OL	2.5	0.80	400	0.05	0.3	0.9	2	2	0	0	0.0	0.10	0.25	0.25	0	0.7	0.25
51	SF	2.0	2.00	100	0.00	0.5	0.9	10	2	0	0	0.7	0.18	1.50	0.50	1	0.7	0.80
52	SP	2.0	1.80	100	0.00	0.5	0.9	10	2	0	0	0.7	0.15	1.50	0.50	1	0.7	0.80
53	SL	2.0	1.00	100	0.00	0.5	0.9	10	2	0	0	0.7	0.10	1.50	0.50	1	0.7	0.80

The LZSN parameter value for till soils was reduced from 4.5 to 2.0. The LZSN parameter value for outwash soils was reduced from 5.0 to 2.5. The LZSN parameter value for all saturated soils was reduced from 4.5 to 2.0. The LZSN parameter was reduced in order to increase winter runoff and reduce summer evaporation. The UZSN parameter value for all soils was reduced by one half. The INFEXP parameter value for flat sloped soils has been changed from 3.5 to 2.0. The INFEXP parameter value for steep sloped soils has been changed from 1.5 to 2.0. The AGWRC parameter value for all soils was reduced from 0.996 to 0.90. The AGWRC parameter value was reduced in order to increase the groundwater flow during the winter months and decrease the groundwater flow in the summer months.

Land Use

Current conditions land use for the Lake Stevens watershed has been computed by Snohomish County Surface Water Management for 92 subbasins. For a listing of the PERLND areas for the Lake Stevens watershed HSPF model see Table 2.

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Table 2 Lake Stevens Current Land Use

RCHRES		501	502	101	102	111	121	999	131	132	133	141
PERLND	Number	CAEA1	CAEA2	EBBU1	EBBU2	EBCA1	EBFI1	EBFL1	EBHU1	EBHU2	EBHU3	EBMO1
TFF	11	2.19	99.83	0.04	25.42	9.19	4.38	0.17	3.32	50.42	61.06	72.86
TFM	12	1.23	3.02	1.81	8.08	30.35	7.51	5.72	23.96	51.51	30.89	13.99
TFS	13	0.00	0.00	8.66	0.14	2.58	0.41	0.26	1.72	39.46	1.01	10.55
TPF	21	2.40	62.24	0.04	30.35	37.24	6.98	6.45	0.17	59.64	64.50	111.75
TPM	22	1.51	3.63	0.37	11.82	44.24	1.28	45.13	2.01	36.48	15.20	23.26
TPS	23	0.00	0.00	0.01	0.00	1.53	0.03	16.18	0.09	16.55	0.00	1.46
TLF	31	48.07	44.84	0.30	25.37	12.78	1.87	6.69	0.04	33.34	19.02	38.69
TLM	32	34.49	5.30	0.33	7.76	43.27	0.64	12.06	0.03	13.58	5.00	10.29
TLS	33	0.00	0.00	0.14	0.02	5.21	0.17	3.21	0.00	2.09	0.11	0.99
OF	41	0.00	0.38	8.13	6.17	39.39	20.53	1.19	3.65	3.69	0.00	33.41
OP	42	0.00	0.06	2.30	6.69	29.12	5.49	5.28	2.27	7.34	0.00	22.83
OL	43	0.00	0.21	2.10	4.46	36.26	0.88	2.68	0.00	5.78	0.00	10.00
SF	51	0.14	0.84	0.00	0.00	0.00	0.00	52.91	0.26	0.00	0.00	0.00
SP	52	17.17	9.63	0.00	0.00	0.00	0.00	766.97	0.00	0.00	0.00	0.00
SL	53	8.15	2.48	0.00	0.00	0.00	0.00	8.58	0.01	0.00	0.00	0.00
EIA	91	43.33	34.40	5.30	13.91	60.28	1.92	62.36	0.40	54.08	47.00	47.40
RCHRES		501	502	101	102	111	121	999	131	132	133	141
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		115.36	232.43	24.24	126.28	291.16	50.18	933.48	37.53	319.89	196.78	350.07
Total		158.69	266.84	29.53	140.19	351.44	52.09	995.84	37.93	373.96	243.78	397.47

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Table 2

RCHRES		142	143	144	151	152	161	162	163	164	165	166
PERLND	Number	EBMO2	EBMO3	EBMO4	EBSE1	EBSE2	EBSU1	EBSU2	EBSU3	EBSU4	EBSU5	EBSU6
TFF	11	18.32	59.23	4.89	14.86	7.55	10.18	14.27	29.79	39.27	24.11	126.07
TFM	12	42.83	34.65	0.96	17.68	4.38	13.78	9.85	10.90	17.17	25.07	88.97
TFS	13	40.01	0.01	0.00	1.81	0.00	0.00	0.00	0.00	0.00	0.00	0.22
TPF	21	29.40	11.34	12.53	39.36	15.54	14.28	25.77	43.95	39.59	20.20	81.75
TPM	22	31.29	2.80	5.07	30.65	2.27	46.82	43.86	11.26	27.55	9.78	44.60
TPS	23	4.76	0.00	0.00	0.23	0.00	1.01	1.76	0.00	0.00	0.00	0.00
TLF	31	28.03	29.11	51.20	27.46	1.73	8.35	7.02	19.43	14.36	9.52	39.95
TLM	32	16.83	10.76	15.22	11.44	1.02	16.00	11.93	5.66	5.04	6.90	18.18
TLS	33	6.02	0.33	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.71
OF	41	15.66	13.86	0.00	21.81	6.36	0.00	0.33	0.00	0.00	0.00	0.00
OP	42	6.71	5.76	0.53	12.40	1.33	0.00	4.88	0.00	0.00	0.00	0.00
OL	43	38.93	14.20	2.16	15.67	2.04	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	3.46	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	44.09	29.33	29.54	26.02	3.93	8.98	7.13	6.18	6.05	3.24	11.91
RCHRES		142	143	144	151	152	161	162	163	164	165	166
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		278.79	182.06	92.57	193.42	42.22	110.41	123.13	121.00	142.97	95.59	400.44
Total		322.88	211.39	122.11	219.44	46.15	119.39	130.27	127.18	149.02	98.83	412.35

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Table 2

RCHRES		181	999	999	999	999	999	999	999	191	192	193
PERLND	Number	EBTH1	EBTR1	EBTR2	EBTR3	EBTR4	EBTR5	EBTR6	EBTR7	EBWE1	EBWE2	EBWE3
TFF	11	11.53	0.59	0.03	0.00	0.83	1.53	4.39	3.19	2.74	2.88	1.54
TFM	12	0.48	3.96	0.66	11.91	3.65	4.42	19.31	1.64	5.31	4.67	4.42
TFS	13	0.00	1.14	0.00	5.17	19.72	3.89	8.27	0.00	2.58	4.27	9.53
TPF	21	34.67	1.95	1.91	6.02	2.68	3.72	0.00	36.12	4.00	5.55	1.13
TPM	22	8.90	10.56	11.77	22.02	3.93	13.28	11.66	2.01	7.22	5.59	2.28
TPS	23	0.44	0.69	0.06	1.97	10.54	32.96	3.70	0.00	5.33	1.80	1.23
TLF	31	17.09	0.83	0.62	2.34	8.17	0.03	0.00	13.80	0.00	0.40	1.31
TLM	32	13.18	3.63	11.00	23.63	6.96	0.88	9.25	2.30	0.04	0.00	0.94
TLS	33	0.06	1.09	0.00	2.43	6.81	0.90	1.12	0.00	0.00	0.00	0.07
OF	41	0.11	0.30	0.17	0.49	5.13	2.13	0.00	0.00	0.00	13.30	2.51
OP	42	0.11	4.30	3.18	2.01	16.59	6.43	0.00	0.00	0.00	1.11	0.81
OL	43	1.48	1.68	2.27	2.03	13.08	1.31	0.00	0.00	0.00	0.00	1.23
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.00	0.00	0.00
EIA	91	11.32	4.66	6.30	9.12	3.52	1.80	1.65	7.71	0.01	0.14	0.39
RCHRES		181	999	999	999	999	999	999	999	191	192	193
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		88.05	30.73	31.67	80.02	98.08	71.47	60.00	59.06	27.22	39.57	27.01
Total		99.37	35.39	37.97	89.14	101.60	73.27	61.66	66.77	27.23	39.71	27.41

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Table 2

RCHRES		194	195	196	197	198	301	300	311	300	300	300
PERLND	Number	EBWE4	EBWE5	EBWE6	EBWE7	EBWE8	LABR1	LADR12	LACE1	LADR1	LADR10	LADR11
TFF	11	6.42	8.37	8.22	18.31	7.30	2.50	0.00	62.64	1.04	0.00	6.55
TFM	12	3.76	3.97	10.13	7.91	2.77	2.90	0.00	4.76	3.06	0.00	10.69
TFS	13	2.41	4.90	0.00	0.00	0.00	1.29	0.00	0.00	11.36	0.00	0.89
TPF	21	28.83	43.98	13.67	26.68	6.84	4.54	0.00	73.36	1.12	0.00	5.12
TPM	22	8.14	7.83	10.15	4.40	0.00	8.14	0.00	8.15	5.54	0.00	2.94
TPS	23	0.07	0.00	0.00	0.00	0.00	0.89	0.00	0.00	2.93	0.00	2.14
TLF	31	23.61	30.57	13.09	20.88	19.05	0.54	2.19	44.45	28.91	1.52	22.22
TLM	32	7.02	4.00	3.75	6.32	1.35	4.85	0.93	9.59	34.77	1.58	27.64
TLS	33	0.14	0.05	0.00	0.00	0.00	0.00	0.00	0.00	19.77	0.00	4.84
OF	41	1.78	6.54	0.64	0.22	0.00	4.78	0.00	1.15	0.00	0.00	4.32
OP	42	1.55	0.00	7.53	0.84	0.00	1.99	0.00	0.01	0.00	0.00	0.21
OL	43	4.77	3.13	0.97	3.86	1.23	3.10	0.00	0.31	0.00	0.00	7.46
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	36.10	55.12	18.01	13.78	13.49	2.98	1.10	20.48	37.65	1.32	27.64
RCHRES		194	195	196	197	198	301	300	311	300	300	300
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
PERLND Total		88.49	113.34	68.15	89.42	38.55	35.53	3.12	204.43	108.51	3.10	95.03
Total		124.59	168.47	86.16	103.20	52.03	38.52	4.22	224.90	146.16	4.42	122.67

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Table 2

RCHRES		300	300	300	300	300	300	300	300	300	331	321
PERLND	Number	LADR14	LADR2	LADR3	LADR4	LADR5	LADR6	LADR7	LADR8	LADR9	LAEA1	LAEAS1
TFF	11	0.00	0.00	1.92	0.00	0.71	0.16	0.00	0.00	0.25	0.57	3.83
TFM	12	0.00	0.00	2.09	0.00	2.54	10.58	0.00	0.00	0.00	4.24	1.57
TFS	13	0.00	0.00	0.00	0.00	2.17	0.11	0.00	0.00	0.00	2.39	0.00
TPF	21	0.03	0.74	0.37	2.17	1.74	0.00	0.00	0.00	4.27	0.38	5.00
TPM	22	0.00	1.49	0.36	0.00	2.15	2.12	0.00	0.00	0.00	0.76	1.36
TPS	23	0.00	0.00	0.00	0.00	1.59	0.08	0.00	0.00	0.00	1.13	0.00
TLF	31	6.76	9.11	15.58	11.15	7.79	0.24	3.49	0.00	18.61	1.46	15.55
TLM	32	0.00	12.70	9.19	0.36	11.68	6.75	0.00	0.00	0.19	3.43	5.46
TLS	33	0.00	0.00	0.00	0.00	6.69	0.11	0.00	0.00	0.00	0.55	0.00
OF	41	0.00	0.00	0.00	0.00	4.15	0.01	0.00	0.00	0.00	3.24	0.00
OP	42	0.00	0.00	0.00	0.00	2.94	0.00	0.00	0.00	0.00	0.22	0.00
OL	43	0.00	0.00	0.00	0.00	6.54	0.71	0.00	0.00	0.00	3.28	0.00
SF	51	0.00	0.00	0.62	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00
SP	52	0.00	0.02	1.71	0.00	0.00	1.32	0.06	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	7.73	0.00	0.00	1.66	3.18	1.26	1.20	0.00	0.00
EIA	91	1.22	10.83	13.61	4.36	14.32	2.76	2.34	0.46	7.60	8.54	8.06
RCHRES		300	300	300	300	300	300	300	300	300	331	321
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		6.79	24.07	39.57	13.68	50.68	23.94	6.73	1.26	24.53	21.65	32.76
Total		8.00	34.90	53.19	18.04	65.01	26.70	9.07	1.72	32.12	30.19	40.82

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Table 2

RCHRES		341	351	352	353	300	361	371	372	373	374	381
PERLND	Number	LAFO1	LAKO1	LAKO2	LAKO3	LALA1	LALO1	LALU1	LALU2	LALU3	LALU4	LANW1
TFF	11	11.40	0.00	6.81	0.00	0.00	13.85	21.72	6.80	41.13	80.26	1.58
TFM	12	1.87	1.50	4.71	0.00	0.00	18.16	4.59	12.13	25.28	43.75	1.94
TFS	13	0.39	0.00	0.00	0.00	0.00	1.01	7.98	4.49	1.40	1.74	2.12
TPF	21	8.18	0.00	5.35	0.89	0.00	8.06	14.86	2.94	29.47	52.30	1.60
TPM	22	1.12	0.19	2.58	0.54	0.00	4.50	9.60	3.40	8.67	45.18	1.93
TPS	23	1.08	0.00	0.00	0.00	0.00	0.40	7.16	0.00	0.10	2.61	1.86
TLF	31	14.36	2.51	66.39	10.56	0.00	19.03	51.25	4.49	15.13	20.22	8.15
TLM	32	3.23	7.78	33.38	9.42	0.00	27.16	13.32	6.39	5.30	14.26	6.53
TLS	33	0.46	0.00	0.00	0.00	0.00	1.88	4.77	0.31	0.86	0.05	1.07
OF	41	0.00	0.00	0.00	0.00	0.00	5.85	7.10	0.56	0.00	0.00	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.56	0.48	2.51	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	7.98	1.77	0.96	0.00	0.00	0.02
SF	51	1.99	0.00	0.00	0.00	0.00	8.89	0.00	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	9.72	0.00	0.00	0.00	0.00	0.00
SL	53	2.60	0.00	0.00	0.00	0.00	11.81	0.00	0.00	0.00	0.00	0.00
EIA	91	8.69	3.72	46.25	7.51	0.00	26.44	31.25	7.19	7.70	10.83	6.51
RCHRES		341	351	352	353	300	361	371	372	373	374	381
Lake		0.00	0.00	0.00	0.00	1002.78	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		46.68	11.97	119.22	21.40	0.00	138.86	144.61	45.00	127.33	260.37	26.81
Total		55.37	15.70	165.47	28.91	1002.78	165.30	175.86	52.19	135.03	271.20	33.33

AQUA TERRA Consultants
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Table 2

RCHRES		391	300	401	402	403	404	411	412	413	414	415
PERLND	Number	LASO1	LADR13	LAST1	LAST2	LAST3	LAST4	LASTI1	LASTI2	LASTI3	LASTI4	LASTI5
TFF	11	6.73	0.00	51.90	22.09	56.63	86.98	4.38	1.23	0.40	0.94	28.33
TFM	12	30.68	0.00	52.40	5.64	25.31	60.35	24.85	0.85	2.00	12.28	17.38
TFS	13	0.48	0.00	1.55	0.00	0.00	0.00	8.77	1.53	0.12	0.00	0.81
TPF	21	0.03	0.00	23.62	11.32	83.53	68.99	1.59	0.30	0.40	1.12	40.73
TPM	22	3.16	0.00	23.63	2.95	41.89	43.62	5.02	0.37	1.22	2.37	6.74
TPS	23	0.26	0.00	0.00	0.00	0.00	0.00	1.88	1.25	0.13	0.00	0.00
TLF	31	6.21	4.64	25.60	3.10	27.41	20.47	4.37	2.63	0.74	1.79	43.43
TLM	32	19.62	1.17	27.51	0.18	26.75	19.87	9.51	2.33	6.47	6.21	29.52
TLS	33	0.63	0.00	0.47	0.00	0.00	0.00	2.93	0.85	0.14	0.00	1.06
OF	41	10.95	0.00	0.00	0.00	0.00	1.48	0.00	0.00	3.28	30.80	45.50
OP	42	4.61	0.00	0.00	0.00	0.00	0.13	0.00	0.00	1.26	3.32	15.15
OL	43	8.51	0.00	0.00	0.00	0.00	0.57	0.00	0.00	6.62	9.75	36.86
SF	51	1.27	0.00	0.00	0.00	0.00	0.00	4.16	7.65	0.82	0.00	0.00
SP	52	0.33	0.00	0.00	0.00	0.00	0.00	2.00	5.36	1.22	0.00	0.00
SL	53	0.15	0.00	0.00	0.00	0.00	0.00	1.32	3.44	0.20	0.00	0.00
EIA	91	6.71	2.04	18.33	3.10	38.07	23.47	5.69	2.04	5.77	6.65	42.77
RCHRES		391	300	401	402	403	404	411	412	413	414	415
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.25	0.03	0.00	0.00
PERLND Total		93.62	5.81	206.68	45.28	261.51	302.47	70.77	27.79	25.01	68.57	265.51
Total		100.33	7.85	225.02	48.38	299.58	325.94	76.46	39.08	30.81	75.22	308.28

AQUA TERRA Consultants
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Table 2

RCHRES		421	511	512	513	514	521	522	523	524	525	999
PERLND	Number	LAWE1	PICA1	PICA2	PICA3	PICA4	PICE1	PICE2	PICE3	PICE4	PICE5	PILI1
TFF	11	0.00	103.23	285.22	769.71	24.74	15.39	48.62	28.68	15.78	1.74	2.12
TFM	12	0.00	28.17	27.51	109.01	4.65	8.69	22.49	53.21	25.38	3.01	5.32
TFS	13	0.00	0.00	0.00	8.53	0.00	9.82	4.77	0.14	1.25	0.28	12.82
TPF	21	0.76	53.57	115.42	307.40	30.75	11.76	3.13	17.15	7.68	5.13	3.80
TPM	22	0.00	19.46	4.97	70.32	5.29	7.27	17.66	21.07	11.16	3.25	2.64
TPS	23	0.00	0.00	0.00	3.98	0.00	8.72	4.37	0.06	0.75	0.00	9.85
TLF	31	7.49	82.03	40.63	74.19	46.31	0.70	36.36	15.31	7.30	29.11	0.95
TLM	32	0.35	44.37	5.61	16.70	16.33	3.26	60.41	73.05	21.16	18.42	0.60
TLS	33	0.00	0.00	0.00	0.71	0.00	15.63	7.69	1.88	0.47	0.18	0.93
OF	41	0.00	0.00	0.00	50.47	0.83	78.32	46.27	84.64	47.54	6.67	32.74
OP	42	0.00	0.00	0.00	8.41	8.60	9.93	18.93	44.19	25.27	2.48	23.56
OL	43	0.00	0.00	0.00	7.03	0.03	19.79	2.95	35.56	42.45	9.35	25.90
SF	51	0.00	116.91	82.43	111.59	10.58	3.68	0.00	0.00	0.00	0.00	20.21
SP	52	0.00	95.22	101.72	64.64	14.07	62.82	0.00	0.00	0.00	0.00	77.95
SL	53	0.00	38.44	6.98	5.57	12.74	12.67	0.00	0.00	0.00	0.00	24.75
EIA	91	3.03	95.37	9.85	79.56	27.28	13.32	34.07	55.43	31.93	38.08	11.86
RCHRES		421	511	512	513	514	521	522	523	524	525	999
Lake		0.00	0.00	0.00	136.02	0.00	0.00	0.00	7.89	0.00	0.00	0.00
PERLND Total		8.60	581.39	670.49	1608.28	174.91	268.44	273.64	374.93	206.19	79.62	244.16
Total		11.63	676.76	680.34	1823.85	202.19	281.76	307.71	438.25	238.12	117.70	256.02

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Table 2

RCHRES		999	531	532	999
PERLND	Number	PILI2	PIMA1	PIMA2	PIME1
TFF	11	50.58	19.00	210.78	52.17
TFM	12	15.68	45.73	50.88	4.40
TFS	13	0.04	6.61	5.84	0.25
TPF	21	50.76	9.00	98.33	79.10
TPM	22	4.62	32.62	42.15	6.86
TPS	23	0.24	3.18	0.66	0.35
TLF	31	15.20	8.32	61.14	9.02
TLM	32	3.31	25.63	28.00	0.31
TLS	33	0.45	2.73	0.33	0.00
OF	41	2.60	59.63	97.00	15.41
OP	42	0.17	18.91	46.35	18.75
OL	43	5.41	35.51	47.64	0.09
SF	51	12.52	3.84	6.64	0.22
SP	52	22.09	21.96	22.69	0.00
SL	53	4.83	10.69	13.77	0.00
EIA	91	35.34	22.83	48.11	2.86
RCHRES		999	531	532	999
Lake		0.00	0.00	0.00	0.00
PERLND Total		188.50	303.36	732.21	186.93
Total		223.84	326.19	780.31	189.79

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Table 3 Lake Stevens Future Land Use

RCHRES		501	502	101	102	111	121	220	131	132	133	141
PERLND	Number	CAEA1	CAEA2	EBBU1	EBBU2	EBCA1	EBFI1	EBFL1	EBHU1	EBHU2	EBHU3	EBMO1
TFF	11	0.00	53.22	0.00	1.18	1.72	0.00	0.17	1.74	30.22	25.46	13.11
TFM	12	0.00	1.21	1.39	0.24	8.35	0.07	0.20	16.26	21.57	10.64	3.83
TFS	13	0.00	0.00	7.52	0.14	0.74	0.19	0.01	1.35	29.90	0.34	3.04
TPF	21	0.71	22.40	0.00	12.89	21.50	0.00	4.70	1.66	25.77	49.18	138.02
TPM	22	0.19	1.76	0.22	5.69	56.15	0.12	15.16	9.27	23.80	19.46	31.12
TPS	23	0.00	0.00	0.00	0.00	2.24	0.02	0.28	0.43	16.89	0.00	8.49
TLF	31	45.29	95.69	0.33	54.55	15.97	1.96	7.00	0.04	69.29	44.66	51.27
TLM	32	31.82	7.06	0.72	17.79	45.64	1.64	36.54	0.03	41.93	19.39	10.42
TLS	33	0.00	0.00	0.99	0.02	5.93	0.14	14.92	0.00	5.66	0.89	0.99
OF	41	0.00	0.24	2.96	0.65	7.05	4.36	0.49	3.21	2.11	0.00	8.95
OP	42	0.00	0.19	0.04	2.09	29.12	0.35	4.96	2.62	1.53	0.00	43.13
OL	43	0.00	0.20	7.30	11.13	43.22	6.78	3.27	0.00	11.25	0.00	10.09
SF	51	0.00	0.83	0.00	0.00	0.00	0.00	52.81	0.18	0.00	0.00	0.00
SP	52	13.28	8.57	0.00	0.00	0.00	0.00	758.12	0.08	0.00	0.00	0.00
SL	53	6.82	2.51	0.00	0.00	0.00	0.00	13.69	0.01	0.00	0.00	0.00
EIA	91	60.57	72.95	8.08	33.82	113.82	36.44	83.54	1.03	94.05	73.76	75.02
RCHRES		501	502	101	102	111	121	220	131	132	133	141
Type		COPY	RCHRES	RCHRES	RCHRES	COPY	RCHRES	COPY	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		98.12	193.89	21.46	106.38	237.62	15.65	912.30	36.89	279.91	170.02	322.45
Total		158.69	266.84	29.53	140.19	351.44	52.09	995.84	37.92	373.96	243.78	397.47

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Table 3

RCHRES		142	143	144	151	152	161	162	163	164	165	166
PERLND	Number	EBMO2	EBMO3	EBMO4	EBSE1	EBSE2	EBSU1	EBSU2	EBSU3	EBSU4	EBSU5	EBSU6
TFF	11	7.66	10.29	0.00	0.10	0.00	1.60	0.37	4.17	1.86	1.85	16.69
TFM	12	12.70	4.54	0.00	1.17	0.00	0.89	0.09	0.33	0.46	0.48	2.97
TFS	13	11.52	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPF	21	38.55	29.64	9.06	8.20	3.82	9.91	1.86	27.18	16.54	0.37	85.20
TPM	22	58.81	13.00	3.76	3.01	0.88	19.32	0.94	3.37	7.98	0.22	25.77
TPS	23	31.48	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	28.03	46.43	42.05	38.28	9.65	17.01	33.81	48.64	56.82	38.83	111.46
TLM	32	16.83	22.90	12.23	26.18	3.63	44.52	48.61	18.64	31.47	30.78	92.78
TLS	33	6.02	0.33	0.00	0.82	0.00	0.75	1.30	0.00	0.00	0.00	0.75
OF	41	4.51	3.26	0.00	2.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OP	42	17.02	13.15	0.00	5.58	0.25	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	38.93	16.08	1.80	22.15	5.06	0.00	3.86	0.00	0.00	0.00	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	3.38	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	50.81	51.78	53.22	110.80	22.86	25.39	36.04	24.84	33.90	26.29	76.73
RCHRES		142	143	144	151	152	161	162	163	164	165	166
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		272.07	159.61	68.89	108.63	23.29	94.00	94.22	102.33	115.12	72.54	335.63
Total		322.88	211.39	122.11	219.44	46.15	119.39	130.27	127.18	149.02	98.83	412.35

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Table 3

RCHRES		181	221	222	223	224	225	226	227	191	192	193
PERLND	Number	EBTH1	EBTR1	EBTR2	EBTR3	EBTR4	EBTR5	EBTR6	EBTR7	EBWE1	EBWE2	EBWE3
TFF	11	0.29	0.01	0.00	0.00	0.19	0.65	1.26	0.15	2.74	0.09	1.03
TFM	12	0.00	0.05	0.00	0.25	3.62	2.40	5.56	0.29	5.31	4.43	4.10
TFS	13	0.00	0.01	0.00	0.00	16.51	1.09	2.86	0.00	2.15	4.27	9.43
TPF	21	10.53	0.00	0.00	1.78	2.09	4.42	2.95	0.33	0.28	0.13	0.20
TPM	22	0.21	0.02	0.00	0.00	2.46	11.83	24.19	0.00	3.60	2.96	1.51
TPS	23	0.00	0.15	0.00	0.00	9.72	24.94	8.67	0.00	3.61	1.80	1.23
TLF	31	43.01	0.92	1.93	5.07	7.64	0.03	0.00	40.79	2.75	6.48	2.08
TLM	32	17.83	6.50	18.24	44.50	7.11	3.09	9.25	4.44	2.70	2.12	1.58
TLS	33	0.37	2.06	0.04	7.32	9.70	8.11	1.12	0.00	1.59	0.00	0.14
OF	41	0.00	0.00	0.00	0.06	0.32	0.61	0.00	0.00	0.00	3.69	0.24
OP	42	0.00	0.17	0.00	0.00	1.49	7.60	0.00	0.00	0.00	0.11	0.81
OL	43	1.23	3.47	4.31	3.46	25.60	1.31	0.00	0.00	0.00	7.85	2.70
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.00	0.00	0.00
EIA	91	25.90	22.04	13.44	26.70	15.15	7.19	3.53	20.77	2.50	5.78	2.36
RCHRES		181	221	222	223	224	225	226	227	191	192	193
Type		RCHRES	COPY	COPY	COPY	COPY	COPY	COPY	COPY	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		73.47	13.35	24.53	62.44	86.44	66.08	58.13	46.00	24.72	33.93	25.05
Total		99.37	35.39	37.97	89.14	101.60	73.27	61.66	66.77	27.23	39.71	27.41

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Table 3

RCHRES		194	195	196	197	198	301	311	442	443	444	441
PERLND	Number	EBWE4	EBWE5	EBWE6	EBWE7	EBWE8	LABR1	LACE1	LADR1	LADR10	LADR11	LADR12
TFF	11	1.23	0.20	0.00	6.35	0.04	1.34	16.48	0.00	0.00	0.00	0.00
TFM	12	1.56	2.05	0.00	0.08	0.00	0.39	0.13	0.00	0.00	0.00	0.00
TFS	13	2.30	4.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
TPF	21	7.76	4.32	6.66	11.81	0.76	1.61	44.98	0.00	0.00	0.19	0.00
TPM	22	3.38	1.46	7.01	2.51	0.00	1.50	3.52	0.00	0.00	0.00	0.00
TPS	23	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	37.89	35.41	13.87	29.55	21.52	3.57	98.73	30.51	1.52	23.39	2.19
TLM	32	12.14	6.55	9.00	9.31	2.33	11.62	16.41	41.14	1.58	34.91	0.93
TLS	33	0.23	0.07	0.00	0.00	0.00	1.61	0.00	30.23	0.00	7.02	0.00
OF	41	0.85	4.86	0.00	0.00	0.00	0.72	0.20	0.00	0.00	0.00	0.00
OP	42	0.65	0.00	0.00	0.84	0.00	0.51	0.04	0.00	0.00	0.00	0.00
OL	43	6.14	3.37	4.93	2.90	0.94	7.20	0.98	0.00	0.00	10.65	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	50.42	105.31	44.69	39.85	26.45	8.43	43.43	44.29	1.32	46.50	1.10
RCHRES		194	195	196	197	198	301	311	442	443	444	441
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	COPY	COPY	COPY	COPY
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
PERLND Total		74.17	63.15	41.48	63.35	25.59	30.08	181.47	101.87	3.10	76.17	3.12
Total		124.59	168.46	86.17	103.20	52.03	38.52	224.90	146.17	4.42	122.67	4.22

AQUA TERRA Consultants
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Table 3

RCHRES		454	445	446	447	448	449	450	451	452	453	331
PERLND	Number	LADR13	LADR14	LADR2	LADR3	LADR4	LADR5	LADR6	LADR7	LADR8	LADR9	LAEA1
TFF	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34
TFM	12	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00	2.37
TFS	13	0.00	0.00	0.00	0.00	0.00	1.47	0.10	0.00	0.00	0.00	1.55
TPF	21	0.00	0.00	0.00	0.00	0.25	0.03	0.00	0.00	0.00	0.74	0.38
TPM	22	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.76
TPS	23	0.00	0.00	0.00	0.00	0.00	0.16	0.06	0.00	0.00	0.00	1.13
TLF	31	4.64	5.80	8.90	15.11	12.43	9.28	0.32	3.49	0.00	20.37	1.62
TLM	32	1.17	0.00	13.80	9.85	0.35	14.84	14.94	0.00	0.00	0.19	4.73
TLS	33	0.00	0.00	0.00	0.00	0.00	8.10	0.13	0.00	0.00	0.00	1.11
OF	41	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.81
OP	42	0.00	0.00	0.00	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.22
OL	43	0.00	0.00	0.00	0.00	0.00	10.58	0.58	0.00	0.00	0.00	5.02
SF	51	0.00	0.00	0.00	0.62	0.00	0.00	0.08	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.94	0.00	0.00	1.32	0.06	0.00	0.00	0.00
SL	53	0.00	0.00	0.02	7.61	0.00	0.00	1.64	3.18	1.26	1.07	0.00
EIA	91	2.04	2.21	12.17	19.05	5.00	18.89	7.49	2.34	0.46	9.76	10.14
RCHRES		454	445	446	447	448	449	450	451	452	453	331
Type		COPY	COPY	COPY	COPY	COPY	COPY	COPY	COPY	COPY	COPY	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		5.81	5.80	22.72	34.13	13.04	46.11	19.21	6.73	1.26	22.37	20.06
Total		7.85	8.00	34.89	53.18	18.04	65.00	26.70	9.07	1.72	32.13	30.19

AQUA TERRA Consultants
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Table 3

RCHRES		321	341	351	352	353	300	361	371	372	373	374
PERLND	Number	LAEAS1	LAFO1	LAKO1	LAKO2	LAKO3	LALA1	LALO1	LALU1	LALU2	LALU3	LALU4
TFF	11	1.15	0.42	0.00	0.00	0.00	0.00	4.40	11.68	2.31	5.67	31.71
TFM	12	0.32	0.96	0.00	0.00	0.00	0.00	3.01	0.55	2.11	1.53	22.31
TFS	13	0.00	0.09	0.00	0.00	0.00	0.00	0.00	2.68	0.66	0.48	0.50
TPF	21	1.43	3.73	0.00	2.57	0.34	0.00	2.12	12.31	0.92	5.48	96.29
TPM	22	0.28	0.68	0.00	1.03	0.00	0.00	0.45	1.75	0.23	1.25	63.76
TPS	23	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	3.67
TLF	31	20.10	25.76	2.50	73.31	10.96	0.00	28.69	58.36	8.63	56.74	20.25
TLM	32	7.18	4.24	9.03	38.01	9.81	0.00	41.28	21.65	14.92	25.98	14.30
TLS	33	0.00	1.46	0.00	0.00	0.00	0.00	2.89	13.85	3.14	1.57	0.05
OF	41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	12.67	7.20	3.24	0.00	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	8.22	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	8.82	0.00	0.00	0.00	0.00
SL	53	0.00	4.04	0.00	0.00	0.00	0.00	12.90	0.00	0.00	0.00	0.00
EIA	91	10.36	13.95	4.16	50.54	7.79	0.00	39.85	45.43	16.02	36.34	18.36
RCHRES		321	341	351	352	353	300	361	371	372	373	374
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	1002.79	0.00	0.00	0.00	0.00	0.00
PERLND Total		30.46	41.42	11.53	114.92	21.12	0.00	125.45	130.43	36.16	98.69	252.83
Total		40.82	55.37	15.70	165.47	28.91	1002.79	165.30	175.86	52.19	135.03	271.20

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Table 3

RCHRES		381	391	401	402	403	404	411	412	413	414	415
PERLND	Number	LANW1	LASO1	LAST1	LAST2	LAST3	LAST4	LASTI1	LASTI2	LASTI3	LASTI4	LASTI5
TFF	11	0.50	0.91	18.22	0.00	31.36	36.78	0.17	0.61	0.19	0.44	5.01
TFM	12	0.09	3.41	0.60	1.66	14.23	24.41	4.78	0.00	0.75	0.00	0.35
TFS	13	0.05	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.38
TPF	21	0.61	0.01	15.78	2.07	105.42	110.65	0.06	0.20	0.20	0.53	8.77
TPM	22	0.17	0.00	0.63	0.88	51.40	76.27	0.19	0.00	0.08	0.00	1.00
TPS	23	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	9.35	9.70	53.51	24.71	27.42	23.15	8.28	2.97	1.01	1.90	64.13
TLM	32	9.18	38.79	77.89	4.51	26.75	19.90	26.44	2.84	7.73	16.04	39.43
TLS	33	3.94	1.07	1.53	0.00	0.00	0.00	10.02	2.71	0.29	0.00	1.21
OF	41	0.00	4.46	0.00	0.00	0.00	0.61	0.00	0.00	1.05	4.18	6.86
OP	42	0.00	0.85	0.00	0.00	0.00	0.94	0.00	0.00	0.08	1.12	1.81
OL	43	0.02	14.73	0.00	0.00	0.00	0.56	0.00	0.00	8.68	26.11	65.06
SF	51	0.00	1.08	0.00	0.00	0.00	0.00	3.68	7.02	0.36	0.00	0.00
SP	52	0.00	0.33	0.00	0.00	0.00	0.00	1.29	4.05	0.73	0.00	0.00
SL	53	0.00	0.25	0.00	0.00	0.00	0.00	2.15	4.84	0.90	0.00	0.00
EIA	91	9.35	24.74	56.84	14.54	42.99	32.66	19.02	4.61	8.72	24.89	114.26
RCHRES		381	391	401	402	403	404	411	412	413	414	415
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.25	0.03	0.00	0.00
PERLND Total		23.98	75.59	168.17	33.83	256.58	293.28	57.45	25.22	22.05	50.33	194.02
Total		33.33	100.33	225.02	48.38	299.58	325.94	76.46	39.08	30.81	75.22	308.28

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Table 3

RCHRES		421	511	512	513	514	521	522	523	524	525	601
PERLND	Number	LAWE1	PICA1	PICA2	PICA3	PICA4	PICE1	PICE2	PICE3	PICE4	PICE5	PILI1
TFF	11	0.00	27.52	152.24	276.30	4.28	4.43	8.66	7.55	2.54	0.00	0.64
TFM	12	0.00	0.27	18.06	24.80	0.44	2.50	3.20	13.06	2.74	0.00	1.67
TFS	13	0.00	0.00	0.00	1.86	0.00	2.83	1.37	0.00	0.00	0.00	3.83
TPF	21	0.00	80.04	231.93	650.05	23.92	21.63	17.53	13.51	3.70	0.90	5.20
TPM	22	0.00	2.56	13.69	97.42	0.49	12.81	14.02	29.90	8.97	0.21	6.06
TPS	23	0.00	0.00	0.00	8.30	0.00	14.97	6.09	0.00	0.00	0.00	18.14
TLF	31	7.62	112.07	44.11	157.34	53.74	0.70	50.88	27.84	18.94	26.72	0.54
TLM	32	0.35	76.22	5.61	54.97	21.16	3.26	76.19	90.79	37.14	16.83	0.48
TLS	33	0.00	0.00	0.00	2.24	0.00	15.63	8.72	2.03	1.80	0.32	0.93
OF	41	0.00	0.00	0.00	14.86	0.48	22.93	15.00	36.15	8.62	0.00	10.93
OP	42	0.00	0.00	0.00	41.70	8.21	61.95	45.98	68.02	37.85	0.89	43.51
OL	43	0.00	0.00	0.00	7.03	0.43	19.79	4.56	51.73	55.13	11.03	22.27
SF	51	0.00	25.77	53.42	91.75	0.01	1.06	0.00	0.00	0.00	0.00	7.01
SP	52	0.00	56.29	126.29	82.40	5.04	63.32	0.00	0.00	0.00	0.00	87.90
SL	53	0.00	87.60	7.90	5.56	20.46	13.68	0.00	0.00	0.00	0.00	18.63
EIA	91	3.66	208.43	27.10	171.23	63.54	20.27	55.51	89.78	60.68	60.80	28.29
RCHRES		421	511	512	513	514	521	522	523	524	525	601
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	COPY
Lake		0.00	0.00	0.00	136.02	0.00	0.00	0.00	7.89	0.00	0.00	0.00
PERLND Total		7.98	468.34	653.24	1516.59	138.66	261.49	252.20	340.59	177.44	56.90	227.74
Total		11.64	676.76	680.34	1823.84	202.20	281.76	307.71	438.25	238.12	117.70	256.03

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Table 3

RCHRES		602	531	532	541
PERLND	Number	PILI2	PIMA1	PIMA2	PIME1
TFF	11	0.68	1.36	97.22	37.10
TFM	12	1.16	0.58	10.18	1.89
TFS	13	0.00	0.84	1.68	0.11
TPF	21	20.37	10.41	178.40	87.79
TPM	22	3.68	7.88	40.88	9.22
TPS	23	0.00	3.32	4.33	0.48
TLF	31	22.79	18.77	79.55	13.16
TLM	32	5.10	74.17	57.36	0.32
TLS	33	0.11	6.60	0.52	0.00
OF	41	0.00	11.41	37.55	14.09
OP	42	0.16	44.32	94.98	19.84
OL	43	5.35	50.61	52.48	0.09
SF	51	0.27	1.11	3.41	0.22
SP	52	14.49	23.83	24.94	0.00
SL	53	9.04	7.01	10.36	0.00
EIA	91	140.62	63.99	86.48	5.49
RCHRES		602	531	532	541
Type		COPY	RCHRES	RCHRES	COPY
Lake		0.00	0.00	0.00	0.00
PERLND Total		83.22	262.21	693.83	184.30
Total		223.84	326.19	780.31	189.79

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Table 4 Lake Stevens Predevelopment (forest)

RCHRES		501	502	101	102	111	121	220	131	132	133
PERLND	Number	CAEA1	CAEA2	EBBU1	EBBU2	EBCA1	EBFI1	EBFL1	EBHU1	EBHU2	EBHU3
TFF	11	71.55	230.85	1.68	90.61	66.14	14.03	18.82	3.81	171.52	180.57
TFM	12	54.17	15.36	3.46	30.23	133.77	10.04	78.84	26.04	117.83	61.44
TFS	13	0.00	0.00	9.30	0.29	33.52	0.78	25.61	1.81	65.04	1.77
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	0.00	0.71	15.09	19.06	118.00	27.24	15.01	5.91	19.58	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	32.96	19.92	0.00	0.00	0.00	0.00	857.56	0.35	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		501	502	101	102	111	121	220	131	132	133
Type		COPY	RCHRES	RCHRES	RCHRES	COPY	RCHRES	COPY	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		158.69	266.84	29.53	140.19	351.44	52.09	995.84	37.92	373.96	243.78
Total		158.69	266.84	29.53	140.19	351.44	52.09	995.84	37.92	373.96	243.78

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Table 4

RCHRES		141	142	143	144	151	152	161	162	163	164
PERLND	Number	EBMO1	EBMO2	EBMO3	EBMO4	EBSE1	EBSE2	EBSU1	EBSU2	EBSU3	EBSU4
TFF	11	247.42	86.33	115.96	90.97	93.17	26.92	34.91	49.88	97.98	96.83
TFM	12	60.82	99.62	53.73	27.64	62.36	8.42	83.48	69.94	29.19	52.18
TFS	13	15.49	52.12	0.35	0.00	2.08	0.00	1.01	1.76	0.00	0.00
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	73.74	84.80	41.35	3.50	61.82	10.81	0.00	5.21	0.00	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.47	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		141	142	143	144	151	152	161	162	163	164
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		397.47	322.88	211.39	122.11	219.44	46.15	119.39	130.27	127.18	149.02
Total		397.47	322.88	211.39	122.11	219.44	46.15	119.39	130.27	127.18	149.02

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Table 4

RCHRES		165	166	181	221	222	223	224	225	226	227
PERLND	Number	EBSU5	EBSU6	EBTH1	EBTR1	EBTR2	EBTR3	EBTR4	EBTR5	EBTR6	EBTR7
TFF	11	56.53	255.26	71.25	3.59	2.66	8.63	12.55	5.46	4.39	59.48
TFM	12	42.30	156.08	25.41	19.56	29.03	64.07	15.10	19.50	41.09	7.29
TFS	13	0.00	1.01	0.50	3.57	0.06	11.55	37.69	38.27	13.13	0.00
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	0.00	0.00	2.21	8.68	6.22	4.89	36.25	10.04	0.00	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.05	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		165	166	181	221	222	223	224	225	226	227
Type		RCHRES	RCHRES	RCHRES	COPY	COPY	COPY	COPY	COPY	COPY	COPY
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		98.83	412.35	99.37	35.39	37.97	89.14	101.60	73.27	61.66	66.77
Total		98.83	412.35	99.37	35.39	37.97	89.14	101.60	73.27	61.66	66.77

AQUA TERRA Consultants
Engineer: Beyerlein
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Table 4

RCHRES		191	192	193	194	195	196	197	198	301	311
PERLND	Number	EBWE1	EBWE2	EBWE3	EBWE4	EBWE5	EBWE6	EBWE7	EBWE8	LABR1	LACE1
TFF	11	6.74	8.98	4.13	83.86	132.85	50.08	74.39	44.50	7.77	197.38
TFM	12	12.58	10.25	7.74	25.36	18.53	25.58	21.13	4.51	17.60	25.95
TFS	13	7.91	6.08	10.84	2.88	5.04	0.00	0.00	0.00	2.18	0.00
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	0.00	14.41	4.69	12.50	12.04	10.50	7.67	3.03	10.96	1.58
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		191	192	193	194	195	196	197	198	301	311
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		27.23	39.71	27.41	124.59	168.46	86.17	103.20	52.03	38.51	224.90
Total		27.23	39.71	27.41	124.59	168.46	86.17	103.20	52.03	38.52	224.90

AQUA TERRA Consultants
Engineer: Beyerlein
Project No. 9713
Date: 29-May-97

Table 4

RCHRES		442	443	444	441	454	445	446	447	448	449
PERLND	Number	LADR1	LADR10	LADR11	LADR12	LADR13	LADR14	LADR2	LADR3	LADR4	LADR5
TFF	11	43.74	2.14	46.06	2.96	6.27	8.00	14.96	23.30	17.50	14.11
TFM	12	58.00	2.28	51.35	1.26	1.58	0.00	19.91	16.34	0.54	20.55
TFS	13	44.42	0.00	9.82	0.00	0.00	0.00	0.00	0.00	0.00	14.47
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	0.00	0.00	15.44	0.00	0.00	0.00	0.00	0.00	0.00	15.87
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	0.00	0.00	0.00	0.00	0.00	0.00	0.02	13.55	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		442	443	444	441	454	445	446	447	448	449
Type		COPY	COPY	COPY	COPY	COPY	COPY	COPY	COPY	COPY	COPY
Lake		0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		146.17	4.42	122.67	4.21	7.85	8.00	34.90	53.18	18.04	65.00
Total		146.17	4.42	122.67	4.22	7.85	8.00	34.90	53.19	18.04	65.00

AQUA TERRA Consultants
Engineer: Beyerlein
Project No. 9713
Date: 29-May-97

Table 4

RCHRES		450	451	452	453	331	321	341	351	352	353
PERLND	Number	LADR6	LADR7	LADR8	LADR9	LAEA1	LAEAS1	LAFO1	LAKO1	LAKO2	LAKO3
TFF	11	0.43	4.72	0.00	30.18	3.64	30.12	39.82	3.43	111.79	15.47
TFM	12	20.81	0.00	0.00	0.25	11.55	10.70	7.44	12.26	53.68	13.43
TFS	13	0.40	0.00	0.00	0.00	4.55	0.00	2.10	0.00	0.00	0.00
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	1.20	0.00	0.00	0.00	10.46	0.00	0.00	0.00	0.00	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	3.87	4.35	1.72	1.69	0.00	0.00	6.01	0.00	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		450	451	452	453	331	321	341	351	352	353
Type		COPY	COPY	COPY	COPY	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		26.70	9.07	1.72	32.13	30.19	40.82	55.37	15.70	165.47	28.91
Total		26.70	9.07	1.72	32.13	30.19	40.82	55.37	15.70	165.47	28.91

AQUA TERRA Consultants
Engineer: Beyerlein
Project No. 9713
Date: 29-May-97

Table 4

RCHRES		300	361	371	372	373	374	381	391	401	402
PERLND	Number	LALA1	LALO1	LALU1	LALU2	LALU3	LALU4	LANW1	LASO1	LAST1	LAST2
TFF	11	0.00	48.49	108.89	16.06	92.60	158.87	15.08	14.00	114.24	38.52
TFM	12	0.00	61.12	33.32	26.60	39.81	107.78	12.76	55.95	108.71	9.85
TFS	13	0.00	3.93	22.25	5.14	2.62	4.55	5.45	1.44	2.07	0.00
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	0.00	17.42	11.39	4.38	0.00	0.00	0.03	27.15	0.00	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	0.00	34.34	0.00	0.00	0.00	0.00	0.00	1.78	0.00	0.00
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		300	361	371	372	373	374	381	391	401	402
Type			RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		1002.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PERLND Total		0.00	165.30	175.86	52.19	135.03	271.20	33.33	100.33	225.02	48.38
Total		1002.79	165.30	175.86	52.19	135.03	271.20	33.33	100.33	225.02	48.38

AQUA TERRA Consultants
Engineer: Beyerlein
Project No. 9713
Date: 29-May-97

Table 4

RCHRES		403	404	411	412	413	414	415	421	511	512
PERLND	Number	LAST3	LAST4	LASTI1	LASTI2	LASTI3	LASTI4	LASTI5	LAWE1	PICA1	PICA2
TFF	11	193.69	186.33	11.44	4.96	1.89	7.10	130.93	11.16	268.85	448.51
TFM	12	105.89	136.54	41.28	4.19	13.28	22.42	65.24	0.48	111.43	38.70
TFS	13	0.00	0.00	15.89	3.68	0.39	0.00	1.96	0.00	0.00	0.00
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	0.00	3.08	0.00	0.00	12.96	45.71	110.15	0.00	0.00	0.00
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	0.00	0.00	7.86	17.01	2.25	0.00	0.00	0.00	296.48	193.14
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		403	404	411	412	413	414	415	421	511	512
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES
Lake		0.00	0.00	0.00	9.25	0.03	0.00	0.00	0.00	0.00	0.00
PERLND Total		299.58	325.94	76.46	29.83	30.77	75.22	308.28	11.64	676.76	680.34
Total		299.58	325.94	76.46	39.08	30.81	75.22	308.28	11.64	676.76	680.34

AQUA TERRA Consultants
Engineer: Beyerlein
Project No. 9713
Date: 29-May-97

Table 4

RCHRES		513	514	521	522	523	524	525	601	602	531
PERLND	Number	PICA3	PICA4	PICE1	PICE2	PICE3	PICE4	PICE5	PILI1	PILI2	PIMA1
TFF	11	1220.82	118.10	28.33	97.00	72.40	36.31	58.14	6.96	142.67	37.56
TFM	12	203.22	30.21	19.99	121.94	177.52	67.10	35.41	8.59	28.59	112.11
TFS	13	14.96	0.00	35.14	19.59	2.74	2.89	1.39	23.63	0.76	12.76
TPF	21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPM	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TPS	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLF	31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLM	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TLS	33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OF	41	66.68	9.70	109.97	69.18	177.69	131.82	22.76	87.05	9.11	122.46
OP	42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
OL	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SF	51	182.16	44.18	88.33	0.00	0.00	0.00	0.00	129.80	42.71	41.31
SP	52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SL	53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EIA	91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RCHRES		513	514	521	522	523	524	525	601	602	531
Type		RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	RCHRES	COPY	COPY	RCHRES
Lake		136.02	0.00	0.00	0.00	7.89	0.00	0.00	0.00	0.00	0.00
PERLND Total		1687.83	202.19	281.76	307.71	430.36	238.12	117.70	256.03	223.84	326.19
Total		1823.84	202.19	281.76	307.71	438.25	238.12	117.70	256.03	223.84	326.19

AQUA TERRA Consultants
Engineer: Beyerlein
Project No. 9713
Date: 29-May-97

Table 4

RCHRES		532	541
PERLND	Number	PIMA2	PIME1
TFF	11	389.44	143.10
TFM	12	130.68	11.60
TFS	13	6.85	0.60
TPF	21	0.00	0.00
TPM	22	0.00	0.00
TPS	23	0.00	0.00
TLF	31	0.00	0.00
TLM	32	0.00	0.00
TLS	33	0.00	0.00
OF	41	207.19	34.27
OP	42	0.00	0.00
OL	43	0.00	0.00
SF	51	46.15	0.22
SP	52	0.00	0.00
SL	53	0.00	0.00
EIA	91	0.00	0.00
RCHRES		532	541
Type		RCHRES	COPY
Lake		0.00	0.00
PERLND Total		780.31	189.79
Total		780.31	189.79

Lake Stevens

There are two major destinations for runoff in the Lake Stevens watershed area: (1) Ebby Slough or (2) the Pilchuck River via Catherine Creek and Lake Stevens. Lake Stevens is the focal point of the calibration of the Lake Stevens watershed model. Understanding the behavior of Lake Stevens was crucial to obtaining a satisfactory calibration of the model.

From the period of mid-April to mid-October boards are placed in the outlet structure from Lake Stevens. The purpose of the boards is to keep the lake at a more stable elevation year round. During the summer months the lake level will drop down below an elevation 210 unless the boards are placed in the outlet-structure.

It was observed when comparing the simulated lake level data with the observed lake level data that the simulated data was a consistent one foot below the observed lake level data. From this we concluded that there is a groundwater source contributing to the lake from outside the watershed. The Pilchuck River is the most likely candidate for the source of the groundwater. This was simulated by adding 3600 acres of Till Forest Flat PERLND to the model and routing it to an artificial stream reach. The artificial reach contributes a constant 20 cfs to Lake Stevens. In addition to the inflow of groundwater to Lake Stevens there is a subsurface outflow from Lake Stevens. The outflow, listed in Table 4, is less then the inflow and is variable depending on the time of year. The subsurface outflow is connected directly to RCHRES 514 which is PICA4 subcatchment and the downstream reach of Catherine Creek.

Representing the groundwater in this way produced a good calibration of the Lake Stevens lake levels (see Figure 6).

Summary

The short time span of observed data does not allow for a conclusive calibration in the traditional sense. However a good match of the existing data has been achieved and a reasonable understanding of the behavior of Lake Stevens and Catherine Creek have been accomplished.

LONG TERM SIMULATIONS

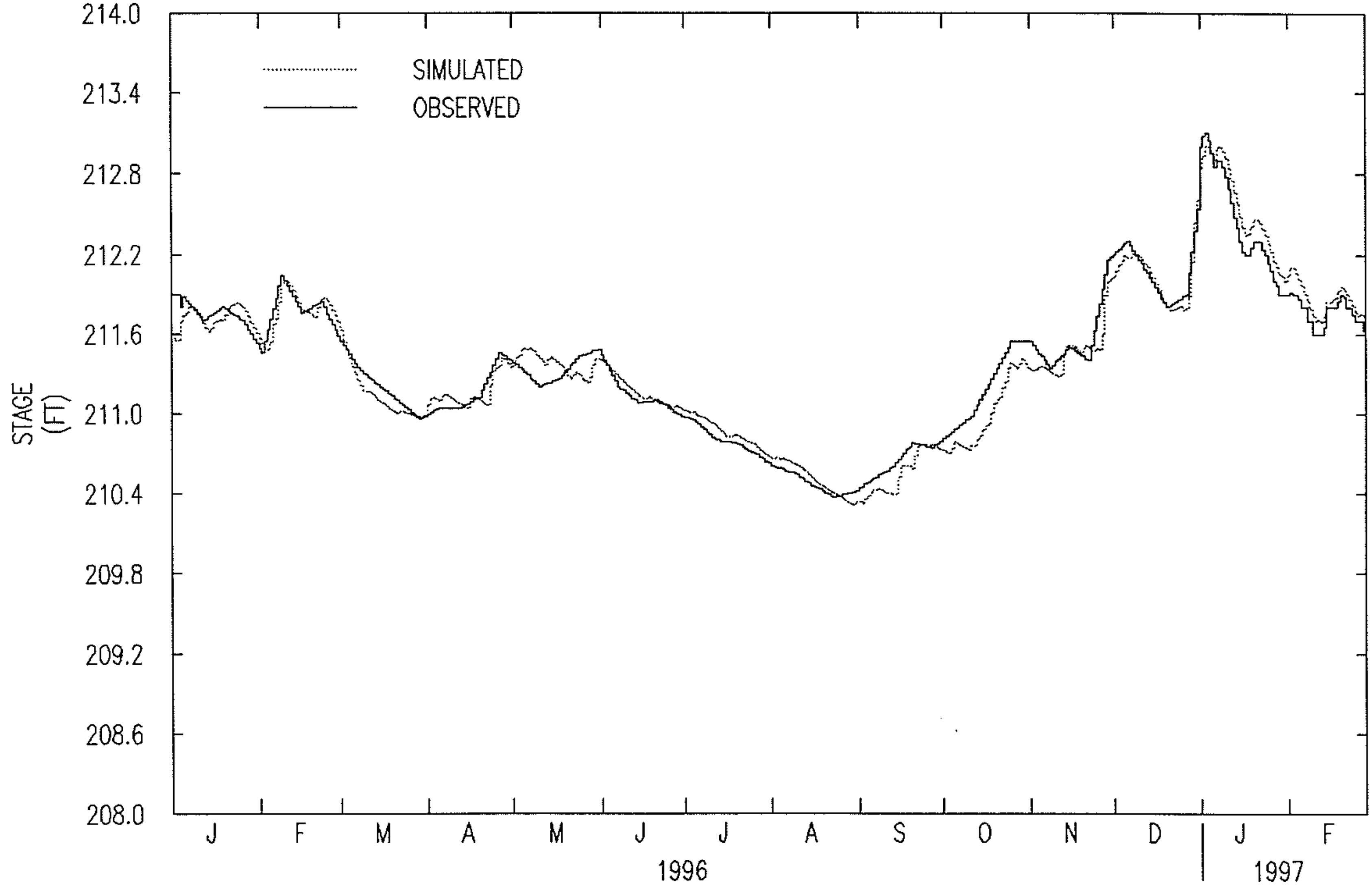
Using the calibrated Lake Stevens HSPF model the following three long term simulations were conducted:

forested

current

future no mitigation.

Each scenario was modeled with Everett NOAA hourly precipitation (1949-1991) and Snohomish County hourly precipitation (1991-1997). The Snohomish County precipitation gage is located at the Hewlett Packard building on Soper Hilll Road. Forty-eight years of hourly streamflow was generated by the HSPF model for each scenario. The maximum hourly simulated streamflow value was identified for each water year (October through September) and used to compute flood



LAKE STEVENS STAGE SITE E
5/18/97
FIGURE 6

frequency and flow duration. Flood frequency results for each scenario were computed using a Log Pearson Type III distribution (WRC Bulletin 17B procedure). Flood frequency results are presented below.

AQUA TERRA Consultants
Lake Stevens Flood Frequency
Date: 5/22/97
Engineer: Joe Brascher

Table 5

Forested Conditions

	Flood event in years						
	2	5	10	25	50	100	
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	
EBBU1.	4.2	5.7	6.7	8.1	9.2	10.3	
EBBU2.	3.8	5.6	7.0	9.0	10.6	12.3	
EBCA1.	8.6	11.4	13.4	15.9	17.8	19.8	
EBFI1.	1.0	1.4	1.6	1.9	2.1	2.3	
EBHU1.	16.8	22.5	26.4	31.5	35.5	39.5	
EBHU2.	9.8	13.4	15.8	19.2	21.8	24.5	
EBHU3.	6.9	10.6	13.4	17.6	21.2	25.1	
EBMO1.	22.9	29.1	33.2	38.3	42.0	45.7	
EBMO2.	14.9	18.8	21.4	24.5	26.9	29.2	
EBMO3.	7.7	10.1	11.6	13.4	14.8	16.2	
EBMO4.	3.0	4.2	5.1	6.2	7.1	8.1	
EBSE1.	6.4	8.8	10.5	12.8	14.6	16.5	
EBSE2.	1.2	1.8	2.2	2.8	3.3	3.9	
EBSU1.	23.5	32.3	38.4	46.6	52.9	59.4	
EBSU2.	3.7	5.0	5.8	6.8	7.6	8.3	
EBSU3.	3.4	4.7	5.7	6.8	7.7	8.6	
EBSU4.	19.9	30.5	38.8	50.8	61.0	72.3	
EBSU5.	3.1	4.7	6.0	7.9	9.4	11.2	
EBSU6.	12.7	19.5	24.9	32.8	39.4	46.9	
EBTH1.	2.7	4.0	5.0	6.4	7.5	8.7	
EBWE1.	15.5	21.2	25.1	30.3	34.3	38.5	
EBWE2.	1.1	1.4	1.7	2.1	2.4	2.7	
EBWE3.	14.4	20.6	25.2	31.5	36.5	41.9	
EBWE4.	3.8	6.0	7.7	10.3	12.5	14.9	
EBWE5.	10.7	16.0	19.9	25.6	30.2	35.2	
EBWE6.	5.9	8.2	9.9	12.1	13.8	15.6	
EBWE7.	2.6	3.7	4.5	5.6	6.5	7.4	
EBWE8.	1.5	2.3	3.0	4.0	4.8	5.7	
LABR1.	1.1	1.5	1.9	2.3	2.7	3.1	
LACE1.	4.8	6.3	7.4	8.7	9.8	10.8	
LAEAS1	1.1	1.7	2.2	2.8	3.3	3.9	
LAEA1.	0.8	1.1	1.2	1.5	1.6	1.8	
LAFO1.	1.3	1.8	2.1	2.6	2.9	3.3	– Kokanee
LAKO1.	5.2	6.9	8.1	9.6	10.7	11.9	
LAKO2.	5.3	7.6	9.3	11.6	13.4	15.2	
LAKO3.	0.7	1.0	1.1	1.3	1.5	1.7	
LALA1.	42.0	49.3	53.8	59.3	63.2	67.1	– outflow . [illegible]
LALO1.	4.4	6.3	7.6	9.3	10.7	12.2	
LALU1.	14.4	18.8	21.8	25.6	28.5	31.5	– LUNDEEN

Table 5

Forested Conditions

	Flood event in years						
	2	5	10	25	50	100	
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	
LALU2.	7.6	9.9	11.5	13.5	15.1	16.7	
LALU3.	3.6	5.1	6.3	7.8	9.1	10.4	
LALU4.	8.6	13.1	16.5	21.3	25.4	29.7	
LANW1.	1.0	1.4	1.6	2.0	2.3	2.7	
LASO1.	2.2	2.9	3.4	4.0	4.5	5.0	
LAST1.	20.2	26.2	30.2	35.3	39.0	42.9	– Steven Creek
LAST2.	15.6	20.5	23.6	27.6	30.6	33.5	
LAST3.	9.1	12.8	15.3	18.6	21.1	23.6	
LAST4.	7.4	9.7	11.3	13.2	14.8	16.3	
LASTI1	10.8	14.5	17.0	20.3	22.8	25.5	– Stitch
LASTI2	9.0	12.0	14.1	16.7	18.8	20.9	
LASTI3	9.3	12.7	15.1	18.3	20.7	23.3	
LASTI4	1.7	2.3	2.7	3.2	3.6	4.0	
LASTI5	7.5	10.7	13.1	16.4	19.0	21.8	
LAWE1.	0.3	0.5	0.7	0.9	1.1	1.3	
PICA1.	81.8	118.6	145.1	181.2	209.8	239.9	– upstream of Hartford
PICA2.	54.5	75.2	89.8	109.1	124.2	140.0	– upstream of 92
PICA3.	34.0	45.5	53.4	63.9	72.1	80.5	– Lake Cassidy outlet
PICA4.	146.6	196.2	229.8	273.3	306.4	340.3	– Catherine Confluence
PICE1.	28.8	38.8	45.7	54.8	61.7	68.9	
PICE2.	22.3	29.2	33.7	39.3	43.4	47.5	
PICE3.	15.1	20.0	23.3	27.4	30.5	33.6	
PICE4.	7.2	9.4	10.8	12.7	14.1	15.5	
PICE5.	2.5	3.3	3.8	4.4	4.9	5.4	
PIMA1.	26.6	36.5	43.4	52.5	59.6	66.8	
PIMA2.	20.4	28.9	34.8	42.7	48.8	55.2	
CAEA1.	5.0	7.5	9.3	11.8	13.7	15.8	
CAEA2.	6.2	8.7	10.5	12.9	14.8	16.8	
EBFL1.	57.2	88.0	109.8	138.7	161.1	184.2	
EBTR1.	0.9	1.2	1.4	1.7	1.9	2.1	
EBTR2.	1.0	1.3	1.5	1.8	2.0	2.2	
EBTR3.	2.6	3.4	4.0	4.8	5.4	6.0	
EBTR4.	2.7	3.6	4.2	5.0	5.6	6.2	
EBTR5.	2.3	3.1	3.6	4.3	4.8	5.4	
EBTR6.	1.9	2.6	3.1	3.7	4.2	4.7	
EBTR7.	1.8	2.8	3.5	4.6	5.5	6.4	
PILI2.	6.9	10.4	13.1	16.8	19.9	23.1	
PILI1.	10.2	15.5	19.1	23.5	26.8	30.1	
PIME1.	4.8	7.0	8.7	11.2	13.2	15.3	
LADR12	0.1	0.2	0.2	0.3	0.3	0.4	
LADR1.	4.6	6.2	7.5	9.1	10.4	11.7	
LADR10	0.1	0.2	0.2	0.3	0.3	0.4	
LADR11	3.3	4.6	5.5	6.7	7.6	8.6	
LADR14	0.2	0.3	0.4	0.6	0.7	0.8	

Table 5

Forested Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LADR2.	1.0	1.4	1.6	2.0	2.3	2.7
LADR3.	1.8	2.7	3.3	4.1	4.8	5.5
LADR4.	0.5	0.8	1.0	1.2	1.5	1.8
LADR5.	1.8	2.3	2.8	3.3	3.7	4.1
LADR6.	0.8	1.1	1.3	1.6	1.8	2.0
LADR7.	0.4	0.6	0.7	0.9	1.1	1.2
LADR8.	0.1	0.2	0.2	0.3	0.3	0.3
LADR9.	0.9	1.4	1.8	2.4	2.8	3.3
LADR13	0.2	0.3	0.4	0.5	0.6	0.7

AQUA TERRA Consultants
Lake Stevens Flood Frequency
Date: 5/22/97
Engineer: Joe Brascher

Table 6

Current Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
EBBU1.	9.9	13.8	16.5	20.1	22.9	25.8
EBBU2.	9.8	14.2	17.3	21.5	24.8	28.3
EBCA1.	24.6	34.9	42.2	51.9	59.6	67.7
EBFI1.	1.4	1.8	2.1	2.5	2.8	3.1
EBHU1.	37.8	51.5	61.1	73.7	83.4	93.5
EBHU2.	23.0	32.4	39.1	48.1	55.2	62.6
EBHU3.	21.6	32.1	39.9	50.8	59.5	68.9
EBMO1.	41.6	54.0	62.5	73.7	82.4	91.4
EBMO2.	27.5	35.4	40.9	48.2	53.9	59.8
EBMO3.	18.9	27.0	33.1	41.6	48.5	55.8
EBMO4.	11.6	16.5	20.1	24.8	28.5	32.4
EBSE1.	15.7	22.0	26.5	32.5	37.2	42.0
EBSE2.	2.6	3.7	4.5	5.7	6.6	7.6
EBSU1.	37.3	53.1	64.4	79.5	91.4	103.9
EBSU2.	5.8	7.4	8.5	9.8	10.8	11.8
EBSU3.	5.7	7.4	8.5	9.9	10.9	11.9
EBSU4.	34.8	53.7	68.4	89.5	107.2	126.6
EBSU5.	5.6	8.6	11.0	14.3	17.2	20.3
EBSU6.	21.8	33.7	42.9	56.1	67.2	79.3
EBTH1.	7.3	10.8	13.4	16.9	19.8	22.9
EBWE1.	46.7	60.7	69.8	81.1	89.5	97.8
EBWE2.	1.2	1.7	2.1	2.6	3.0	3.5
EBWE3.	54.7	79.9	98.2	123.1	143.0	164.0
EBWE4.	20.2	30.0	37.2	47.1	54.9	63.3
EBWE5.	44.5	65.0	79.6	99.4	115.0	131.3
EBWE6.	18.3	26.3	32.0	39.7	45.8	52.1
EBWE7.	7.0	10.6	13.3	17.2	20.4	23.8
EBWE8.	6.9	10.2	12.5	15.7	18.2	20.8
LABR1.	2.6	3.8	4.7	6.0	7.0	8.1
LACE1.	8.8	12.0	14.1	16.8	18.9	21.0
LAEAS1	4.5	6.7	8.2	10.3	12.0	13.7
LAEA1.	3.3	4.7	5.8	7.1	8.2	9.4
LAFO1.	3.0	4.1	4.8	5.8	6.5	7.3
LAKO1.	19.1	25.4	29.7	35.1	39.2	43.3
LAKO2.	19.1	25.9	30.6	36.8	41.7	46.6
LAKO3.	2.3	3.1	3.6	4.2	4.7	5.2
LALA1.	43.5	51.0	55.4	60.5	64.1	67.5
LALO1.	10.0	13.7	16.2	19.6	22.2	24.8
LALU1.	25.9	33.4	38.1	43.8	48.0	52.1

Table 6

Current Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LALU2.	11.4	15.5	18.3	22.1	24.9	27.9
LALU3.	6.2	9.0	11.0	13.7	15.9	18.2
LALU4.	15.1	21.9	26.8	33.5	39.0	44.7
LANW1.	3.3	4.7	5.8	7.2	8.4	9.6
LASO1.	3.7	5.0	5.8	6.9	7.7	8.5
LAST1.	33.2	41.8	47.2	53.8	58.6	63.3
LAST2.	26.6	32.4	35.8	39.8	42.6	45.2
LAST3.	18.5	23.0	25.8	29.3	31.8	34.3
LAST4.	11.3	15.0	17.5	20.8	23.3	25.8
LASTI1	21.0	26.5	30.1	34.5	37.7	40.8
LASTI2	19.4	25.9	30.4	36.4	41.0	45.8
LASTI3	28.6	41.9	51.6	64.8	75.3	86.4
LASTI4	4.5	6.4	7.7	9.6	11.1	12.7
LASTI5	25.9	38.3	47.3	59.5	69.1	79.2
LAWE1.	1.7	2.5	3.1	3.9	4.5	5.2
PICA1.	122.8	172.3	207.3	254.0	290.6	328.8
PICA2.	64.0	88.7	106.0	128.9	146.6	164.9
PICA3.	38.7	51.1	59.9	71.7	80.9	90.6
PICA4.	218.4	291.6	341.1	404.9	453.3	502.7
PICE1.	51.4	68.5	80.2	95.5	107.2	119.3
PICE2.	44.6	60.6	71.7	86.2	97.5	109.1
PICE3.	23.2	29.8	34.3	40.2	44.8	49.4
PICE4.	17.2	21.8	24.8	28.5	31.3	34.0
PICE5.	8.8	11.0	12.3	13.9	14.9	15.9
PIMA1.	45.1	62.4	74.7	91.1	103.9	117.4
PIMA2.	35.8	48.9	58.2	70.5	80.2	90.4
CAEA1.	19.4	28.3	34.8	43.5	50.3	57.5
CAEA2.	13.2	18.7	22.8	28.4	32.9	37.8
EBFL1.	67.8	101.0	123.3	151.6	172.6	193.6
EBTR1.	2.2	3.1	3.8	4.6	5.3	6.0
EBTR2.	2.9	4.2	5.1	6.5	7.5	8.7
EBTR3.	5.7	8.4	10.3	13.1	15.3	17.7
EBTR4.	4.6	6.7	8.1	10.1	11.7	13.4
EBTR5.	3.1	4.3	5.1	6.1	6.9	7.8
EBTR6.	2.6	3.8	4.5	5.6	6.5	7.3
EBTR7.	4.9	7.3	9.0	11.3	13.2	15.2
PILI2.	15.8	22.3	26.9	33.0	37.8	42.7
PILI1.	12.5	18.1	22.0	27.1	31.0	35.0
PIME1.	6.6	10.0	12.7	16.6	19.9	23.5
LADR12	0.6	0.8	1.0	1.3	1.5	1.8
LADR1.	17.2	25.4	31.4	39.7	46.4	53.5
LADR10	0.6	0.9	1.1	1.4	1.6	1.9
LADR11	12.4	18.2	22.4	28.2	32.8	37.7
LADR14	1.0	1.5	1.9	2.4	2.8	3.3

Table 6

Current Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LADR2.	4.6	6.8	8.4	10.6	12.4	14.3
LADR3.	6.2	9.0	11.0	13.7	15.8	18.0
LADR4.	2.3	3.5	4.3	5.4	6.3	7.2
LADR5.	6.2	9.1	11.2	14.0	16.3	18.7
LADR6.	1.6	2.3	2.8	3.5	4.1	4.7
LADR7.	1.1	1.6	1.9	2.3	2.7	3.0
LADR8.	0.2	0.3	0.3	0.4	0.4	0.5
LADR9.	4.0	6.0	7.3	9.2	10.7	12.2
LADR13	1.1	1.6	2.0	2.5	2.9	3.4

AQUA TERRA Consultants
Lake Stevens Flood Frequency
Date: 5/22/97
Engineer: Joe Brascher

Table 7

Future Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
EBBU1.	16.4	21.9	25.4	29.7	32.8	35.8
EBBU2.	17.1	23.8	28.3	34.0	38.3	42.6
EBCA1.	38.1	53.8	65.0	80.1	92.1	104.7
EBFI1.	8.2	11.2	13.3	16.2	18.4	20.8
EBHU1.	56.8	81.3	99.2	123.7	143.3	164.1
EBHU2.	35.8	51.8	63.3	79.0	91.5	104.6
EBHU3.	33.5	50.8	63.7	81.5	95.8	111.1
EBMO1.	52.3	67.9	78.7	92.6	103.4	114.4
EBMO2.	34.2	44.6	51.8	61.2	68.5	76.0
EBMO3.	29.4	42.9	52.8	66.5	77.6	89.3
EBMO4.	15.5	22.5	27.7	35.0	41.0	47.4
EBSE1.	40.9	58.3	71.1	88.7	102.8	117.9
EBSE2.	8.8	12.5	15.1	18.7	21.6	24.7
EBSU1.	82.1	117.1	141.8	174.6	200.3	226.9
EBSU2.	11.0	14.5	16.9	20.0	22.4	24.8
EBSU3.	9.0	11.7	13.5	15.7	17.4	19.2
EBSU4.	93.1	143.5	181.5	234.7	278.0	324.6
EBSU5.	17.7	27.3	34.6	44.8	53.1	62.1
EBSU6.	54.8	84.1	106.1	136.8	161.7	188.5
EBTH1.	12.6	18.6	23.0	28.9	33.5	38.5
EBWE1.	69.6	90.9	105.2	123.7	137.7	152.0
EBWE2.	3.5	5.0	6.2	7.7	8.9	10.2
EBWE3.	88.5	124.2	149.1	181.8	207.1	233.2
EBWE4.	27.4	40.9	51.0	64.8	76.0	88.0
EBWE5.	76.3	105.2	125.0	150.7	170.4	190.6
EBWE6.	31.3	37.9	41.4	45.0	47.2	49.2
EBWE7.	14.4	21.7	27.1	34.5	40.5	46.9
EBWE8.	10.8	15.3	18.4	22.4	25.4	28.5
LABR1.	5.4	8.2	10.3	13.2	15.6	18.2
LACE1.	13.6	18.1	21.0	24.5	27.2	29.8
LAEAS1	5.5	8.1	10.0	12.6	14.7	16.8
LAEA1.	3.9	5.6	6.8	8.5	9.9	11.3
LAFO1.	4.3	5.8	6.9	8.3	9.4	10.5
LAKO1.	20.3	27.1	31.6	37.4	41.7	46.1
LAKO2.	20.3	27.7	32.9	39.7	45.0	50.5
LAKO3.	2.4	3.2	3.6	4.3	4.8	5.2
LALA1.	44.4	51.9	56.3	61.6	65.2	68.7
LALO1.	13.2	18.2	21.6	26.2	29.7	33.3
LALU1.	35.3	42.7	47.1	52.0	55.4	58.6

Table 7

Future Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LALU2.	14.7	20.6	24.8	30.5	35.0	39.8
LALU3.	15.5	22.2	26.8	33.0	37.8	42.7
LALU4.	18.0	25.7	31.2	38.8	44.9	51.3
LANW1.	4.2	6.1	7.5	9.5	11.0	12.6
LASO1.	7.2	9.8	11.6	13.9	15.7	17.5
LAST1.	47.8	61.8	71.0	82.5	91.1	99.7
LAST2.	30.3	35.9	39.1	42.7	45.2	47.6
LAST3.	19.3	24.0	26.9	30.6	33.2	35.9
LAST4.	13.0	17.3	20.3	24.3	27.4	30.5
LASTI1	32.5	38.4	42.2	46.8	50.2	53.6
LASTI2	38.1	53.9	65.3	80.9	93.3	106.3
LASTI3	57.7	82.3	99.8	123.3	141.8	161.1
LASTI4	12.8	18.8	23.3	29.5	34.6	40.1
LASTI5	50.3	70.3	84.0	102.0	115.8	129.9
LAWE1.	1.8	2.7	3.4	4.3	5.0	5.7
PICA1.	172.7	238.6	284.2	343.9	389.8	437.1
PICA2.	73.8	100.2	118.8	143.4	162.6	182.6
PICA3.	45.3	59.5	69.6	82.9	93.4	104.4
PICA4.	290.4	388.2	455.1	542.3	609.2	677.9
PICE1.	65.9	87.4	102.1	121.1	135.6	150.5
PICE2.	60.7	82.6	97.6	117.2	132.1	147.5
PICE3.	31.3	39.2	44.4	51.0	56.0	61.0
PICE4.	24.8	29.0	31.2	33.5	35.0	36.3
PICE5.	11.3	13.2	14.1	15.2	15.9	16.5
PIMA1.	68.1	95.8	115.5	141.7	162.3	183.7
PIMA2.	46.6	64.2	76.5	92.9	105.7	118.9
CAEA1.	23.0	33.3	40.7	50.6	58.5	66.7
CAEA2.	23.2	34.4	42.5	53.7	62.6	72.1
EBFL1.	71.9	105.4	128.0	156.7	178.2	199.7
EBTR1.	6.6	9.2	11.1	13.8	15.9	18.1
EBTR2.	4.9	7.2	8.9	11.3	13.2	15.2
EBTR3.	11.0	16.4	20.4	26.0	30.6	35.6
EBTR4.	7.5	10.7	13.0	16.1	18.5	21.1
EBTR5.	4.5	6.3	7.6	9.4	10.8	12.3
EBTR6.	3.2	4.5	5.5	6.9	8.0	9.1
EBTR7.	9.8	14.4	17.8	22.4	26.0	29.8
PILI2.	41.5	57.5	68.8	84.2	96.4	109.1
PILI1.	15.2	21.0	25.0	30.2	34.2	38.3
PIME1.	7.5	11.4	14.3	18.5	22.0	25.7
LADR12	0.6	0.8	1.0	1.3	1.5	1.8
LADR1.	19.5	29.1	36.2	46.0	53.9	62.4
LADR10	0.6	0.9	1.1	1.4	1.6	1.9
LADR11	17.4	25.3	31.1	39.1	45.5	52.3
LADR14	1.2	1.7	2.1	2.7	3.1	3.6

Table 7

Future Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LADR2.	4.9	7.3	9.0	11.4	13.3	15.3
LADR3.	7.5	10.8	13.1	16.3	18.7	21.3
LADR4.	2.6	3.8	4.7	5.9	6.9	7.9
LADR5.	7.6	11.2	13.8	17.4	20.2	23.3
LADR6.	3.1	4.6	5.7	7.2	8.4	9.7
LADR7.	1.1	1.6	1.9	2.3	2.7	3.0
LADR8.	0.2	0.3	0.3	0.4	0.4	0.5
LADR9.	4.7	6.8	8.4	10.5	12.2	14.0
LADR13	1.1	1.6	2.0	2.5	2.9	3.4

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AQUA TERRA Consultants
Lake Stevens Flood Frequency
Date: 10/3/97
Engineer: Joe Brascher

Forested, Current, Future and Future Mitigated Conditions

Location	100 Year Forest (cfs)	Current (cfs)	Future (cfs)	Future Mit (cfs)	Future Mit-Current (cfs)	Percent Increase	Future - Current (cfs)	Percent Increase	Current - Forest (cfs)	Percent Increase
EBBU1.	10.3	25.8	35.8	28.8	3.0	11.6%	10.0	39%	15.5	150%
EBBU2.	12.3	28.3	42.6	29.9	1.6	5.7%	14.3	51%	16.0	130%
EBCA1.	19.8	67.7	105.0	75.7	8.0	11.8%	37.3	55%	47.9	242%
EBFI1.	2.3	3.1	20.8	10.7	7.6	245.2%	17.7	571%	0.8	35%
EBHU1.	39.5	93.5	164.8	97.0	3.5	3.7%	71.3	76%	54.0	137%
EBHU2.	24.5	62.6	104.7	61.6	-1.0	-1.6%	42.1	67%	38.1	156%
EBHU3.	25.1	68.9	111.6	68.8	-0.1	-0.1%	42.7	62%	43.8	175%
EBMO1.	45.7	91.4	114.1	102.7	11.3	12.4%	22.7	25%	45.7	100%
EBMO2.	29.2	59.8	73.8	66.6	6.8	11.4%	14.0	23%	30.6	105%
EBMO3.	16.2	55.8	84.2	60.7	4.9	8.8%	28.4	51%	39.6	244%
EBMO4.	8.1	32.4	37.7	33.3	0.9	2.8%	5.3	16%	24.3	300%
EBSE1.	16.5	42.0	113.5	48.3	6.3	15.0%	71.5	170%	25.5	155%
EBSE2.	3.9	7.6	24.5	9.8	2.2	28.9%	16.9	222%	3.7	95%
EBSU1.	59.4	103.9	227.5	150.8	46.9	45.1%	123.6	119%	44.5	75%
EBSU2.	8.3	11.8	24.8	19.6	7.8	66.1%	13.0	110%	3.5	42%
EBSU3.	8.6	11.9	19.2	16.7	4.8	40.3%	7.3	61%	3.3	38%
EBSU4.	72.3	126.6	325.5	148.1	21.5	17.0%	198.9	157%	54.3	75%
EBSU5.	11.2	20.3	62.1	24.0	3.7	18.2%	41.8	206%	9.1	81%
EBSU6.	46.9	79.3	189.3	82.2	2.9	3.7%	110.0	139%	32.4	69%
EBTH1.	8.7	22.9	38.5	23.4	0.5	2.2%	15.6	68%	14.2	163%
EBWE1.	38.5	97.8	151.1	109.7	11.9	12.2%	53.3	54%	59.3	154%
EBWE2.	2.7	3.5	10.2	5.4	1.9	54.3%	6.7	191%	0.8	30%
EBWE3.	41.9	164.0	233.7	166.7	2.7	1.6%	69.7	43%	122.1	291%
EBWE4.	14.9	63.3	87.5	64.9	1.6	2.5%	24.2	38%	48.4	325%
EBWE5.	35.2	131.3	190.5	131.9	0.6	0.5%	59.2	45%	96.1	273%
EBWE6.	15.6	52.1	50.5	52.1	0.0	0.0%	-1.6	-3%	36.5	234%
EBWE7.	7.4	23.8	42.9	26.5	2.7	11.3%	19.1	80%	16.4	222%
EBWE8.	5.7	20.8	27.5	21.1	0.3	1.4%	6.7	32%	15.1	265%
LABR1.	3.1	8.1	18.2	13.8	5.7	70.4%	10.1	125%	5.0	161%
LACE1.	10.8	21.0	29.8	24.1	3.1	14.8%	8.8	42%	10.2	94%
LAEAS1	3.9	13.7	16.8	15.0	1.3	9.5%	3.1	23%	9.8	251%
LAEA1.	1.8	9.4	11.2	9.4	0.0	0.0%	1.8	19%	7.6	422%
LAFO1.	3.3	7.3	10.5	8.7	1.4	19.2%	3.2	44%	4.0	121%
LAKO1.	11.9	43.3	46.1	47.1	3.8	8.8%	2.8	6%	31.4	264%
LAKO2.	15.2	46.6	50.4	55.2	8.6	18.5%	3.8	8%	31.4	207%
LAKO3.	1.7	5.2	5.3	5.1	-0.1	-1.9%	0.1	2%	3.5	206%
LALA1.	67.1	67.5	68.6	68.3	0.8	1.2%	1.1	2%	0.4	1%
LALO1.	12.2	24.8	33.3	26.7	1.9	7.7%	8.5	34%	12.6	103%
LALU1.	31.5	52.1	58.9	55.7	3.6	6.9%	6.8	13%	20.6	65%
LALU2.	16.7	27.9	40.7	35.3	7.4	26.5%	12.8	46%	11.2	67%
LALU3.	10.4	18.2	42.6	29.2	11.0	60.4%	24.4	134%	7.8	75%

LALU4.	29.7	44.7	53.3	53.3	8.6	19.2%	8.6	19%	15.0	51%
LANW1.	2.7	9.6	12.6	9.9	0.3	3.1%	3.0	31%	6.9	256%
LASO1.	5.0	8.5	17.5	10.1	1.6	18.8%	9.0	106%	3.5	70%
LAST1.	42.9	63.3	99.7	81.2	17.9	28.3%	36.4	58%	20.4	48%
LAST2.	33.5	45.2	47.9	47.7	2.5	5.5%	2.7	6%	11.7	35%
LAST3.	23.6	34.3	36.1	36.1	1.8	5.2%	1.8	5%	10.7	45%
LAST4.	16.3	25.8	31.4	30.8	5.0	19.4%	5.6	22%	9.5	58%
LASTI1	25.5	40.8	52.0	46.8	6.0	14.7%	11.2	27%	15.3	60%
LASTI2	20.9	45.8	100.4	59.1	13.3	29.0%	54.6	119%	24.9	119%
LASTI3	23.3	86.4	154.3	94.7	8.3	9.6%	67.9	79%	63.1	271%
LASTI4	4.0	12.7	39.6	17.2	4.5	35.4%	26.9	212%	8.7	218%
LASTI5	21.8	79.2	122.9	82.4	3.2	4.0%	43.7	55%	57.4	263%
LAWE1.	1.3	5.2	5.7	4.7	-0.5	-9.6%	0.5	10%	3.9	300%
PICA1.	239.9	328.8	440.7	348.9	20.1	6.1%	111.9	34%	88.9	37%
PICA2.	140.0	164.9	185.2	183.0	18.1	11.0%	20.3	12%	24.9	18%
PICA3.	80.5	90.6	105.6	103.8	13.2	14.6%	15.0	17%	10.1	13%
PICA4.	340.3	502.7	673.0	526.0	23.3	4.6%	170.3	34%	162.4	48%
PICE1.	68.9	119.3	151.8	130.2	10.9	9.1%	32.5	27%	50.4	73%
PICE2.	47.5	109.1	148.3	120.3	11.2	10.3%	39.2	36%	61.6	130%
PICE3.	33.6	49.4	60.6	57.0	7.6	15.4%	11.2	23%	15.8	47%
PICE4.	15.5	34.0	36.8	35.9	1.9	5.6%	2.8	8%	18.5	119%
PICE5.	5.4	15.9	16.4	16.2	0.3	1.9%	0.5	3%	10.5	194%
PIMA1.	66.8	117.4	185.6	132.7	15.3	13.0%	68.2	58%	50.6	76%
PIMA2.	55.2	90.4	120.9	103.3	12.9	14.3%	30.5	34%	35.2	64%
CAEA1.	15.8	57.5	62.9	58.6	1.1	1.9%	5.4	9%	41.7	264%
CAEA2.	16.8	37.8	71.9	50.2	12.4	32.8%	34.1	90%	21.0	125%
EBFL1.	184.2	193.6	199.7	195.2	1.6	0.8%	6.1	3%	9.4	5%
EBTR1.	2.1	6.0	18.1	6.6	0.6	10.0%	12.1	202%	3.9	186%
EBTR2.	2.2	8.7	15.2	8.7	0.0	0.0%	6.5	75%	6.5	295%
EBTR3.	6.0	17.7	35.6	22.6	4.9	27.7%	17.9	101%	11.7	195%
EBTR4.	6.2	13.4	21.0	14.5	1.1	8.2%	7.6	57%	7.2	116%
EBTR5.	5.4	7.8	12.4	9.7	1.9	24.4%	4.6	59%	2.4	44%
EBTR6.	4.7	7.3	9.5	9.5	2.2	30.1%	2.2	30%	2.6	55%
EBTR7.	6.4	15.2	29.8	23.2	8.0	52.6%	14.6	96%	8.8	138%
PILI2.	23.1	42.7	108.9	47.6	4.9	11.5%	66.2	155%	19.6	85%
PILI1.	30.1	35.0	38.5	35.6	0.6	1.7%	3.5	10%	4.9	16%
PIME1.	15.3	23.5	26.0	24.9	1.4	6.0%	2.5	11%	8.2	54%
LADR12	0.4	1.8	1.8	1.8	0.0	0.0%	0.0	0%	1.4	350%
LADR1.	11.7	53.5	62.4	55.4	1.9	3.6%	8.9	17%	41.8	357%
LADR10	0.4	1.9	1.9	1.9	0.0	0.0%	0.0	0%	1.5	375%
LADR11	8.6	37.7	50.5	38.7	1.0	2.7%	12.8	34%	29.1	338%
LADR14	0.8	3.3	3.6	2.3	-1.0	-30.3%	0.3	9%	2.5	313%
LADR2.	2.7	14.3	15.2	14.3	0.0	0.0%	0.9	6%	11.6	430%
LADR3.	5.5	18.0	20.3	18.9	0.9	5.0%	2.3	13%	12.5	227%
LADR4.	1.8	7.2	7.9	7.1	-0.1	-1.4%	0.7	10%	5.4	300%
LADR5.	4.1	18.7	23.3	18.6	-0.1	-0.5%	4.6	25%	14.6	356%
LADR6.	2.0	4.7	9.7	4.8	0.1	2.1%	5.0	106%	2.7	135%
LADR7.	1.2	3.0	3.0	3.0	0.0	0.0%	0.0	0%	1.8	150%
LADR8.	0.3	0.5	0.5	0.5	0.0	0.0%	0.0	0%	0.2	67%
LADR9.	3.3	12.2	14.0	12.6	0.4	3.3%	1.8	15%	8.9	270%
LADR13	0.7	3.4	3.3	5.4	2.0	58.8%	-0.1	-3%	2.7	386%

AQUA TERRA Consultants
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Table 8

Future Mitigated Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
EBBU1.	10.9	15.3	18.3	22.4	25.6	28.8
EBBU2.	10.7	15.4	18.6	23.0	26.4	29.9
EBCA1.	27.7	39.0	47.2	58.1	66.7	75.7
EBFI1.	3.4	5.1	6.4	8.1	9.4	10.7
EBHU1.	38.2	52.8	62.9	76.2	86.4	97.0
EBHU2.	22.2	31.5	38.2	47.1	54.2	61.6
EBHU3.	22.3	33.1	40.9	51.6	60.0	68.8
EBMO1.	45.3	59.2	69.0	82.0	92.1	102.7
EBMO2.	29.4	38.3	44.6	53.0	59.6	66.6
EBMO3.	20.6	29.6	36.2	45.4	52.8	60.7
EBMO4.	11.8	16.9	20.5	25.4	29.2	33.3
EBSE1.	18.2	25.3	30.4	37.3	42.7	48.3
EBSE2.	3.3	4.8	5.9	7.4	8.5	9.8
EBSU1.	50.5	74.3	91.3	114.1	132.1	150.8
EBSU2.	8.1	11.1	13.2	15.7	17.7	19.6
EBSU3.	7.2	9.7	11.3	13.5	15.1	16.7
EBSU4.	45.4	68.8	86.0	109.5	128.3	148.1
EBSU5.	7.3	11.1	13.8	17.7	20.7	24.0
EBSU6.	26.9	39.8	49.1	61.8	71.7	82.2
EBTH1.	8.0	11.7	14.3	17.8	20.6	23.4
EBWE1.	51.3	67.1	77.4	90.4	100.1	109.7
EBWE2.	2.0	2.9	3.5	4.2	4.8	5.4
EBWE3.	60.0	85.7	103.9	128.1	147.0	166.7
EBWE4.	21.1	31.0	38.3	48.3	56.4	64.9
EBWE5.	48.8	69.0	83.2	102.0	116.7	131.9
EBWE6.	20.4	28.5	34.0	41.2	46.6	52.1
EBWE7.	8.6	12.9	15.9	20.0	23.2	26.5
EBWE8.	7.2	10.4	12.8	15.9	18.4	21.1
LABR1.	4.6	6.6	8.2	10.2	11.9	13.8
LACE1.	9.8	13.3	15.8	19.0	21.5	24.1
LAEAS1	4.8	7.2	8.9	11.2	13.1	15.0
LAEA1.	3.4	4.8	5.8	7.2	8.3	9.4
LAFO1.	3.4	4.7	5.6	6.8	7.7	8.7
LAKO1.	19.5	26.5	31.3	37.5	42.2	47.1
LAKO2.	19.5	27.5	33.4	41.5	48.2	55.2
LAKO3.	2.4	3.1	3.6	4.2	4.7	5.1
LALA1.	44.1	51.6	56.0	61.3	64.9	68.3
LALO1.	10.6	14.5	17.2	20.9	23.7	26.7
LALU1.	28.8	36.9	41.8	47.6	51.7	55.7

LALU2.	13.4	18.6	22.3	27.3	31.2	35.3
LALU3.	9.7	14.5	17.9	22.3	25.7	29.2
LALU4.	18.3	26.3	32.1	40.1	46.5	53.3
LANW1.	3.4	5.0	6.1	7.6	8.7	9.9
LASO1.	3.7	5.1	6.2	7.6	8.8	10.1
LAST1.	39.3	50.8	58.3	67.6	74.4	81.2
LAST2.	29.3	35.1	38.5	42.5	45.2	47.7
LAST3.	19.4	24.1	27.1	30.8	33.5	36.1
LAST4.	12.9	17.4	20.4	24.4	27.5	30.8
LASTI1	24.2	30.6	34.6	39.6	43.2	46.8
LASTI2	21.6	30.0	36.1	44.7	51.6	59.1
LASTI3	31.7	46.3	56.8	71.2	82.6	94.7
LASTI4	5.7	8.3	10.2	12.8	14.9	17.2
LASTI5	28.5	41.4	50.6	62.8	72.4	82.4
LAWE1.	1.6	2.3	2.9	3.6	4.1	4.7
PICA1.	139.2	190.8	226.7	274.1	310.9	348.9
PICA2.	71.4	98.0	116.9	142.2	162.2	183.0
PICA3.	42.5	56.7	66.9	80.8	92.0	103.8
PICA4.	236.4	311.3	361.8	426.7	475.9	526.0
PICE1.	57.0	75.8	88.5	105.0	117.5	130.2
PICE2.	48.9	66.7	79.0	95.1	107.6	120.3
PICE3.	25.0	32.8	38.2	45.4	51.1	57.0
PICE4.	18.7	23.5	26.6	30.4	33.2	35.9
PICE5.	9.2	11.4	12.7	14.2	15.2	16.2
PIMA1.	50.9	70.4	84.3	102.8	117.4	132.7
PIMA2.	41.0	56.1	66.7	80.8	91.8	103.3
CAEA1.	19.9	29.0	35.5	44.3	51.3	58.6
CAEA2.	15.5	22.9	28.5	36.4	43.0	50.2
EBFL1.	68.1	101.3	123.7	152.3	173.7	195.2
EBTR1.	2.6	3.6	4.3	5.2	5.9	6.6
EBTR2.	3.2	4.5	5.4	6.7	7.7	8.7
EBTR3.	7.3	10.9	13.4	16.9	19.7	22.6
EBTR4.	5.2	7.4	8.9	11.0	12.7	14.5
EBTR5.	3.8	5.2	6.2	7.6	8.6	9.7
EBTR6.	3.2	4.6	5.7	7.1	8.3	9.5
EBTR7.	7.0	10.8	13.5	17.2	20.2	23.2
PILI2.	19.2	26.2	31.1	37.5	42.5	47.6
PILI1.	13.2	18.7	22.5	27.6	31.5	35.6
PIME1.	7.1	10.9	13.7	17.8	21.2	24.9
LADR12	0.6	0.8	1.0	1.3	1.5	1.8
LADR1.	17.7	26.2	32.5	41.1	48.1	55.4
LADR10	0.6	0.9	1.1	1.4	1.6	1.9
LADR11	12.8	18.7	23.1	29.0	33.7	38.7
LADR14	0.8	1.1	1.4	1.7	2.0	2.3
LADR2.	4.6	6.8	8.4	10.6	12.4	14.3
LADR3.	6.4	9.3	11.3	14.2	16.5	18.9
LADR4.	2.3	3.4	4.2	5.3	6.2	7.1
LADR5.	6.3	9.1	11.2	14.0	16.2	18.6
LADR6.	1.8	2.5	3.0	3.7	4.2	4.8
LADR7.	1.1	1.6	1.9	2.3	2.6	3.0
LADR8.	0.2	0.3	0.3	0.4	0.4	0.5

LADR9.	4.0	6.0	7.4	9.4	10.9	12.6
LADR13	1.7	2.6	3.2	4.1	4.7	5.4

AQUA TERRA Consultants
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Forested, Current and Future Conditions

Location	Forest (cfs)	100 Year Current (cfs)	Future (cfs)	Future - Current (cfs)	Percent increase	Current - Forest (cfs)	Percent Increase
EBBU1.	10.3	25.8	35.8	10.0	39%	15.5	150%
EBBU2.	12.3	28.3	42.6	14.3	51%	16.0	130%
EBCA1.	19.8	67.7	105.0	37.3	55%	47.9	242%
EBFI1.	2.3	3.1	20.8	17.7	571%	0.8	35%
EBHU1.	39.5	93.5	164.8	71.3	76%	54.0	137%
EBHU2.	24.5	62.6	104.7	42.1	67%	38.1	156%
EBHU3.	25.1	68.9	111.6	42.7	62%	43.8	175%
EBMO1.	45.7	91.4	114.1	22.7	25%	45.7	100%
EBMO2.	29.2	59.8	73.8	14.0	23%	30.6	105%
EBMO3.	16.2	55.8	84.2	28.4	51%	39.6	244%
EBMO4.	8.1	32.4	37.7	5.3	16%	24.3	300%
EBSE1.	16.5	42.0	113.5	71.5	170%	25.5	155%
EBSE2.	3.9	7.6	24.5	16.9	222%	3.7	95%
EBSU1.	59.4	103.9	227.5	123.6	119%	44.5	75%
EBSU2.	8.3	11.8	24.8	13.0	110%	3.5	42%
EBSU3.	8.6	11.9	19.2	7.3	61%	3.3	38%
EBSU4.	72.3	126.6	325.5	198.9	157%	54.3	75%
EBSU5.	11.2	20.3	62.1	41.8	206%	9.1	81%
EBSU6.	46.9	79.3	189.3	110.0	139%	32.4	69%
EBTH1.	8.7	22.9	38.5	15.6	68%	14.2	163%
EBWE1.	38.5	97.8	151.1	53.3	54%	59.3	154%
EBWE2.	2.7	3.5	10.2	6.7	191%	0.8	30%
EBWE3.	41.9	164.0	233.7	69.7	43%	122.1	291%
EBWE4.	14.9	63.3	87.5	24.2	38%	48.4	325%
EBWE5.	35.2	131.3	190.5	59.2	45%	96.1	273%
EBWE6.	15.6	52.1	50.5	-1.6	-3%	36.5	234%
EBWE7.	7.4	23.8	42.9	19.1	80%	16.4	222%
EBWE8.	5.7	20.8	27.5	6.7	32%	15.1	265%
LABR1.	3.1	8.1	18.2	10.1	125%	5.0	161%
LACE1.	10.8	21.0	29.8	8.8	42%	10.2	94%
LAEAS1	3.9	13.7	16.8	3.1	23%	9.8	251%
LAEA1.	1.8	9.4	11.2	1.8	19%	7.6	422%
LAFO1.	3.3	7.3	10.5	3.2	44%	4.0	121%
LAKO1.	11.9	43.3	46.1	2.8	6%	31.4	264%
LAKO2.	15.2	46.6	50.4	3.8	8%	31.4	207%
LAKO3.	1.7	5.2	5.3	0.1	2%	3.5	206%
LALA1.	67.1	67.5	68.6	1.1	2%	0.4	1%
LALO1.	12.2	24.8	33.3	8.5	34%	12.6	103%
LALU1.	31.5	52.1	58.9	6.8	13%	20.6	65%
LALU2.	16.7	27.9	40.7	12.8	46%	11.2	67%
LALU3.	10.4	18.2	42.6	24.4	134%	7.8	75%

LALU4.	29.7	44.7	53.3	8.6	19%	15.0	51%
LANW1.	2.7	9.6	12.6	3.0	31%	6.9	256%
LASO1.	5.0	8.5	17.5	9.0	106%	3.5	70%
LAST1.	42.9	63.3	99.7	36.4	58%	20.4	48%
LAST2.	33.5	45.2	47.9	2.7	6%	11.7	35%
LAST3.	23.6	34.3	36.1	1.8	5%	10.7	45%
LAST4.	16.3	25.8	31.4	5.6	22%	9.5	58%
LASTI1	25.5	40.8	52.0	11.2	27%	15.3	60%
LASTI2	20.9	45.8	100.4	54.6	119%	24.9	119%
LASTI3	23.3	86.4	154.3	67.9	79%	63.1	271%
LASTI4	4.0	12.7	39.6	26.9	212%	8.7	218%
LASTI5	21.8	79.2	122.9	43.7	55%	57.4	263%
LAWE1.	1.3	5.2	5.7	0.5	10%	3.9	300%
PICA1.	239.9	328.8	440.7	111.9	34%	88.9	37%
PICA2.	140.0	164.9	185.2	20.3	12%	24.9	18%
PICA3.	80.5	90.6	105.6	15.0	17%	10.1	13%
PICA4.	340.3	502.7	673.0	170.3	34%	162.4	48%
PICE1.	68.9	119.3	151.8	32.5	27%	50.4	73%
PICE2.	47.5	109.1	148.3	39.2	36%	61.6	130%
PICE3.	33.6	49.4	60.6	11.2	23%	15.8	47%
PICE4.	15.5	34.0	36.8	2.8	8%	18.5	119%
PICE5.	5.4	15.9	16.4	0.5	3%	10.5	194%
PIMA1.	66.8	117.4	185.6	68.2	58%	50.6	76%
PIMA2.	55.2	90.4	120.9	30.5	34%	35.2	64%
CAEA1.	15.8	57.5	62.9	5.4	9%	41.7	264%
CAEA2.	16.8	37.8	71.9	34.1	90%	21.0	125%
EBFL1.	184.2	193.6	199.7	6.1	3%	9.4	5%
EBTR1.	2.1	6.0	18.1	12.1	202%	3.9	186%
EBTR2.	2.2	8.7	15.2	6.5	75%	6.5	295%
EBTR3.	6.0	17.7	35.6	17.9	101%	11.7	195%
EBTR4.	6.2	13.4	21.0	7.6	57%	7.2	116%
EBTR5.	5.4	7.8	12.4	4.6	59%	2.4	44%
EBTR6.	4.7	7.3	9.5	2.2	30%	2.6	55%
EBTR7.	6.4	15.2	29.8	14.6	96%	8.8	138%
PILI2.	23.1	42.7	108.9	66.2	155%	19.6	85%
PILI1.	30.1	35.0	38.5	3.5	10%	4.9	16%
PIME1.	15.3	23.5	26.0	2.5	11%	8.2	54%
LADR12	0.4	1.8	1.8	0.0	0%	1.4	350%
LADR1.	11.7	53.5	62.4	8.9	17%	41.8	357%
LADR10	0.4	1.9	1.9	0.0	0%	1.5	375%
LADR11	8.6	37.7	50.5	12.8	34%	29.1	338%
LADR14	0.8	3.3	3.6	0.3	9%	2.5	313%
LADR2.	2.7	14.3	15.2	0.9	6%	11.6	430%
LADR3.	5.5	18.0	20.3	2.3	13%	12.5	227%
LADR4.	1.8	7.2	7.9	0.7	10%	5.4	300%
LADR5.	4.1	18.7	23.3	4.6	25%	14.6	356%
LADR6.	2.0	4.7	9.7	5.0	106%	2.7	135%
LADR7.	1.2	3.0	3.0	0.0	0%	1.8	150%
LADR8.	0.3	0.5	0.5	0.0	0%	0.2	67%
LADR9.	3.3	12.2	14.0	1.8	15%	8.9	270%
LADR13	0.7	3.4	3.3	-0.1	-3%	2.7	386%

AQUA TERRA Consultants
Lake Stevens Flood Frequency
Date: 10/3/97
Engineer: Joe Brascher

Table 5

Forested Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
EBBU1.	4.2	5.7	6.7	8.1	9.2	10.3
EBBU2.	3.8	5.6	7.0	9.0	10.6	12.3
EBCA1.	8.6	11.4	13.4	15.9	17.8	19.8
EBFI1.	1.0	1.4	1.6	1.9	2.1	2.3
EBHU1.	16.8	22.5	26.4	31.5	35.5	39.5
EBHU2.	9.8	13.4	15.8	19.2	21.8	24.5
EBHU3.	6.9	10.6	13.4	17.6	21.2	25.1
EBMO1.	22.9	29.1	33.2	38.3	42.0	45.7
EBMO2.	14.9	18.8	21.4	24.5	26.9	29.2
EBMO3.	7.7	10.1	11.6	13.4	14.8	16.2
EBMO4.	3.0	4.2	5.1	6.2	7.1	8.1
EBSE1.	6.4	8.3	10.5	12.8	14.6	16.5
EBSE2.	1.2	1.8	2.2	2.8	3.3	3.9
EBSU1.	23.5	32.3	38.4	46.6	52.9	59.4
EBSU2.	3.7	5.0	5.8	6.8	7.6	8.3
EBSU3.	3.4	4.7	5.7	6.8	7.7	8.6
EBSU4.	19.9	30.5	38.8	50.8	61.0	72.3
EBSU5.	3.1	4.7	6.0	7.9	9.4	11.2
EBSU6.	12.7	19.5	24.9	32.8	39.4	46.9
EBTH1.	2.7	4.0	5.0	6.4	7.5	8.7
EBWE1.	15.5	21.2	25.1	30.3	34.3	38.5
EBWE2.	1.1	1.4	1.7	2.1	2.4	2.7
EBWE3.	14.4	20.6	25.2	31.5	36.5	41.9
EBWE4.	3.8	6.0	7.7	10.3	12.5	14.9
EBWE5.	10.7	16.0	19.9	25.6	30.2	35.2
EBWE6.	5.9	8.2	9.9	12.1	13.8	15.6
EBWE7.	2.6	3.7	4.5	5.6	6.5	7.4
EBWE8.	1.5	2.3	3.0	4.0	4.8	5.7
LABR1.	1.1	1.5	1.9	2.3	2.7	3.1
LACE1.	4.8	6.3	7.4	8.7	9.8	10.8
LAEAS1	1.1	1.7	2.2	2.8	3.3	3.9
LAEA1.	0.8	1.1	1.2	1.5	1.6	1.8
LAFO1.	1.3	1.8	2.1	2.6	2.9	3.3
LAKO1.	5.2	6.9	8.1	9.6	10.7	11.9
LAKO2.	5.3	7.6	9.3	11.6	13.4	15.2
LAKO3.	0.7	1.0	1.1	1.3	1.5	1.7
LALA1.	42.0	49.3	53.8	59.3	63.2	67.1
LALO1.	4.4	6.3	7.6	9.3	10.7	12.2
LALU1.	14.4	18.8	21.8	25.6	28.5	31.5

Table 5

Forested Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LALU2.	7.6	9.9	11.5	13.5	15.1	16.7
LALU3.	3.6	5.1	6.3	7.8	9.1	10.4
LALU4.	8.6	13.1	16.5	21.3	25.4	29.7
LANW1.	1.0	1.4	1.6	2.0	2.3	2.7
LASO1.	2.2	2.9	3.4	4.0	4.5	5.0
LAST1.	20.2	26.2	30.2	35.3	39.0	42.9
LAST2.	15.6	20.5	23.6	27.6	30.6	33.5
LAST3.	9.1	12.8	15.3	18.6	21.1	23.6
LAST4.	7.4	9.7	11.3	13.2	14.8	16.3
LASTI1	10.8	14.5	17.0	20.3	22.8	25.5
LASTI2	9.0	12.0	14.1	16.7	18.8	20.9
LASTI3	9.3	12.7	15.1	18.3	20.7	23.3
LASTI4	1.7	2.3	2.7	3.2	3.6	4.0
LASTI5	7.5	10.7	13.1	16.4	19.0	21.8
LAWE1.	0.3	0.5	0.7	0.9	1.1	1.3
PICA1.	81.8	118.6	145.1	181.2	209.8	239.9
PICA2.	54.5	75.2	89.8	109.1	124.2	140.0
PICA3.	34.0	45.5	53.4	63.9	72.1	80.5
PICA4.	146.6	196.2	229.8	273.3	306.4	340.3
PICE1.	28.8	38.8	45.7	54.8	61.7	68.9
PICE2.	22.3	29.2	33.7	39.3	43.4	47.5
PICE3.	15.1	20.0	23.3	27.4	30.5	33.6
PICE4.	7.2	9.4	10.8	12.7	14.1	15.5
PICE5.	2.5	3.3	3.8	4.4	4.9	5.4
PIMA1.	26.6	36.5	43.4	52.5	59.6	66.8
PIMA2.	20.4	28.9	34.8	42.7	48.8	55.2
CAEA1.	5.0	7.5	9.3	11.8	13.7	15.8
CAEA2.	6.2	8.7	10.5	12.9	14.8	16.8
EBFL1.	57.2	88.0	109.8	138.7	161.1	184.2
EBTR1.	0.9	1.2	1.4	1.7	1.9	2.1
EBTR2.	1.0	1.3	1.5	1.8	2.0	2.2
EBTR3.	2.6	3.4	4.0	4.8	5.4	6.0
EBTR4.	2.7	3.6	4.2	5.0	5.6	6.2
EBTR5.	2.3	3.1	3.6	4.3	4.8	5.4
EBTR6.	1.9	2.6	3.1	3.7	4.2	4.7
EBTR7.	1.8	2.8	3.5	4.6	5.5	6.4
PILI2.	6.9	10.4	13.1	16.8	19.9	23.1
PILI1.	10.2	15.5	19.1	23.5	26.8	30.1
PIME1.	4.8	7.0	8.7	11.2	13.2	15.3
LADR12	0.1	0.2	0.2	0.3	0.3	0.4
LADR1.	4.6	6.2	7.5	9.1	10.4	11.7
LADR10	0.1	0.2	0.2	0.3	0.3	0.4
LADR11	3.3	4.6	5.5	6.7	7.6	8.6
LADR14	0.2	0.3	0.4	0.6	0.7	0.8

Table 5

Forested Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LADR2.	1.0	1.4	1.6	2.0	2.3	2.7
LADR3.	1.8	2.7	3.3	4.1	4.8	5.5
LADR4.	0.5	0.8	1.0	1.2	1.5	1.8
LADR5.	1.8	2.3	2.8	3.3	3.7	4.1
LADR6.	0.8	1.1	1.3	1.6	1.8	2.0
LADR7.	0.4	0.6	0.7	0.9	1.1	1.2
LADR8.	0.1	0.2	0.2	0.3	0.3	0.3
LADR9.	0.9	1.4	1.8	2.4	2.8	3.3
LADR13	0.2	0.3	0.4	0.5	0.6	0.7

AQUA TERRA Consultants
Lake Stevens Flood Frequency
Date: 10/3/97
Engineer: Joe Brascher

Table 6

Current Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
EBBU1.	9.9	13.8	16.5	20.1	22.9	25.3
EBBU2.	9.8	14.2	17.3	21.5	24.8	28.3
EBCA1.	24.6	34.9	42.2	51.9	59.6	67.7
EBFI1.	1.4	1.8	2.1	2.5	2.8	3.1
EBHU1.	37.8	51.5	61.1	73.7	83.4	93.5
EBHU2.	23.0	32.4	39.1	48.1	55.2	62.6
EBHU3.	21.6	32.1	39.9	50.8	59.5	68.9
EBMO1.	41.6	54.0	62.5	73.7	82.4	91.4
EBMO2.	27.5	35.4	40.9	48.2	53.9	59.8
EBMO3.	18.9	27.0	33.1	41.6	48.5	55.8
EBMO4.	11.6	16.5	20.1	24.8	28.5	32.4
EBSE1.	15.7	22.0	26.5	32.5	37.2	42.0
EBSE2.	2.6	3.7	4.5	5.7	6.6	7.6
EBSU1.	37.3	53.1	64.4	79.5	91.4	103.9
EBSU2.	5.8	7.4	8.5	9.8	10.8	11.8
EBSU3.	5.7	7.4	8.5	9.9	10.9	11.9
EBSU4.	34.8	53.7	68.4	89.5	107.2	126.6
EBSU5.	5.6	8.6	11.0	14.3	17.2	20.3
EBSU6.	21.8	33.7	42.9	56.1	67.2	79.3
EBTH1.	7.3	10.8	13.4	16.9	19.8	22.9
EBWE1.	46.7	60.7	69.8	81.1	89.5	97.8
EBWE2.	1.2	1.7	2.1	2.6	3.0	3.5
EBWE3.	54.7	79.9	98.2	123.1	143.0	164.0
EBWE4.	20.2	30.0	37.2	47.1	54.9	63.3
EBWE5.	44.5	65.0	79.6	99.4	115.0	131.3
EBWE6.	18.3	26.3	32.0	39.7	45.8	52.1
EBWE7.	7.0	10.6	13.3	17.2	20.4	23.8
EBWE8.	6.9	10.2	12.5	15.7	18.2	20.8
LABR1.	2.6	3.8	4.7	6.0	7.0	8.1
LACE1.	8.8	12.0	14.1	16.8	18.9	21.0
LAEAS1	4.5	6.7	8.2	10.3	12.0	13.7
LAEA1.	3.3	4.7	5.8	7.1	8.2	9.4
LAFO1.	3.0	4.1	4.8	5.8	6.5	7.3
LAKO1.	19.1	25.4	29.7	35.1	39.2	43.3
LAKO2.	19.1	25.9	30.6	36.8	41.7	46.6
LAKO3.	2.3	3.1	3.6	4.2	4.7	5.2
LALA1.	43.5	51.0	55.4	60.5	64.1	67.5
LALO1.	10.0	13.7	16.2	19.6	22.2	24.8
LALU1.	25.9	33.4	38.1	43.8	48.0	52.1

Table 6

Current Conditions

Location	Flood event in years 2 (cfs)	5 (cfs)	10 (cfs)	25 (cfs)	50 (cfs)	100 (cfs)
LALU2.	11.4	15.5	18.3	22.1	24.9	27.9
LALU3.	6.2	9.0	11.0	13.7	15.9	18.2
LALU4.	15.1	21.9	26.8	33.5	39.0	44.7
LANW1.	3.3	4.7	5.8	7.2	8.4	9.6
LASO1.	3.7	5.0	5.8	6.9	7.7	8.5
LAST1.	33.2	41.9	47.2	53.3	58.3	63.3
LAST2.	26.6	32.4	35.8	39.8	42.6	45.2
LAST3.	18.5	23.0	25.8	29.3	31.8	34.3
LAST4.	11.3	15.0	17.5	20.8	23.3	25.8
LASTI1	21.0	26.5	30.1	34.5	37.7	40.8
LASTI2	19.4	25.9	30.4	36.4	41.0	45.8
LASTI3	28.6	41.9	51.6	64.8	75.3	86.4
LASTI4	4.5	6.4	7.7	9.6	11.1	12.7
LASTI5	25.9	38.3	47.3	59.5	69.1	79.2
LAWE1.	1.7	2.5	3.1	3.9	4.5	5.2
PICA1.	122.8	172.3	207.3	254.0	290.6	328.8
PICA2.	64.0	88.7	106.0	128.9	146.6	164.9
PICA3.	38.7	51.1	59.9	71.7	80.9	90.6
PICA4.	218.4	291.6	341.1	404.9	453.3	502.7
PICE1.	51.4	68.5	80.2	95.5	107.2	119.3
PICE2.	44.6	60.6	71.7	86.2	97.5	109.1
PICE3.	23.2	29.8	34.3	40.2	44.8	49.4
PICE4.	17.2	21.8	24.8	28.5	31.3	34.0
PICE5.	8.8	11.0	12.3	13.9	14.9	15.9
PIMA1.	45.1	62.4	74.7	91.1	103.9	117.4
PIMA2.	35.8	48.9	58.2	70.5	80.2	90.4
CAEA1.	19.4	28.3	34.8	43.5	50.3	57.5
CAEA2.	13.2	18.7	22.8	28.4	32.9	37.8
EBFL1.	67.8	101.0	123.3	151.6	172.6	193.6
EBTR1.	2.2	3.1	3.8	4.6	5.3	6.0
EBTR2.	2.9	4.2	5.1	6.5	7.5	8.7
EBTR3.	5.7	8.4	10.3	13.1	15.3	17.7
EBTR4.	4.6	6.7	8.1	10.1	11.7	13.4
EBTR5.	3.1	4.3	5.1	6.1	6.9	7.8
EBTR6.	2.6	3.8	4.5	5.6	6.5	7.3
EBTR7.	4.9	7.3	9.0	11.3	13.2	15.2
PILI2.	15.8	22.3	26.9	33.0	37.8	42.7
PILI1.	12.5	18.1	22.0	27.1	31.0	35.0
PIME1.	6.6	10.0	12.7	16.6	19.9	23.5
LADR12	0.6	0.8	1.0	1.3	1.5	1.8
LADR1.	17.2	25.4	31.4	39.7	46.4	53.5
LADR10	0.6	0.9	1.1	1.4	1.6	1.9
LADR11	12.4	18.2	22.4	28.2	32.8	37.7
LADR14	1.0	1.5	1.9	2.4	2.8	3.3

Table 6

Current Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LADR2.	4.6	6.8	8.4	10.6	12.4	14.3
LADR3.	6.2	9.0	11.0	13.7	15.8	18.0
LADR4.	2.3	3.5	4.3	5.4	6.3	7.2
LADR5.	6.2	9.1	11.2	14.0	16.3	18.7
LADR6.	1.6	2.3	2.8	3.5	4.1	4.7
LADR7.	1.1	1.6	1.9	2.3	2.7	3.0
LADR8.	0.2	0.3	0.3	0.4	0.4	0.5
LADR9.	4.0	6.0	7.3	9.2	10.7	12.2
LADR13	1.1	1.6	2.0	2.5	2.9	3.4

AQUA TERRA Consultants
Lake Stevens Flood Frequency
Date: 10/3/97
Engineer: Joe Brascher

Table 7

Future Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
EBBU1.	16.3	21.8	25.3	29.6	32.7	35.3
EBBU2.	17.0	23.7	28.2	33.9	38.2	42.6
EBCA1.	38.2	53.9	65.1	80.3	92.4	105.0
EBFI1.	8.2	11.2	13.3	16.1	18.4	20.8
EBHU1.	56.9	81.6	99.5	124.1	143.8	164.8
EBHU2.	35.8	51.8	63.4	79.1	91.6	104.7
EBHU3.	33.6	51.1	64.0	81.9	96.3	111.6
EBMO1.	51.4	67.2	78.0	92.1	102.9	114.1
EBMO2.	32.8	43.0	50.0	59.3	66.4	73.8
EBMO3.	26.8	39.6	49.0	62.2	72.8	84.2
EBMO4.	12.7	18.4	22.6	28.3	32.8	37.7
EBSE1.	39.3	56.2	68.5	85.5	99.0	113.5
EBSE2.	8.7	12.4	15.0	18.6	21.5	24.5
EBSU1.	82.3	117.4	142.2	175.1	200.8	227.5
EBSU2.	11.0	14.5	16.9	20.0	22.4	24.8
EBSU3.	9.1	11.7	13.5	15.8	17.5	19.2
EBSU4.	93.3	143.9	182.0	235.3	278.8	325.5
EBSU5.	17.7	27.3	34.6	44.8	53.1	62.1
EBSU6.	55.0	84.5	106.6	137.4	162.4	189.3
EBTH1.	12.6	18.6	22.9	28.8	33.5	38.5
EBWE1.	67.8	89.2	103.7	122.4	136.6	151.1
EBWE2.	3.5	5.0	6.2	7.7	8.9	10.2
EBWE3.	86.0	122.0	147.2	180.7	206.7	233.7
EBWE4.	27.3	40.7	50.7	64.5	75.6	87.5
EBWE5.	73.8	103.0	123.1	149.5	169.7	190.5
EBWE6.	29.6	37.0	41.0	45.2	48.0	50.5
EBWE7.	12.8	19.5	24.4	31.3	36.9	42.9
EBWE8.	10.0	14.3	17.4	21.3	24.4	27.5
LABR1.	5.4	8.1	10.2	13.2	15.6	18.2
LACE1.	13.6	18.1	21.0	24.5	27.2	29.8
LAEAS1	5.5	8.1	10.0	12.6	14.7	16.8
LAEA1.	3.9	5.6	6.8	8.5	9.8	11.2
LAFO1.	4.3	5.8	6.9	8.3	9.4	10.5
LAKO1.	20.3	27.1	31.6	37.4	41.7	46.1
LAKO2.	20.3	27.7	32.9	39.7	45.0	50.4
LAKO3.	2.4	3.2	3.7	4.3	4.8	5.3
LALA1.	44.3	51.8	56.3	61.5	65.1	68.6
LALO1.	13.2	18.2	21.6	26.2	29.7	33.3
LALU1.	35.4	42.9	47.2	52.2	55.7	58.9

Table 7

Future Conditions

Location	2 (cfs)	5 (cfs)	10 (cfs)	25 (cfs)	50 (cfs)	100 (cfs)
	Flood event in years					
LALU2.	14.9	20.9	25.3	31.1	35.8	40.7
LALU3.	15.5	22.1	26.8	33.0	37.7	42.6
LALU4.	18.3	26.3	32.1	40.1	46.5	53.3
LANW1.	4.2	6.1	7.5	9.4	11.0	12.6
LASO1.	7.2	9.8	11.6	13.9	15.7	17.5
LAST1.	47.9	61.9	71.1	82.6	91.2	99.7
LAST2.	30.5	36.0	39.3	43.0	45.5	47.9
LAST3.	19.4	24.1	27.1	30.8	33.5	36.1
LAST4.	13.2	17.7	20.8	24.9	28.1	31.4
LASTI1	31.5	37.3	41.0	45.5	48.8	52.0
LASTI2	35.2	50.0	60.9	75.7	87.7	100.4
LASTI3	54.0	77.8	94.7	117.5	135.5	154.3
LASTI4	12.6	18.5	23.0	29.2	34.2	39.6
LASTI5	46.4	65.7	78.9	96.2	109.4	122.9
LAWE1.	1.8	2.8	3.4	4.3	5.0	5.7
PICA1.	173.8	240.4	286.4	346.6	393.0	440.7
PICA2.	74.7	101.6	120.4	145.4	164.9	185.2
PICA3.	45.6	60.1	70.2	83.8	94.4	105.6
PICA4.	286.7	383.9	450.6	537.5	604.4	673.0
PICE1.	65.6	87.4	102.3	121.7	136.6	151.8
PICE2.	60.4	82.5	97.7	117.5	132.7	148.3
PICE3.	30.6	38.5	43.8	50.5	55.5	60.6
PICE4.	24.1	28.6	31.0	33.6	35.3	36.8
PICE5.	10.4	12.4	13.6	14.8	15.6	16.4
PIMA1.	68.6	96.6	116.4	143.0	163.8	185.6
PIMA2.	47.1	65.0	77.6	94.3	107.4	120.9
CAEA1.	21.3	31.0	38.0	47.5	55.0	62.9
CAEA2.	22.6	33.7	41.8	53.1	62.2	71.9
EBFL1.	71.9	105.4	128.0	156.8	178.2	199.7
EBTR1.	6.6	9.2	11.1	13.8	15.9	18.1
EBTR2.	4.9	7.2	8.9	11.2	13.1	15.2
EBTR3.	11.0	16.4	20.4	26.0	30.6	35.6
EBTR4.	7.5	10.7	13.0	16.1	18.5	21.0
EBTR5.	4.5	6.3	7.7	9.4	10.9	12.4
EBTR6.	3.2	4.6	5.7	7.1	8.3	9.5
EBTR7.	9.8	14.4	17.8	22.4	26.0	29.8
PILI2.	41.4	57.3	68.7	84.0	96.1	108.9
PILI1.	15.2	21.1	25.1	30.4	34.4	38.5
PIME1.	7.6	11.4	14.4	18.7	22.2	26.0
LADR12	0.6	0.8	1.0	1.3	1.5	1.8
LADR1.	19.5	29.1	36.2	46.0	53.9	62.4
LADR10	0.6	0.9	1.1	1.4	1.6	1.9
LADR11	16.5	24.2	29.9	37.6	43.9	50.5
LADR14	1.2	1.7	2.1	2.7	3.1	3.6

Table 7

Future Conditions

	Flood event in years					
	2	5	10	25	50	100
Location	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
LADR2.	4.8	7.2	8.9	11.3	13.2	15.2
LADR3.	7.0	10.1	12.4	15.4	17.8	20.3
LADR4.	2.6	3.8	4.7	5.9	6.9	7.9
LADR5.	7.6	11.2	13.8	17.4	20.2	23.3
LADR6.	3.1	4.5	5.6	7.2	8.4	9.7
LADR7.	1.1	1.6	1.9	2.3	2.6	3.0
LADR8.	0.2	0.3	0.3	0.4	0.4	0.5
LADR9.	4.7	6.9	8.4	10.6	12.2	14.0
LADR13	1.1	1.6	2.0	2.5	2.9	3.3

APPENDIX B

1997 King County SWM Drainage Facility Cost Study

The 1997 King County study on the cost of the new drainage standards established eight different cost impact zones which combine the two proposed levels of flow control with four proposed levels of water quality treatment. Total construction and opportunity cost impacts vary between these zones based on factors such as the number and size of facilities required to meet the proposed level of flow control (FC) and water quality treatment (WQ) within that zone.

Table 6-4
Cost Impact Zones

	Level 1 Flow Control (FC)	**Level 2 Flow Control (FC)**
Basic WQ Treatment	Zone 1	Zone 2
Sensitive Lake WQ Treatment	Zone 3	Zone 4
Resource Stream WQ Treatment	Zone 5	Zone 6
Sphagnum Bog WQ Treatment	Zone 7	Zone 8

Based on these eight categories, the analysis then compares total costs under existing and proposed drainage design standards and regulations in both urban and rural residential areas, resulting in sixteen different cost impact graphs. In King County, most areas saw decreased or unchanged facility costs due to improved facility design. Small, previously exempt projects in rural areas experienced increased costs due to a combination of more stringent treatment standards and the inability to share costs among multiple lots. The results of the cost analysis are summarized below in Tables 3, 4, and 5. Zones 5-8 (Urban development type) and zones 7-8 (Rural development type) are not included in the tables because each zone accounts for less than 1% of developable urban or rural residential area in King County.

Table 6-5
Cost Decrease under King County Runoff Time Series Design Standards

Development Type	Development Size	Zone	Reason for Cost Decrease	Affected Area
Urban Residential	Large Plats	1-4	Proposed stacked detention/water quality ponds require less tract area and have lower construction costs than currently required separate detention ponds, wetponds, and bioswales.	44% of urban area
Urban Residential	Short Plats, small plats	1, 3	Proposed minimum size bioswales are smaller than those currently required	16% of urban area
Rural Residential	All	2	Proposed 3.0 stacked ponds have lower construction costs than pond and bioswale currently required (current Level 2 FC areas only)	39% of rural area
Commercial	> 2 acres	--	Proposed stacked detention/water quality ponds require less tract area and have lower construction cost than currently required separate detention ponds, wetponds, and bioswales	39% of commercial applications
Commercial	< 0.7 acre sites	--	Proposed minimum size bioswales are smaller than those currently required.	29% of commercial applications.

Table 6-6
Cost Neutral under Proposed Changes

Development Type	Development Size	Zone*	Offsetting Costs	Affected Area
Urban Residential	Short plats, small and medium plats	2	Reduced opportunity costs from proposed minimum size bioswale offset increased costs of construction of larger tanks/ponds.	19% of urban area
Rural Residential	< 22,000 sq ft impervious surface	1	Reduced construction costs from proposed minimum size bioswale offsets increased construction costs of larger detention ponds.	5% of rural area
Rural Residential	> 22,000 sq ft impervious surface	2 3	Construction cost of proposed 3.0 combined ponds about equal to current Level 1 ponds and bioswales (Level 1 flow control areas only. Construction cost of proposed 4.5 combined pond about equal to current ponds and bioswales.	15% of rural area

Table 6-7
Cost Increase under Proposed Changes

Development Type	Development Size	Zone*	Reason for Increased Costs	Affected Area
Urban Residential	Small, medium plats	1, 3	Larger detention tanks required in Level 1 areas.	15% of urban area.
Urban Residential	Short plats, small plats, medium plats.	4	Sand filters required in sensitive lake water quality areas.	6% of urban area
Rural Residential	< 22,000 sq ft impervious surface	2 3	Conversion from current Level 1 to proposed Level 2 requires detention ponds for small projects previously exempt. Additional wet pond required in sensitive lake water quality areas.	36% of rural area
Rural Residential	all	5, 6	Sand filters required in significant stream reach water quality areas.	5% of rural area
Commercial	0.7-2 acre sites	--	increased detention volumes result in larger tanks and ponds compared to current (note assumption of 100% pasture conversion results in large volume differences.	32% of commercial applications.

Finally, Table 6 shows the average difference in facility cost according to urban, residential, or commercial development type.

Table 6-8
Average Cost Differences under Proposed Changes

	Decreased Costs		No Change		Increased Costs	
Develop-ment type	***% of Develop.***	***Change in Costs***	***% of Develop.***	***Cost***	***% of Develop.***	***Change in Co***
Urban Residential	60	$8200→ $5400 (34%)	19	$11500	15 6	$6700→$7900 $11600→$15900
Rural Residential	39	$6400→$4800 (25%)	20	$5100	36	$2500→$6400 ($5200→$6900 (
Commercia l	29 39	$18000→$12000 (33%) $150000→$120000 (20%)			32	$55000→ $77000

APPENDIX C

Water Quality Monitoring Plan

5

Appendix C

SAMPLING PLAN
CATHERINE CREEK BASIN

Prepared by:

Gary R. Minton
Resource Planning Associates

September 9, 1997
Amended September 27, 1997

1.0 PROJECT DESCRIPTION

1.1 Site: The project area covers the watersheds of Catherine, Lundeen, and Stevens Creeks, and the outlet of Lake Stevens to its confluence with Catherine Creek.

1.2 Project Background: As part of the Catherine Creek Basin Plan being conducted by Gray and Osborne for Snohomish County Drainage Improvement District #8, RPA will be collecting data during base and stormflow conditions.

1.3 Project Objectives: The project objective is to provide a characterization of current water quality. The data will be compared to Ecology receiving water standards. The data will also be used as the basis for predicting future water quality with development of the study area.

1.4 Sampling Design: Table 1 summarizes the types of data to be collected that are covered by this plan. Sampling stations are coincident with the District's flow monitoring stations at B, D, F and G. Sampling will also occur at the outlet of Lake Stevens and immediately downstream of the intersection of 20th Street and Hartford Drive. These later two stations are referred to as Station A and AC given there nearness to the District's Station A.

TABLE 1

Flow condition	Climatic condition	Water quality parameters	Comments
Base flow	Summer- high ambient temperature period (>85F) Winter- no special condition	Ambient* and water temperature, DO, conductivity, pH, fecal coliform, phosphorus, ammonia, nitrate, total nitrogen (TKN) Water temperature, DO, conductivity, pH, and intergravel DO, fecal coliform	Temperature, DO and pH are relevant to fish; fecal coliform, ammonia, and nitrate are relevant to public health** because elevated levels suggest failing septic tanks. TP is indicators of potential for excessive primary productivity in creeks
Storm flow	Storm depth of 0.25 to 0.75 over 24 hours with antece-dent dry period of at least one week, preferably two	TSS, total and dissolved zinc and copper, pH, DO, temperature, conductivity, hardness, phosphorus, ammonia, nitrate, and total nitrogen (TKN).	Zinc and copper are the only metals found to frequently exceed Ecology standards.

* Obtain this data from District weather stations.
** If septic tanks are not an issue (i.e. numbers in area are not significant and/or health department has not indicated that there is a problem), fecal coliform and nitrate will be dropped.

1.5 Schedule: Base flow and stormflow data will be collected during three time periods. Late summer, winter and early spring. These three periods have been selected as the critical periods: the first period is rearing, the second period is emergence of coho and kokanee fry, and the third period is emergence of cutthroat fry.

1.6 Project Organization: The following personnel are responsible for the project:

Project manager: Warren Perkins, Gray and Osborne, 284-0680, 701, Dexter Ave N. Seattle, WA

Task Leader: Dr. Gary Minton, Resource Planning Associates, 311 W. McGraw, Seattle, WA.

282-1681

Laboratory: Analytical Resources, Inc. 333 9th Ave N, Seattle, WA 98109

2.0 DATA QUALITY OBJECTIVES

2.1 Precision and Bias: Analytical method and lower reporting limits will be equivalent to those used at the Manchester Laboratory and listed in Appendix C of Ecology's Guidelines and Specifications for Preparing Quality Assurance Project Plans.

2.2 Representativeness: With regard to storm sampling, representativeness is achieved by selecting storm events that meet the Ecology criteria; this is a storm with a total depth of between 0.25 and 0.75 inches over 24 hours. A minimum of one week but preferably two, of dry weather is to occur prior to each storm (rainfall not exceeding 0.10 inches over this period or greater if no runoff occurred during the event). This may not be possible during the winter period in which case at least 72 hours of dry period will occur prior to sampling.

2.3 Completeness: Stormflow sampling will be by hand grab samples spaced generally at equal time intervals over the storm hydrograph.

2.4 Comparability: The data will be compared to the data from other creeks with similar levels of development for reasonableness.

3.0 SAMPLING PROCEDURES

3.1 Standard Operating Procedures:

3.1.1 Storm sampling: On the order of 10 individual grab samples each of 1 liter volume will be collected during the storm, generally from the beginning of rise in water level at each station until the level has either dropped to prestorm level or the stream has become clear, or 24 hours whichever is less. Sampling bottles will be acid washed. Sampler bottles will be kept on ice during each event. Water temperature, pH, conductivity, and dissolved oxygen will be taken periodically at each station during the event using a meter. The District's staff gage at each station will be read when each grab sample is taken. The District's stage - discharge relationships at each of their stations will be used to determine flow. The approximately 10 individual samples collected at each station will be flow-weight composited using the District's stage-discharge relationship. This will result in one sample for analysis. The compositing will be done with a 500 ml graduated cylinder and a carboy, both of which will be acid washed. Each discrete sample will be thoroughly mixed by inversion prior to decanting in the cylinder. The carboy will be thoroughly mixed by shaking when placing water in the sample bottles. Sample bottles will be provided by ARI. The one exception is the outlet of Lake Stevens where 3 to 5 samples will be taken and composited without consideration to flow.

The procedure will be for RPA to monitor weather service information sources with regard to impending rain events. RPA will proceed to the study area prior to the event and proceed with sampling. During the daylight hours sampling will be done totally by RPA staff. In the event of night sampling, a District employee may be asked to participate for sampling support and for safety. As sampling proceeds, a decision will be made as to whether the storm has met the desired conditions according to the Sampling Plan. If not, the samples will be discarded. If the desired storm objectives have been met, the samples will be flow-weight composited and then taken to ARI. Compositing will occur either at the District's office or at ARI.

3.1.2 Base flow sampling: Continuously recording water quality meters will be placed for two weeks during the summer period and one week during the other two periods of interest. The meters will be placed at or in the vicinity of the District's flow recording Stations A, B, D, F and G. The summer sampling period will be two weeks because the objective will be to identify water quality during a high ambient temperature period followed by period of more normal summer weather. The meters record temperature, dissolved oxygen, conductivity and pH. These parameters will be measured hourly. When the equipment is installed, serviced, and removed, grab samples will be taken to be analyzed for the other parameters in the above table. Intergravel DO probes will be installed in December at locations and depths relevant to spawning. Samples will be withdrawn from the probes biweekly in December and January. For cutthroat, intergravel DO probes will be installed in March at relevant locations and depths. Samples will be withdrawn biweekly during April-May. When samples are taken from these probes, the water column DO and temperature will be measured. Base flow sampling will not occur during the summer F and G.

3.2 Sampling Schedule: See Table 1.

3.3 Field Notes: Field notes will be kept by the Task Leader. Information includes but is not necessarily limited to personnel present, date, sampling locations, staff gage readings, current and relevant antecedent weather conditions, meter readings, and any unusual conditions or circumstances that may bear on the quality of the data.

3.4 Containers, Sample Size, Preservation, and Holding Times: Sample containers, and preservation aspects will be as specified by ARI which are consistent with Appendix D of Ecology's QA/QC. Samples will be taken to ARI within 24 hours of the end of the final grab sample, with the exception of fecal coliform samples which will be returned to ARI within 6 hours of the first sample taken.

3.5 Sample Identification: Samples will be identified by sampling station designation, the dates and times of sample collection.

3.6 Sample Custody: A chain-of-custody form will be completed for each set of samples delivered to ARI.

4.0 ANALYTICAL PROCEDURES

Analytical methods will follow those approved by the Department of Ecology. Detection limits shall be sufficient to detect the particular analyte or the lowest available detection limit.

5.0 DATA REDUCTION, REVIEW, AND REPORTING

Data reporting for laboratory data and QA/QC procedures will follow the standard procedures established by the laboratory.

6.0 QUALITY CONTROL PROCEDURES

6.1 Field QC Procedures

1. Ice will be placed in the coolers.
2. Samples will be delivered to the laboratory within the recommended holding time for the analytical parameters (see above).
3. Field instruments will be calibrated prior to use following the manufacturer's procedures.
4. During each storm event, a duplicate sample will be prepared at one of the stations.

6.2 Laboratory QC procedures: Laboratory QC will be performed by ARI per their standard procedures.

7.0 PERFORMANCE AND SYSTEM AUDITS

7.1 Performance Audit: Laboratory system audits will be performed by ARI per their standard procedures.

8.0 PREVENTIVE MAINTENANCE

Preventive maintenance of analytical meters will be performed as specified by the manufacturer.

9.0 DATA ASSESSMENT PROCEDURES AND CORRECTIVE ACTION

9.1 Precision: Essentially whole-storm composites will be collected.

9.2 Reasonableness: The data will be compared to data obtained from other streams with similar levels of development, to the extent such data are available.

10.0 QUALITY ASSURANCE REPORTS

The data will be summarized in the task report for Task 3.

APPENDIX D

Grab Sample and Composite Water Quality Data

CATHERINE CREEK

BASE FLOWS PRELIMINARY SAMPLING

BASE FLOW September 9, 1997

Analyte	Channel @lake	Channel at 20th NE	Station B
TSS			
TrZn			
DisZn			
TrCu			
DisCu			
TP	0.034		0.400
NH3	0.078		0.086
NO3	0.110		0.170
TKN	0.500		<0.2
Fecal			
Entero			
BOD			
Hardness			
Cond	126		124
pH	***6.4***		7.0
DO	***6.2***		***8.1***
Temp	***18.7***		***18.5***
%SatDO	66%		86%

BASE FLOW September 11, 1997

Analyte	Channel at 20th NE	Channel at 20th NE	Station B
TSS			
TrZn	<0.004		0.010
DisZn	<0.004		<0.004
TrCu	<0.002		0.002
DisCu	0.002		0.002
TP			
NH3			0.039
NO3			0.170
TKN			0.500
Fecal			
Entero			
BOD			
Hardness			55
Cond			
pH			7.3
DO			***5.3***
Temp			16
%SatDO			54%

BASE FLOW September 24, 1997

Analyte	Channel @lake	Station A	Channel at 20th NE	Channel at C. Creek	C. Creek at L. Pilchuck
TSS					
TrZn					
DisZn					
TrCu					
DisCu					
TP					
NH3					
NO3					
TKN					
Hardness					
Cond	52	62		59	67
pH	6.9	6.9		6.9	6.9
DO	9.8	9.3		8.8	9.65
Temp	***22.75***	***19.7***		***18.2***	***15.3***
%SatDO	113%	102%		93%	96%

Focus of sampling was DO and temperature, not chemical contaminants

Measurements with meter. Average of two meter readings at each station, one at mid-day and one late afternoon

BASE FLOW WATER QUALITY DATA

March 13, 1998

Analyte	Channel at 20th NE	Station D	Catherine@ L. Pilchuck
TP	0.027	0.058	0.042
NH3	<0.010	<0.010	0.026
NO3	0.24	0.4	0.33
TKN	0.50	0.40	0.03
Fecal	20	30	<32
Entero	10	43	53
BOD	2	2	3
Cond			
pH	***8.6***	6.9	7.3
DO	11	11	11
Temp	9.5	10	11
%SatDO	96%	97%	100%
Flow	22.5	13.4	

"WINTER" SAMPLING

March 19, 1998

Analyte	Channel at 20th NE	Station D	Catherine@ L. Pilchuck
TP	0.03	0.068	0.046
NH3	0.034	0.055	0.058
NO3	0.18	0.18	0.35
TKN	0.2	0.6	0.5
Fecal	38	73	82
Entero	9	55	29
BOD			
Cond	89	44	70
pH	***8.7***	6.7	7.5
DO	14	10	11
Temp	9	9	9.5
%SatDO	122%	91%	100%
Flow	20.4	7.7	

Poor zerox
I have
originals

CATHERINE CREEK
BASE FLOW WATER QUALITY DATA — "SPRING" SAMPLING

	May 29, 1998				June 2, 1998				June 5, 1998		
Analyte	Channel at 20th NE	Station D	Catherine@ L. Pilchuck	Analyte	Channel at 20th NE	Station D	Catherine@ L. Pilchuck	Analyte	Channel at 20th NE	Station D	Catherine@ L. Pilchuck
TP	0.022	0.089	0.076	TP	0.023	0.054	0.048	TP	0.023	0.1	0.35
NH3	0.11	0.063	0.025	NH3	0.015	0.026	0.019	NH3	<0.010	0.056	0.032
NO3	0.086	0.1	0.16	NO3	0.013	0.055	0.056	NO3	<0.010	0.15	0.057
TKN	0.3	0.7	0.6	TKN	0.5	0.8	0.6	TKN	0.4	1	0.6
Fecal	140	200	240	Fecal	14	76	200	Fecal	31	180	2400
Entero	24	690	480	Entero	5	180	57	Entero	4	42	27
BOD	4	3	3	BOD				BOD	1	3	2
Cond	96	44	65	Cond	95	46	80	Cond	94	52	98
pH	8.8	6.8	7.2	pH	9	7	7.5	pH	8.9	6.7	7.4
DO	10	8.1	8.8	DO	11	7.8	8.3	DO	10	8.1	8.6
Temp	18	14	14	Temp	19.5	18	18.5	Temp	19	16	18
%SatDO	105%	79%	85%	%SatDO	120%	82%	88%	%SatDO	108%	82%	91%
Flow	18	17	69	Flow		3	57?	Flow	16	0	
2nd DO		7.6 in morning			Flows on all 3 dates make no sense					Was flow	

CATHERINE CREEK
BASE FLOW WATER QUALITY DATA — "SUMMER" SAMPLING

	July 22, 1998			July 28, 1998			September 4		September 8		September 11	
Analyte	Channel at 20th NE	Station D	Catherine@ L. Pilchuck	Channel at 20th NE	Station D	Catherine@ L. Pilchuck	Channel at 20th NE	Catherine@ L. Pilchuck	Channel at 20th NE	Catherine@ L. Pilchuck	Channel at 20th NE	Catherine@ L. Pilchuck
TP	<0.016	0.092	0.03	0.018	0.096	0.03	0.03	0.033	0.039	0.039	0.026	0.036
NH3	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
NO3	0.021	0.3	0.046	<0.010	0.24	0.017	0.01	0.037	<0.010	0.045	0.014	0.064
TKN	0.7	1.2	0.7	0.6	0.8	0.5	0.7	0.70	0.6	0.4	0.5	0.4
Fecal	31	600	140	43	580	200	23	60	140	64	19	72
Entero	53	88	85	320	360	30			300	43	67	140
BOD	3	2	7				1	1			2	<1
Cond	100	74	100	100	88	99	99	100	100	100	95	97
pH	7.7	6.9	7.4	7.3	6.8	7.3	8	7.6	7.5	7.6	7.4	7.5
DO	8.5	6.8	7.4	7.3	5	7.4	8.4	8.2	7.5	8.6	8	8.8
Temp	25	18.5	23	26	19	24	22.5	21	21	18	20	16
%SatDO	103%	72%	86%	90%	54%	88%	0.99	92%	84%	91%	88%	89%
Flow	4.2	<0.5	21.5?	6.1		25.2?	5.6		4.2		2.6	
							8.6		7.7		8.4	Outlet DO
							Sta D, 6.3					

STEVENS AND LUNDEEN CREEKS

BASE FLOW SAMPLING			"WINTER" SAMPLING				BASE FLOWS "SPRING" SAMPLING					
April 1, 1998			April 6, 1998		April 9, 1998		May 11, 1998		May 14, 1998		May 19, 1998	
	Station (Lundeen)	Station (Stevens)	Station	Station	Station	Station	Station	Station	Station	Station	Station	Station
Analyte	F	G	F	G	F	G	F	G	F	G	F	G
TP	0.054	0.044	0.052	0.055	0.056	0.053	0.067	0.064	0.098	0.12	0.09	0.053
NH3	0.016	0.029	0.015	0.011	<0.01	<0.01	0.051	0.053	0.11	0.077	0.016	0.01
NO3	2.4	2.4	1.7	1.5	3.1	1.5	0.61	0.45	0.98	0.59	0.74	0.48
TKN	0.8	0.6	0.5	0.5	0.9	0.9	0.6	0.5	0.7	0.6	0.8	0.7
Fecal	98	20	***300***	27	93	92	***860***	***190***	***2400***	***1100***	***600***	95
Entero	***85***	5	***36***	7	***98***	***36***	***92***	20	***2100***	***3000***	***300***	***160***
BOD	<1	<1			2	1	2	2		2	1	1
Cond	110	96	110	100	94	110	140	120	120	110	140	120
pH	7.1	7.2	7.2	7.1	7.1	7.2	7.6	7.2	7.1	7	7.1	6.8
DO	10	11	11	11	11		10.4	9	10.8	10	9.6	8.3
Temp	9	8	8	9	6.9	7.6	11	11	9	10	10	10.5
%SatDO	87%	93%	93%	96%			95%	82%	93%	89%	85%	73%
Flow		7.6				5		3.9		5.9		4.9

avg of all 67 ug/l

CATHERINE CREEK

STORMS — PRELIMINARY SAMPLING

September 11, 1997

Analyte	Channel at Lake outlet	Channel at 20th NE
TSS		
TrZn		0.035
DisZn		0.016
TrCu		0.005
DisCu		<0.002
TP		
NH3		0.200
NO3		0.440
TKN		0.700
Hardness		60
Cond		55
pH		7.4
DO		***6.5***
Temp		16.5
%SatDO		66%

September 25, 1997

Analyte	Channel at Lake outlet	Channel at 20th NE	Station B
TSS	7.1	20	10
TrZn	0.005	0.049	0.010
DisZn	<0.004	0.015	0.006
TrCu	<0.002	0.003	0.002
DisCu	0.001	0.002	0.002
TP	0.030	0.100	0.074
NH3	0.026	0.190	0.084
NO3	0.043	0.360	0.230
TKN	<1	<1	<1
Hardness	35	34	41
Cond		49	59
pH		6.9	6.9
DO		9.2	***7.9***
Temp		***19***	18
%SatDO		99%	83%

"WINTER" STORM — March 22, 1998

Analyte	Channel at Lake outlet	Channel at 20th NE	Station D	Station B	123rd St outfall	L.Stevens Channel
TSS	1.5	3.6	5	7.6	31	5.8
TrZn	<0.004	0.005	0.007	0.007	0.059	0.015
DisZn	<0.004	<0.004	<0.004	<0.004	0.023	0.01
TrCu	<0.002	<0.002	0.004	0.002	0.004	0.007
DisCu	<0.002	<0.002	0.003	<0.002	<0.002	0.007
TP	0.031	0.028	0.069	0.044	0.13	0.05
NH3	0.04	0.024	0.12	0.038	0.082	0.16
NO3	0.16	0.27	0.32	0.024	0.17	0.12
Hardness	35	35	18	30	35	25
pH	***8.9***	7.6	6.9	7.2	***8.7***	6.7
DO		13	9.8	11		
Temp		9.8	9.8	9.6		
%SatDO		1.15	0.88			

"SPRING" STORM — June 15, 1998

Analyte	Channel at Lake outlet	Channel at 20th NE	Station D	Station B	123rd St outfall	L.Stevens Channel
TSS	1.9	11	9.8	14	38	9.5
TrZn	0.009	0.021	0.008	0.012	0.086	0.022
DisZn	0.004	0.032	0.005	***0.045***	***0.086***	0.030
TrCu	<0.002	0.002	0.002	0.002	0.004	0.002
DisCu	0.002	0.002	0.003	<0.002	0.005	0.003
TP	0.018	0.046	0.059	0.071	0.12	0.14
NH3	0.01	<0.010	0.051	0.037	0.028	0.14
NO3	0.48	0.079	0.095	0.16	0.28	0.091
TKN	0.6	0.7	1.5	1.5	0.9	1.3
Hardness	34	32	17	27	26	27
pH	7.5	7.7	6.9	7.2	7.2	6.5
DO		9.6	***8***	8.3		
Temp		***18.5***	16	17		
%SatDO		102%	81%	74%		
Fecal	13	***500***	***1800***	***480***		***1300***
Entero	9	***360***	***290***	***380***		***1700***

CATHERINE CREEK

"SUMMER" STORM September 18, 1998

Analyte	Channel at Lake outlet	Channel at 20th NE	Station D	Station B	123rd St outfall	CBD outfall	L.Stevens Channel
TSS		24		3.4	140	130	49
TrZn	0.005	0.071		0.007	0.461	0.523	0.18
DisZn	0.012	0.027	NO	0.006	0.024	0.114	***0.136***
TrCu	<0.002	0.007	FLOW	0.002	0.024	0.02	0.011
DisCu	<0.002	0.004	AT	<0.002	0.005	<0.002	0.006
TP	0.024	0.13	THIS		0.53	0.41	0.19
NH3	0.022	0.018	STATION	<0.010	0.017	1.90	0.31
NO3	0.13	0.45		0.16	0.92	0.41	0.85
TKN	0.40	0.90		0.60	1.10	3.80	1.50
Hardness	36	45		40	83	110	40
Cond	93	110		98	150	250	130
pH	7.3	7.3		7.2	7.6	7	6.6
BOD		24		7	39	43	
Fecal	***680***	***TNTC***		***1800***	***TNTC***	*3*	***1200***
Entero	***860***	***3500***		***3000***	***4900***	***800***	***2300***

"SUMMER" STORM September 25, 1998

Analyte	Channel at Lake outlet	Channel at 20th NE	Station D	Station B	123rd St outfall	CBD outfall	L.Stevens Channel
TSS	<2	33		7.9	72	93	14
TrZn	0.005	0.07		0.083	0.159	0.197	0.066
DisZn	<0.004	0.018	NO	0.006	0.015	0.067	***0.045***
TrCu	<0.002	0.006	FLOW	0.004	0.01	0.021	0.006
DisCu	<0.002	0.004	AT	<0.002	0.003	0.006	0.004
TP	0.03	0.17	THIS	0.093	0.25	0.38	0.15
NH3	0.044	0.18	STATION	0.089	0.2	0.62	0.17
NO3	0.15	0.56		0.44	0.59	0.66	0.54
TKN	0.50	0.70		0.60	0.90	1.40	0.70
Hardness	35	36		41	36	80	34
Cond	91	86		110	84	180	97
pH	7.4	7.2		7.1	7.4	6.7	6.8
BOD	1.3	39		9	18	19	18
DO	8.3	8.5		6.7			
Temp	17	16		13			
%SatDO	86%	86%		64%			
Fecal	***1300***	***4800***		***TNTC***	***4500***	***760***	***2200***
Entero	***3500***			***4800***	***5700***	***2200***	***4200***

STEVENS AND LUNDEEN CREEKS

STORMS	"WINTER"		"SPRING"		"SUMMER"			
	March 22, 1998		June 15, 1998		September 18, 1998		September 25, 1998	
	Station	Station	Station	Station	Station	Station	Station	Station
Analyte	F	G	F	G	F	G	F	G
TSS	65	20	150	34			32	
TrZn	0.016	0.009	0.035	0.012			0.012	
DisZn	<0.004	<0.004	0.024	0.011	NO	NO	<0.004	NO
TrCu	0.007	0.004	0.008	0.003	FLOW	FLOW	0.004	FLOW
DisCu	0.003	0.002	0.006	0.003	AT		0.002	AT
TP	0.23	<0.004	0.49	0.17	THIS	THIS	0.31	THIS
NH3	0.06	0.16	0.023	0.024	STATION	STATION	0.169	STATION
NO3	1.8	4.2	0.60	0.55			1.3	
TKN			2.3	1			1.1	
Hardness	47	37	61	47			73	
pH	7.2	7.1	7.2	7.1			7.5	
DO	10	9.2		***7.1***			8.4	
Temp	8.6	8.5	12	13			13	
%SatDO	85%	79%	0%	67%			80%	
Fecal			***5100***	***1800***			***TNTC***	
Entero			***4000***	***1800***			***TNTC***	

EFFICIENCY OF REMOVAL OF REENTRAINED ROAD DUST FOR STANDARDS UNDER THE NATIONAL URBAN RUNOFF PROGRAM AS A RESULT OF STREET SWEEPING

The attached graph is from a study by Roger Sutherland, Street Sweeper Pick-up Performance, Memorandum to Jim Peterson/HDR Engineering, Inc., Kurahashi & Associates, July 31, 1995.

This data shows an 87% reduction over NURP ERA machines by Enviro Whirl machines in the removal and containment of particulate from roadways for the reduction of water pollution.

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APPENDIX E

Pollutant Loading Simulation Model

APPENDIX E
CALCULATION OF STORMWATER LOADINGS

The possible effects of continued urbanization within the Basin Planning Boundary are evaluated in part by estimating the existing and future average annual loadings of key constituents. Loading is the total pounds of a pollutant generated over an average year, or pounds per year, within the watershed. Estimating the loadings of constituents involves considerable uncertainty for a variety of factors: the limited amount of data on stormwater quality, variation in pollutant loading between different land uses, as well as for the same land use because of the variation in the specific activities, differences in the age and type of pavement surfaces, etc.

Appendix DD describes the procedure used to estimate pollutant loadings in stormwater from following sources.

- From developed land areas, such as pavements, lawns, rooftops, and pasture and forest areas that remain undeveloped.
- From construction sites, that is, loadings that occur while the land is being developed.
- From the erosion of stream channels due to the increases in storm flows that occurs because of urbanization.

ESTIMATED LOADINGS IN STORM RUNOFF FROM DEVELOPED LAND

Loading estimates were made for three conditions:

Condition #1: Loading from land use under existing conditions

Condition #2: Loading when development in the basins has reached essentially saturation as defined by the Snohomish County land use plan, but without treatment systems installed in each new development

Condition #3: The same as Condition #2, but with treatment systems installed in each new development following the current requirements of Snohomish County.

General procedure

A loading simulation model was developed using a simple spreadsheet program. The modeling area covers the entire watersheds of Catherine Creek and Lake Stevens. Table DD.1 summarizes the loading data at the points of interest.

Estimates of the annual loadings were made in the following steps:

- Divide the two watersheds into subbasins.
- Define the types of land uses.

- Estimate the total amount of each type of land use, existing and at buildout. The estimates of the various types of land use (for example, multifamily residential) used the same data base as that used for the HSPF stormwater modeling (Chapter 4).
- Select the constituents to model.
- For each selected pollutant, calculate a unit loading, that is pounds per acre per year, for each type of land use.
- Multiply the unit loading for each type of land use type times the acreage of that land use type in each subbasin.
- Sum the loadings of all land use types in each subbasin to obtain the total loading for each pollutant.
- Take into consideration the effect of stormwater treatment systems that are required in new developments to calculate future loadings.
- Identify the particular points of interest in the watersheds. Where these points of interest drain two or more subbasins, sum the loadings from the subbasins to obtain a total loading at each point.

Estimates of current and future pollutant loading are made based the identification of basic land uses types and the anticipated unit loading from each type of land use. These land uses are:

Basin and subbasin delineation: The same basin and subbasin delineation that was used for the HSPF hydrologic model analysis (Chapter 4).

Land use types: For this analysis the following land use types were used: forest, pasture, parks, government, low density residential, medium density residential, commercial and industrial.

Estimates of acreages for each land use type: The estimates of the various types of land use also used the same data base as that used for the HSPF stormwater modeling. Estimates are for two conditions: existing land use *(199???),* and buildout (*Warren: is what Doug did represent complete buildout or something close to it?)* Presented in Tables DD.2 and DD.3 is the estimated acreages for each type of land use for the existing and buildout conditions, respectively. Acreages are provided for each subbasin. See Figure 4.X in Chapter 4 for the boundaries of the subbasins.

Constituents modeled: As there a large number of constituents only a few can be modeled to avoid the generation of a large body of simulations that are of little use. Three constituents were modeled: totals suspended solids (TSS) or sediment, phosphorus and zinc. These three were selected based on the following rationale. TSS represents sediment. Sediment itself can be injurious to trout and salmon in particular when it settles on the stream bed. The fine sediment in particular chokes spawning gravels, preventing successful reproduction. Sediment also is a carrier of metals, petroleum, pesticides, and other toxic constituents. These toxicants can desorb from the sediments, creating lethal and or sublethal conditions. Sediment also carries phosphorus which is a nutrient. TSS is also the primary parameter by which the effectiveness of stormwater treatment systems is based. Phosphorus was selected to represent nutrients (the others are ammonia, organic nitrogen, and nitrate). It is of particular concern to Lake Stevens. There is a very large number of constituents that are potential toxicants in stormwater: various metals, herbicides and pesticides, oil and grease, and the byproducts of fuel combustion in homes and cars like PAHs. Zinc was selected to represent these toxicants because it is always present in urban stormwater at significant concentrations, frequently exceeded the Department of Ecology standards. s metals and toxicant constituents.

Unit loadings: Unit loadings have been developed from national (USEPA, 198x; Novotny and Olem, 1994) and regional, that is western Washington, data bases (Horner, 1990). Using regional data is preferred where the data base is sufficient, particular for western Washington since the climate is significantly different that the remainder of the United States. Therefore, loadings for this study were prepared from regional data. The unit loading for each type of land use was developed as follows:

For each land use, an average concentration was selected for each of the three constituents from a review of regional data bases (Pitt and Bissonette, 1984; Kulzer, 1996; Merrill, et al. 1989; and Woodward-Clyde, 1997). The average concentration was multiplied times the average annual rainfall (47"), times the runoff coefficient for each type of land use. The runoff coefficient is the fraction of the annual rainfall that leaves the site as storm-water. Presented in Table DD.4 are the selected concentrations and the unit loadings.

TABLE DD.4 UNIT LOADINGS

LAND USE	Runoff Coef		TSS		Phosphorus		Zinc	
			Conc[1]	Load[2]	Conc	Load	Conc	Load
Forest	0.1		75	80	0.10	0.10	0.010	0.01
Pasture	0.2		125	200	0.30	0.50	0.025	0.04
Parks	0.3		80	250	0.25	0.80	0.070	0.20
Government	0.8		95	800	0.25	2.10	0.150	1.25
LD residential	0.2		80	125	0.20	0.30	0.090	0.15
MD residential	0.35		80	300	0.25	0.90	0.150	0.60
HD residential	0.5		80	550	0.25	1.70	0.150	1.00
Commercial	0.8		95	800	0.25	2.10	0.200	1.70
Industrial	0.2		125	1100	0.25	2.10	0.200	1.70

1. All concentrations in mg/L 2. All loadings in pound/acre/year

There s little published data of concentrations of any of the three constituents in stormwater from forested and agricultural areas in western Washington. One study (Prych and Brenner, 1983) in southeast King County found an average concentrations of 132 mg/L and 158 mg/L in runoff from forest and pasture areas, respectively. The average concentration for an urban area (Enumclaw) was only 61 mg/L. The average phosphorus concentrations for the forest and agricultural areas were 0.099 and 0.667

mg/L. The agricultural areas included dairies and nondairy livestock. There is therefore considerably greater uncertainty in the estimated unit loadings from forest and pasture areas then from urban areas.

The USEPA (1983) concluded that there was no significant differences in the concentrations between urban land uses (medium to high density residential, commercial and industrial). The concluded that the variations in concentration within different sampled sites of the same land use were greater than the variations between the urban land use types that were studied. The inference is that differences that have been observed between land uses in studies conducted in western Washington are not true, statistical differences but rather are apparent differences because of the limited number of sites and/or storms that were sampled. Consequently, the concentrations in Table DD.3 for similar land uses are the same.

Effect of lakes on stormwater quality

Lakes are by default large treatment systems. The volumes of Lakes Cassidy, Stevens and Stitch are all very large relative to the volume of stormwater runoff. It is therefore expected that the three constituents, and other stormwater constituents as well, will be entirely treated and/or transformed within each lake and therefore what exits each lake will be a reflection of processes within each lake itself rather than of the stormwater. A possible exception is Stitch Lake whose shape is such that during larger storms the incoming stormwater in the creek may shortcircuit directly towards the outlet to Lake Stevens.

Treatment in new developments

The common practice is to assume that the various treatment systems (e.g. wet ponds, grass swales) will achieve a certain efficiency. However, there is mounting evidence that (Schueler, 1995) that efficiency is related to the influent concentration; the lower the influent concentration the lower the efficiency, and that there may be a lower limit in effluent quality. Therefore, for this basin plan effluent concentrations were selected based on the analysis by Schueler (199x) and a review of the results from the field studies on several treatment systems located in the Pacific Northwest. After selecting the effluent concentration, an annual effluent loading was calculated. The results are presented in Table DD.5.

TABLE DD.5 UNIT LOADINGS FROM NEW DEVELOPMENTS AFTER TREATMENT

LAND USE	TSS		Phosphorus		Zinc	
	Conc[1]	Load[2]	Conc	Load	Conc	Load
Parks	25	80	0.1	0.35	0.040	0.15
Government	25	215	0.1	0.85	0.075	0.65
MD residential	25	95	0.1	0.40	0.075	0.30

HD residential	25	175	0.1	0.70	0.075	0.50
Commercial	25	215	0.1	0.85	0.075	0.65
Industrial	25	215	0.1	0.85	0.075	0.65

1. All concentrations in mg/L 2. All loadings in pound/acre/year

Estimated loadings

The above procedure was followed with the results presented in Tables DD.6 through D.14. Tables DD.6 through DD.8 are for existing land use for TSS, phosphorus, and zinc, respectively. Tables DD.9 through DD.11 are for these three pollutants for future land use without treatment, and Tables DD.12 through DD.14 are for the same pollutants for future land use with treatment.

CONSTRUCTION SITE SEDIMENT AND PHOSPHORUS

The same procedure previously described on estimating unit loadings from developed land was followed in the generation of likely loadings of sediment and phosphorus from construction sites. There is little published data on the concentrations of phosphorus and sediment, or TSS, that can be expected from construction sites. It would be expected that the concentrations will vary considerably between sites as a function of the soil and the types and effectiveness of soil erosion and control BMPs. Data from six construction sites in Redmond, Washington (Resource Planning Associates, 1998) indicate that where large sediment ponds are used the TSS in the effluent could be on the order of 100 to 400 mg/L. It is not known if sediment concentrations will be higher from sites that do not use sediment ponds. Given the uncertainty, a low and high concentration were selected: 100 and 500 mg/L. With regard to phosphorus, examination of an unpublished data base for one site in western Washington where samples were analyzed for both TSS and phosphorus, the following relationship was developed: TP = 0.003(TSS), both constituents in mg/L. The R^2 was 0.45. A runoff coefficient of 0.70 was used. The following unit loadings were determined.

TABLE DD.15 SEDIMENT AND PHOSPHORUS FROM CONSTRUCTION SITES

SITUATION	LOADING - POUNDS/ACRE/YEAR
TSS loading at 100 mg/L	745
TSS loading at 500 mg/L	3,726
TP loading at a TSS of 100 mg/L	2.24
TP loading at a TSS of 500 mg/L	11.18

The next step is to estimate the number of acres that will be developed each year in each watershed. The total number of acres that will be developed in each watershed was calculated by comparing Tables DD.2 and DD.3. The next consideration is the time period over which the acreage will be developed. A range was selected: 10 years and 20 years. Adding together all of these elements leads to the ranges in sediment and phosphorus loads summarized by subbasin in Table DD.16.

STREAM CHANNEL EROSION AND PHOSPHORUS

Estimates of accelerated erosion of stream channels is based on the anticipated increases in the peak flows of the 2-year event as simulated by HSPF (Chapter 4). The 2-year event is selected because research indicates that the cross-section of a stream channel is determined primarily by storms whose volume and rate cause what is called "bankfull" conditions, and that the return frequency of these storms is on the order of 1 to 2 years. The results are presented in Table DD.17.

A range is provide, reflecting the uncertainty in the increase in the peak flow rate, a recognition that erosion is a function of flow duration as well as flow rate, and the variability of the existing cross-sectional area of the stream channel. The cross-sectional areas shown in Table DD.17 when the flow is at bankfull. The quantity shown is the total amount of erosion which will occur over several decades. For three of the creeks only the stream length south of SR 92 is considered since the area north of SR 92 will remain low-density residential. This is not to state, however, that no erosion will occur in the respective channels north of SR 92. A significant conversion of forested to pasture land cover will increase storm flows and therefore erosion. The estimates of phosphorus use the relationship identified for erosion from construction sites.

TABLE DD.17 ESTIMATES OF CHANNEL EROSION

CREEK	STREAM LENGTH	EXISTING CROSS-SECTION	INCREASE IN THE PEAK OF THE TWO YEAR EVENT	ESTIMATED RANGE OF SEDIMENT[2]	ESTIMATED RANGE OF PHOSPHORUS[3]
Upper Catherine	6,000[1]	10 to 20 ft^2	15%	500 to 1000	3,000 to 6,000
Lower Catherine	6,800	25 to 40 ft^2	21%	2,500 to 3,500	15,000 to 21,000
Stevens Creek	5,000[1]	5 to 10 ft^2	44%	1,000 to 2,000	6,000 to 12,000
Lundeen Creek	5,000[1]	5 to 10 ft^2	36%	500 to 1,000	3,000 to 6,000
Kokanee Creek	1,000	2 to 5 ft^2	8%	15 to 40	90 to 240
Stitch Creek	2,000[4]	5 to 10 ft^2	51%	250 to 500	1,500 to 3,000

1. South of SR 92. 2. Tons 3. Pounds 4. Between 20th SE and Stitch Lake

The amount of erosion in upper Catherine Creek, Stevens Creek and Lundeen Creek may be overstated because each has a large wetland area in the lower area of each stream. The estimates in Table DD.17 might reasonably to occur in the wetlands are developed and the stream is channelized as a result. The channel in Catherine Creek is well defined through the wetland suggesting that cross-sectional enlargement will approximate what is estimated in Table DD.17. A reasonable assumption is that the erosion will occur over a 50 year period.

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TABLE 5.10 ESTIMATED CHANGE IN POLLUTANT LOADINGS DURING STORMS FROM LAND SURFACES

5.10A LOADINGS IN TONS OR POUNDS PER YEAR

WATERSHED Loading Point	TSS[1]			PHOSPHORUS[2]			ZINC[2]		
	Exist	Future w/o treat	Future w treat	Exist	Future w/o treat	Future w treat	Exist	Future w/o treat	Future w treat
CATHERINE CREEK WATERSHED									
Catherine Creek at Hartford Dr	121	136	98	558	734	555	177	465	348
Outlet Channel@20th NE	22	xx	xx	129	xx	xx	89	xx	
Outlet Channel at Catherine Ck	54	94	58	288	554	373	165	358	246
Catherine Creek at L. Pilchuck	192	267	174	933	1500	1047	375	955	673
LAKE STEVENS WATERSHED									
Stevens Creek	60	77	55	265	416	286	57	251	171
Lundeen Creek	46	73	42	214	422	269	67	257	167
Kokanee\Mitchell Creek	35	39	35	199	226	203	123	146	132
Stitch Creek	45	75	39	232	445	271	119	299	195
Total to Lake Stevens	272	432	242	1340	2516	1584	576	1616	1061

1. Tons per year 2. Pounds per year

5.10B PERCENTAGE INCREASE

WATERSHED Loading Point	TSS		PHOSPHORUS		ZINC	
	Future w/o treat	Future w treat	Future w/o treat	Future w treat	Future w/o treat	Future w treat
CATHERINE CREEK WATERSHED						
Catherine Creek at Hartford Drive	12%	-19%	33%	0%	163%	97%
Outlet Channel@20th NE	xx	xx	xx	xx	xx	xx
Outlet Channel at Catherine Creel	74%	7%	92%	30%	117%	49%
Catherine Creek at Little Pilchuck River	39%	-9%	61%	12%	155%	79%
LAKE STEVENS WATERSHED						
Stevens Creek	28%	-8%	57%	8%	340%	207%
Lundeen Creek	59%	-9%	97%	26%	200%	107%
Kokanee\Mitchell Creek	11%	0%	14%	2%	19%	7%
Stitch Creek	67%	-13%	92%	17%	151%	64%
Total to Lake Stevens	59%	-11%	88%	18%	181%	84%

ESTIMATES OF PHOSPHORUS LOADING FROM BASE FLOWS

Estimates are summarized in Table DD.11. The estimates in Table DD.11 for inputs to Lake Stevens were calculated as follows. The estimated mean annual, surface and groundwater, inflow is 10,496 acre-feet derived from HSPF modeling in this study. This total flow was apportioned to the individual watersheds based on the percentage of the lake watershed represented by the particular individual basin in Table DD.11. The proportionate flow was then multiplied by the assumed average concentrations (low and high) in Table DD.11 to give the range in annual loadings in pounds per year. The assumed average concentrations are based on field data collected in this study and in 1994 (KCM, 1995). The estimates in Table DD.11 overstate the loading of phosphorus from base flows as the total mean annual flow also includes storm flows.

The HSPF modeling did not generate a mean annual surface flow for Catherine Creek. Its flow was therefore estimated to be in proportion to that calculated for Lake Stevens. The total acreage of the Catherine Creek watershed is 3,249 acres, about the same as the Lake Stevens watershed. About 286 acres drains directly to the Lake Stevens Outlet Channel. To the flow in the Outlet Channel and lower Catherine Creek is added the outflow of Lake Stevens which is estimated by the HSPF modeling to be 8,355 acre-feet per year.

With regard to the future, it is assumed that loadings from base flows will remain constant although this will not likely be true. With increasing urbanization it is likely that the phosphorus concentrations in the groundwater and therefore base flows will increase because of lawn fertilization, based on the review of regional data bases (Metro, 1994). However, the data from Kokanee Creek (KCM, 1995), as presented in Chapter 5, indicate that groundwater concentrations do not necessarily always increase with urbanization.

TABLE DD.11 ESTIMATED ANNUAL PHOSPHORUS LOADS FROM BASE FLOWS

WATERSHED POINT	ACRES	CONCEN TRATION	PROPORTIO NATE FLOW[1]	LOAD
Catherine Creek at Hartford Dr	3047	0.035\0.070	9753	928\1857
Outlet Channel at 20th NE	120 + 3279[2]	0.015\0.030	8564	349\698
Outlet Channel at Hartford Dr	286 +3279	0.015\0.030	9064	370\739
Catherine Creek at L. Pilchuck	3249 + 3279	0.035\0.070	18852	1793\3587
Stevens Creek	878	0.035\0.070	2810	268\535
Lundeen Creek	634	0.035\0.070	2030	192\385
Kokanee\Mitchell Creek	153	0.010\0.020	267	13\26
Stitch Creek	528	0.025\0.050	1690	115\230
Remainder to Lake Stevens	1086	0.020\0.035	3476	188\330

1. Annual flow in acre-feet
2. Acreage of Lake Stevens watershed

APPENDIX F

Invertebrate Sampling Results

INVERTEBRATE DATA

PROCEDURES

Triplicate invertebrate samples were collected at each of the following locations on the dates indicated. A Surber net was used to collect the samples, following standard procedures. The samples were enumerated and the organisms were identified by Aquatic Biology Associates of Corvallis, Oregon.

DATE	STATION	LOCATION
September 25, 1997	A	Catherine Creek, 100 to 200' upstream of SR92
	B	Catherine Creek, 50 to 100' upstream from 36th NE
	C	Catherine Creek, 200 to 250' upstream of confluence with the Little Pilchuck
September 30, 1997	D	Lake outlet channel between Main Street to 20th NE.
	E	Lake outlet channel, near outlet of lake, just upstream of District control weir
	F	Catherine Creek, about 150' downstream of 20th NE
	G	Repeat of Station C

The invertebrate data were evaluated by Ms. Leska Fore, an independent invertebrate consultant. The essential conclusion of the invertebrate sampling is that the numbers of invertebrates are very low in Catherine Creek in the late summer because the flow in the creek is very low; a reflection of the water levels in Lake Stevens and Lake Cassidy. Hence, invertebrate populations as a food source may be limiting. Ms Fore calculated a biological index, B-IBI. A value above about 25 is expected of streams unaffected by urban development. Streams affected by urban development tend to have B-IBI scores less than 20 (May, 1997).

REVIEW OF INVERTEBRATE DATA

For the Catherine Creek watershed, 7 stream sites were sampled for benthic macroinvertebrates. Five of the seven sites sampled in Catherine Creek had very few numbers of individuals (< 50) collected in each Surber sampler. Sites D and F had more individuals: average number per Surber sample was 292 (site D) and 143 (site F).

Abundance at a site can be low for two reasons: 1) conditions may be extremely degraded or 2) sampling effort may be inadequate to characterize the site. When sample sizes are very small, it is difficult to distinguish between these two possible reasons. Small sample sizes affect taxa richness metrics because the more individuals you collect, the more different kinds you find. A minimum number of individuals is required to be confident that you have collected a representative sample of the taxa present at a stream site. (note:

a third reason was identified in discussions with Ms. Fore, the extremely low flows. It was concluded that this was the reason for the low invertebrate numbers. Given that this is a rural area, degradation would not be expected to be a factor except possibly at Station D. However, Station D had the highest invertebrate densities although it was missing intolerant species, suggesting adverse effects of urbanization. See below).

For Stations D and F there were (almost) adequate numbers to calculate a benthic index of biotic integrity (B-IBI). I have used the same methods to calculate the index that were used to calculate index values reported in May et al. (1997). Since that paper was published, many of the metrics have been changed or modified to Improve the index. Metrics that are the same include: total taxa richness, mayfly taxa richness, stonefly taxa richness, caddisfly taxa richness, intolerant taxa richness, long-lived taxa richness, and percent tolerants. One metric that was used in May et al. (1997) is no longer considered to be reliable: percent planaria and amphipods. The last metric, percent of *taxa* that are predators, is measured instead as percent of *individuals* that are predators. Two metrics have been added: clinger taxa richness and percent relative abundance of the three most abundant taxa (percent dominance). See Karr (1998) for references to the published tests of these metrics.

The B-IBI calculated for these sites includes nine metrics scored as a I (for a very poor metric value), 3 (moderate value) or 5 (good to excellent). The metric scores are summed to provide an index ranging from 9 to 45 .

Station A: This site had an average of 23 individuals collected in each sample. I suspect this site is not as degraded as Station D because two different taxa of stonefly were found. Stoneflies are some of the most sensitive taxa in this region and are not typically found in extremely degraded streams in the Puget Sound lowland area. In addition, an intolerant caddisfly *(Apatania)* and a predator caddisfly *(Rhyacophila blarina)* were found at this site which indicate a less disturbed site.

Station B: This site had an average of20 individuals per Surber; too few to compute a B-IBI. As for Station A, two taxa of stonefly and two taxa of mayfly indicate a better site than Station D. In addition, an intolerant caddisfly *(Apatania)* and a predator caddisfly *(Rhyacophila blarina)* were found at this site which indicate a less disturbed site.

Station C: Very low numbers at this site, less than 10 on average. Many ofthe taxa found at this site were tolerant. I could not make any conclusions because the sample was too small.

Station D: Sample size was large enough to calculate a B-IBI. The low index score is probably correct because there were no stoneflies present and only one taxum each of caddis and mayfly. There were no intolerant or long-lived taxa found in the sample.

B-IBI =13

Station E: Two samples for this site averaged 34 per Surber. Only six taxa were found, most were tolerant taxa. The presence of an odonate suggests a pool or slow water I could not make any conclusions because the sample was too small.

Station F: Although the number of individuals collected was somewhat low, I have calculated the index with the information here. I suspect a larger sample would increase the index scores because four different stonefly taxa were found along with three long-lived taxa. The presence of a mussel (Sphaeriide) was also indicative of a less disturbed site; these animals are very sensitive to sediment.

B-IBI = 17

Station G: Very small number collected at this site (21) and only one replicate. Three different taxa of stonefly collected at this site suggest that it may not be as severely degraded as other sites.

Conclusions: I am very hesitant to compare these streams because of the very low numbers of individuals collected. Based on the narrative statements above, I would tentatively conclude that Stations A, B, F, and possibly G are in better condition than Station D. Stations A, B, and F had higher taxa richness overall and had a greater variety of mayflies, stoneflies and caddisflies present than at Station D. I can't say anything about Stations C or E because I don't know if those stations look poor because they are poor or because not enough individuals were collected (see previous note above concerning the effects of low flow). Two stations had large enough samples to compute a B-IBI score. Those scores of 13 and 17 are near the low end of a scale that ranges from 9 to 45.

I am confident that Station F had higher biotic integrity than Station D. Station F had greater taxa diversity overall as well as in key groups of mayflies, stoneflies and caddisflies. Most of the animals collected at Station D were of a single type of tolerant caddisfly *(Cheumatopsyche):* Station F also had two long-lived beetles, Station D had no long-lived animals. These animals need more than one year to complete their life cycle and may be sensitive to high flows that can flush the channel

Tentative comparisons of other stations were based primarily on the presence and richness of stoneflies (Plecoptera). Stoneflies are some of the first invertebrates to disappear as sediment eliminates their preferred habitat (the spaces between cobble) and as temperatures increase. The stoneflies collected in these samples were shredders and predators, as are most stoneflies. Shredders eat leaves which are less available in streams with no riparian trees or in streams that experience high, scouring flows. Predators need a steady supply of prey and places between rocks to hunt them. For these reasons, the number of different types (or taxa) of stoneflies at a site is a strong indicator ofthat site's condition. This is especially true for the types of human disturbance that affect Puget Sound lowland streams.

Stations A, B, F, and G had more than one taxum of stonefly; and I would tentatively conclude that these sites were in better condition. Station D had enough individuals collected that stoneflies would probably not be found with a slightly larger sampling effort. Stations B and C, on the other hand, had too few individuals in the sample to know if more sampling effort would yield stoneflies, long-lived taxa, or other less tolerant animals; or if it would yield simply more of the same types of animals already collected.

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APPENDIX G

Fish Refuge Survey Results

A POSSIBLE PROCEDURE TO ESTIMATE THE AMOUNT OF STORM REFUGE

Fish needs and preferences with regard to refuge from storms are not well understood. For obvious reasons few field inventories have been completed in streams or rivers to identify where fish are during these periods. This appendix contains a review of selected literature on the subject with a particular focus on one study that considered the question; a PhD thesis by K. Sullivan (Sullivan, 1986). Based on this literature a concept is put forth on how to semi-quantitatively evaluate storm refuge habitat.

Clearly, complex hydraulic conditions are required so that the fish find refuge. The problem for urban streams is that irrespective of flow conditions, it is possible that the types of refuge that fish ideally prefer are limited There is no accepted protocol for estimating refuge area in urban streams. In this study a preliminary concept developed by the Resource Planning Associates was used to estimate the amount of refuge area. A comparison is made to limited data on refuge habitat in non-urban streams that is less affected by human activity. This study found the habitat types that appear to be most suitable for storm refuge are off-channel pool areas, lateral backwater areas, damned pools, and eddy pools. Used to a far lesser extent are plunge and scour pools. Cover and substrate are important as explained below.

RESEARCH

Sullivan (1986) evaluated how habitat types change between winter base and storm flow conditions. Thirteen stream sections were examined in southwest Washington. The return probability of the high flows examined in each of the sections ranged from 90% to 99%, that is 10 to 1% of flows would be greater than what was measured. Bank full was believed to be at about 98.7%; that is, the maximum flow evaluated in each section were generally less than bank full and therefore less than about the 2-year event. Sullivan based habitat suitability (for coho fry) on hydraulic conditions, specifically depth and velocity. Her analysis tended to indicate that the habitat types suitable for refuge during storms included secondary side channels, and backwater and eddy pools, cascade-boulder pools, and some channel edges that come into existence during higher flows that meet both the depth and velocity criteria. Sullivan found that during the winter most of the coho fry were in damned and eddy pools. Scour and plunge pools were not suitable.

Several other studies have examined fish preferences during winter conditions although not necessarily during storm flows. Nickleson, et al. (1992a) found that log, gabion and rock structures placed across the stream full width provided good summer habitat but poor winter habitat for juvenile coho. Rearing densities in constructed habitats were generally similar in winter and summer to their natural counterparts except that constructed dam pools had lower winter densities than natural damned pools. The addition of brush bundles increased the density in damned pools but not plunge pools. The authors concluded that development of off-channel habitat provided best and beaver ponds over backwater pools during the winter. They concluded that the lack of these habitat types is probably the limited factor on production. Quinn et al. (1996) found that the over-winter survival of juvenile coho was most weakly correlated with hydraulic complexity but strongly correlated with the quantity of woody debris and density of habitat units and distance from the estuary. Larger fish had a higher survival rate. Shirvell (1990) observed that juvenile coho increased their use of rootwads when flows increased. Moore et al. (1988) observed that cutthroat fry prefer lateral areas during their first summer in preference to the main channel.

Several researchers found that salmonids prefer covered areas in the winter, the point being that if potential refuge unit or adjacent units do not have suitable cover, the refuge unit may not used because the fish does not find it. These studies include: McMahon, et al. (1989), coho; Bustard et al. (1975), juvenile coho and cutthroat; Cunjak, et al. (1986), brook and brown trout; Heifetz et al. (1986), coho, Dolly Varden, and steelhead; and Heggenes et al. (1991), cutthroat trout. Thus, an assessment of refuge habitat based solely on hydraulic criteria without including cover considerations likely overstates the amount of such habitat.

This consultant relied upon the work of Sullivan (1986) to develop a tentative approach to evaluate semi-quantitatively the amount of possible storm refuge habitat in a urban stream. Basing the approach on only one study raises considerable uncertainty. However, it is the only such study located to this point. Trout Unlimited Canada is preparing an annotated bibliography on the winter biology of salmonids which may identify additional relevant studies. However, the bibliography is overdue from the consultant and Trout Unlimited is uncertain when it will be completed.

Four of the eight stream sections evaluated by Sullivan during storm flows were monitored at flows near bank full (>99%). The four sections varied in length from 8 to 22 meters. Sullivan (1986) divided each of these sections into 1 x 1 meter units. Sullivan determined the average depth and velocity in each unit at winter base and storm flows. Each unit was then characterized as to its acceptability to juvenile coho: optimal, usable, non-usable. The Consultant took data generated by Sullivan for these four stream sections and summed the optimal and useable units, and the total number of units of each habitat type. The sums are presented in Table ZZ.1.

TABLE ZZ.1

	STREAM SECTION number of acceptable units/ total number of units					**PERCENTAGES**		
TYPE	**#3**	**#8**	**#9**	**#11**	**TOTALS**	**OF TYPE**	**OF REFUGE**	**OF AREA**
Slope	*2.4*	*4.1*	*4.8*	*3.2*				
Riffle	6/41	2/27	0/6	0/0	8/74	11%	9%	3%

Cascade	0/7	0/0	1/18	3/43	4/68	6%	4%	2%
Rapids	0/4	0/0	0/0	0/0	0/4	-	-	-
Eddy pool	0/5	11/9	11/10	0/0	22/24	92%	23%	8%
Damned pool	0/0	0/0	14/16	0/0	14/16	88%	15%	5%
Plunge pool	0/0	3/18	0	0/0	3/18	17%	3%	2%
Scour pool	3/40	0/0	0	0/0	3/40	9%	3%	2%
Secondary channels	0/0	0	0	0/0	0/0	-	-	-
Undefined new edge areas	18	4	18	0	40	-	43%	14%
TOTALS	27/ 115	20/58	44/68	3/43	94/284			

Most of an eddy or damned pool continues to be suitable during storms. The percentages of each of the other four habitat types that is suitable is much less but not insignificant. The greatest percentage of refuge areas was represented by edge areas along the stream that became wetted during the storm. As Sullivan identified habitat type only at base flows, these new edge areas could not be correlated with any particular habitat type. As no off-channel areas were formed in any of the four test sections it could be assumed that the new edge areas are reflected in each habitat type in proportion to their presence at base flows.

The suggested approach is to walk the stream, visualizing hydraulic conditions at near bank full. Specific habitat types listed in Table ZZ.2 are identified. Eddy areas on the downstream side of the inside of bends are identified by the substrate. If the substrate is silt or very fine sands, it is assumed that bottom velocities due not exceed 1.5 fps, which makes the area a possible storm refuge area. The square footage of each refuge type is measured approximately. Each type is summed and multiplied by the assumed percentage of that habitat type that remains suitable for refuge. These percentages are presented in Table ZZ.2.

TABLE ZZ.2 % OF EACH HABITAT TYPE SUITABLE FOR STORM REFUGE ASSUMING IT MEETS COVER REQUIREMENT

	% OF EACH SUITABLE FOR REFUGE
Cascade	5%
Eddy pool	90%
Damned pool	90%
Plunge pool	15%
Scour pool	10%
Backwater areas	100%

APPLICATION OF THE RESEARCH TO CATHERINE CREEK

The procedure is to walk the stream, identifying relevant refuge types, and the approximate area of each at both the flow during the inventory and at bankfull. The type and quality of the cover is noted. The candidate area must also meet a substrate requirement of fine sand or silt. Anything larger in size indicates that velocities are likely greater than the velocity criterion for small fish like coho fry (1 fps).

The results of this refuge inventory for Catherine Creek are summarized in Table ZZ.3. Specific areas of possible refuge are presented in Table ZZ.4. There is little refuge in lower Catherine Creek. As a comparison, using data from Sullivan (1986), we estimate that 20 to 30% of the creek sections that she studied met the depth and velocity criteria of refuge habitat. Given that these were forested streams they also likely met the cover criterion. In comparison, about 7% of lower Catherine Creek might be considered suitable refuge. This calculation is based on Table ZZ.3 and an estimated total stream area for lower Catherine Creek of about 40,000 ft^2 (about 2,600 feet with an average width of about 15 feet). Nonetheless the percentage of the creek that provides refuge is considerably less than observed by Sullivan in nonurban streams. It is also noted that all of the estimates of refuge in Table ZZ.3 assume that adequate cover is present, even though this is not likely the case.

TABLE ZZ.3 ESTIMATE OF STORM REFUGE AREA FOR LOWER CATHERINE CREEK

	APPROXIMATE AREA OF EACH IN LOWER CATHERINE	% OF EACH SUITABLE FOR REFUGE	AREA OF EACH SUITABLE FOR REFUGE
Cascade	0	5%	0
Eddy pool	1710	90%	1539
Damned pool	945	90%	850
Plunge pool	1150	15%	172
Scour pool	2915	10%	292
Backwater areas	800	50%	0
		TOTAL	2853

Lower Catherine Creek has little refuge habitat because it lacks the appropriate pools of adequate depth and cover. The stream banks lack the complexity of a natural stream such as rooted areas or root wads, that would afford protection. The upper part of this creek section is incised with little or not material along the banks to afford protective areas. The only pools through here are center channel scour pools that offer essentially no protection during storms as implied in Table ZZ.3.

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APPENDIX H

Interlocal Agreements

After Recording Return To:
Snohomish County Public Works
Surface Water Management - 3rd Floor
Attn.: Ms. Joan M. Lee, P.E., Director
2930 Wetmore Avenue
Everett, Washington 98201-4044

INTERLOCAL AGREEMENT AMONG SNOHOMISH COUNTY, THE CITY OF LAKE STEVENS, AND DRAINAGE IMPROVEMENT DISTRICT #8 REGARDING STORM AND SURFACE WATER MANAGEMENT SERVICES IN THE LAKE STEVENS URBAN GROWTH AREA

THIS AGREEMENT is made and entered into this 26th day of August 1998, by Snohomish County, a political subdivision of the State of Washington (hereinafter referred to as the "County"), the City of Lake Stevens, a city incorporated under the laws of the State of Washington (hereinafter referred to as the "City") and Drainage Improvement District #8, a special service district established under the Revised Code of Washington Chapter 85.08 (hereinafter referred to as the District).

WHEREAS, the Lake Stevens urban growth area (UGA) includes several watersheds and surface water service responsibilities in some of those watersheds are shared among the County, City, and District (hereinafter referred to as the "Jurisdictions" when referring to all three service providers); and

WHEREAS, the Jurisdictions desire to work together to conduct and fund watershed management activities that benefit the residents and environment of the Lake Stevens area;

WHEREAS, the Jurisdictions are committed to providing storm and surface water services effectively and efficiently through more consistent policies, practices, service levels, and rates; and

WHEREAS, it is crucial that an initial operating agreement be put in place that establishes the baseline policies, roles and responsibilities of the Jurisdictions in providing storm and surface water services within the UGA; and

WHEREAS, pursuant to RCW 39.34, the Interlocal Cooperation Act, the parties are each authorized to enter into an agreement for cooperative action. Additionally, pursuant to Article I, Section 1.30 of the County Charter, the County is authorized to enter into a cooperative agreement:

NOW, THEREFORE, in consideration of the terms and conditions contained herein, it is mutually agreed as follows:

Section 1. Parties and Purpose of this Agreement.

1.1 Parties to this Agreement are the County, City and District should each execute this agreement. If one of the executing parties fails to execute this agreement all references to the non-executing party shall be null and void. If an annexation during the term of this agreement results in the assumption of one of the Jurisdiction's service area, it will no longer be a party to this agreement.

1.2 This Agreement provides a framework for the Jurisdictions to further develop specific operating roles and responsibilities regarding cooperative storm and surface water planning and management, service charges and rates, service levels, and annexations in the Lake Stevens UGA.

Section 2. Definitions.

For the purpose of this Agreement, the following words shall have the following meanings, unless another meaning is clearly intended:

2.1. "Area of Influence" is the area outside of the UGA that drains into or out of the UGA.

2.2. "City Council" means the City Council of Lake Stevens, the governing body of the City.

2.3. "City's Jurisdiction" means the service area and storm water system for which the City has primary responsibility for providing urban local storm and surface water services within the City limits, except for the Lake Stevens outlet channel within the City limits. In the event the District fails to execute this agreement, the City's Storm and Surface Water Utility will assume jurisdiction for all storm and surface water systems and services within the city's corporate limits.

2.4. "County Council" means the County Council of Snohomish County, the governing body of the County.

2.5. "County's Jurisdiction" means the service area within which the County is responsible for providing urban local storm and surface water services.

2.6. "District Commissioners" means the Board of Commissioners of Drainage Improvement District #8, the governing body of the District.

2.7. "District's Jurisdiction" means the service area within which the District is responsible for providing urban local storm and surface water services.

2.8. "Ecology" means the Washington State Department of Ecology, or its successor.

2.9. "Facilities" means the physical improvements made to the public storm and surface water system including treatment, conveyance, storage and discharge.

2.10. "Flow" means the volume of storm water flow measured in cubic feet per second.

2.11. "Jurisdictions" means Snohomish County, Drainage Improvement District #8 and the City of Lake Stevens.

2.12. "Operation and Maintenance" means the regular performance of work required to assure continued functioning of the storm and surface water system and corrective measures taken to repair facilities in order to keep them in operating condition.

2.13. "Overhead Costs" means the general administrative, supervisory, and other indirect costs related to the operation of the storm and surface water system.

2.14. "Rates and Charges" are defined as the amount charged to customers, system users and/or system beneficiaries for services provided by the Jurisdictions.

2.15. "Regional Services" are those services provided by the County in both incorporated and unincorporated areas as funded by all properties served within these areas. Regional services are not transferred to the local service provider after annexation or incorporation of the service area except as provided for herein. For purposes of providing guidelines on the potential areas of regional services Exhibit C is attached hereto.

2.16. "Service Standards" means the standards to which operations, maintenance and capital facilities will be provided.

2.17. "Service Levels" are defined as an amount, intensity or quantity of service provided through storm water programs and projects.

2.18. "Standards" means the standards and conditions of use of the storm and surface water system as adopted by the Jurisdictions.

2.19. "Storm and Surface Water Charge" means a regular charge to a property owner or occupant of designated premises for the estimated contribution of runoff or nonpoint source pollution, or both, to the storm and surface water system.

2.20. "Storm and Surface Water Assessment" means a regular charge to a property owner or occupant of designated premises for the estimated use of, or benefits related to, runoff or nonpoint source pollution to the storm and surface water system.

2.21. "Storm and Surface Water System" means any combination of publicly owned storm and surface water treatment facilities, pumping equipment, storm drain pipes and culverts, open channels, creeks and rivers, manholes, catch basins, grates and covers, detention and retention facilities and other publicly owned facilities for the collection, conveyance, treatment, and disposal of storm and surface water comprising the total publicly owned system within the watershed.

The system also includes any privately owned facilities over which the Jurisdictions may have maintenance rights.

2.22. "Storm and Surface Water Facilities Charge" is a one time fee applied to new development or other construction activity that results in or is likely to result in an increase of runoff or nonpoint source pollution from the site were it to remain under natural conditions. Such fee is for the capital improvements and public costs associated with providing the system capacity and facilities necessary to accommodate additional connections to the system as authorized for cities under RCW 35.92.020 and for counties under RCW 36.94.

2.23. "Urban Local Services" are those storm and surface water services provided by the County, City or District within their jurisdictions. For purposes of providing guidelines to the Jurisdictions on the potential areas of urban local services Exhibit B is attached hereto.

Section 3. Management Structure.

3.1. Advisory Committee. Activities conducted pursuant to this Agreement shall be coordinated through the "Storm and Surface Water Advisory Committee" (Committee). The Committee shall be the ongoing mechanism for County, City and District to communicate and coordinate regarding storm and surface water management-related policy actions in the Lake Stevens UGA.

A. The Committee will be composed of two elected officials from each of the three Jurisdictions. Each Jurisdiction shall select its own representatives.

B. The Committee will meet at least on a quarterly basis and may meet more frequently if agreed to by its members.

C. The Committee's overall objective is to annually prepare a jointly developed storm and surface water work program for review by their respective elected bodies and to coordinate a discussion of the rates to be charged in the UGA, cost requirements, and impacts to rate payers. The Committee's policy and coordination work will include recommendations for annual storm and surface water work programs for the UGA, levels of service, financial plans and funding arrangements for surface water services.

D. Recommendations shall be made by majority vote, provided that no action of the Committee can obligate a Jurisdiction without the approval of that Jurisdiction to the proposed action.

E. If one of the Jurisdictions does not execute this agreement, it shall be ineligible from participation in committee membership. Voting will be subject to the majority rules described above for the signature parties.

3.2. Management Leadership Team (MaLT).

A. A Management Leadership Team (MaLT) will be formed. The MaLT will be composed of a senior member from each Jurisdiction's management team to be designated by the Jurisdiction.

B. The MaLT will meet at least on a monthly basis to coordinate implementation of this Agreement and provide staff support (including information packages) for their elected officials on the Committee. The MaLT will also draft the annual storm and surface water work program for the UGA and will develop addendum language to this Agreement that addresses specific outstanding issues identified by the Committee.

3.3. Committee Staffing. Until a majority of the Jurisdictions shall agree to the contrary, the City will be responsible for staff support related to meetings of the Committee and MaLT operations, including notification to all participants, providing a site, agenda preparation, and minutes preparation.

Section 4. Activities.

4.1. Phase 1 Operating Addendum. Within six (6) months of this Agreement being fully executed by the Jurisdictions, or by December 31, 1998, whichever is earlier, the Committee shall prepare a Phase 1 operating addendum to this Agreement that addresses each of the following issues:

A. *Service Levels.* Service levels will be proposed for adoption including the policies, standards, specifications and performance criteria necessary for effective operation of the storm and surface water system in all or specific portions of the UGA.

1. Proposed service levels in the Lake Stevens UGA shall be consistent with: 1) at least the minimum standards established in Ecology's Stormwater Management Manual for the Puget Sound Basin; and 2) facility design criteria either established or to be established through surface water plans approved by the affected Jurisdictions.
2. Appropriate maintenance procedures for public and private surface water facilities will be addressed.
3. The Operating Addendum shall include a requirement that if an area in the rural area of influence is added to the UGA, it will be subject to the higher levels of storm and surface water service designated for the UGA.

B. *Surface Water Planning.* The County's regional role in surface water planning and how the City and District participate in that regional planning will be clarified.

C. *Service Responsibilities.* Specific short- and long-term responsibilities of the Jurisdictions in providing urban local services in the City will be recommended. Clarification of other services in the unincorporated UGA will be accomplished using Exhibit D as a basis for further discussion.

D. *Debt and Facilities.* The appropriate transfer of debt incurred or facilities built prior to this Agreement will be addressed.

E. *Duplications.* Any duplications in service will be identified and recommendations will be made as to how to eliminate unnecessary duplication.

F. *Funding.* The operating addendum will identify the cost of service, revenue requirements, options for development of a facilities charge, long-term costs for maintenance of identified regional facilities (particularly the Lake Stevens aerator), and appropriate analysis in support of each Jurisdiction's proposed rates in the UGA.

G. *Annexations/Incorporations.* The operating addendum will address annexations and related transition of services. Specific objectives will be to: 1) ensure that annexations do not affect the County's regional services and costs; and, 2) balance the costs and timing of service obligations incurred by the City or District with the transition of revenues from the previous service provider.

H. *Relationship of Area of Influence to this Agreement.* The operating addendum will identify the need for extension of any aspect of this Agreement to the Area of Influence.

4.2. <u>Phase 2 Operating Addendum.</u> A Phase 2 operating addendum that addresses outstanding issues identified in 4.1.H above will be initiated after completion of the Phase 1 addendum. As part of its ongoing work, the Committee may continue to identify additional outstanding issues that may be incorporated into additional operating addenda to this Agreement.

4.3. <u>Private System Conversion</u>. The County, City and District will jointly pursue conversion of mutually agreed upon storm and surface water facilities from private to public ownership through the acquisition of easements and other property rights.

4.4. City Responsibilities.

A. The City shall be responsible for urban local surface water services and for the installation, construction, operation, maintenance, repair, replacement, financing, inspection and plan review of local storm and surface water facilities within its jurisdiction, except for those services which are specifically to be provided by the District as set forth herein.

B. Specific elements of the City's responsibilities may be contracted with the County or the District.

4.5. County Responsibilities.

A. The County shall be the local and regional service provider in areas designated as rural by the County's General Policy Plan.

B. In the Lake Stevens UGA, the County shall be responsible for urban local surface water services and the installation, construction, operation, maintenance, repair, replacement, financing, inspection and plan review of local storm and surface water facilities in its jurisdiction. Exhibit B of this Agreement shows the elements of urban local services, except for those services which are specifically to be provided by the District as set forth herein.

C. The County shall be the regional service provider in the UGA including retaining ownership and operating responsibility for any regional facilities that the Jurisdictions identify in the District or City.

4.6. District Responsibilities. The District shall be responsible for provision of urban local storm and surface water services in its jurisdiction in the UGA. The District shall be responsible for urban local surface water services and for the installation, construction, operation, maintenance, repair, replacement, financing, and inspection of local storm and surface water facilities within its jurisdiction, which shall include, but are not limited to the performance of its historic functions including currently provided services related to lake level management, water quality monitoring, and maintenance of a weather station.

4.7. Cooperative System Development. The County, City and District, acting through the Committee, shall cooperatively plan, and when appropriate, cooperatively finance and construct, storm and surface water systems within the Lake Stevens UGA. This system development shall be in accordance with defined service levels (as adopted in the Operating Addendum) and will anticipate the eventual transition of this area into the City's corporate boundaries.

4.8. Regional Facility Maintenance.

A. The County shall retain responsibility for operation and maintenance of regional facilities which it constructs unless an annexation encompasses such a facility and it is mutually agreed by the County and the City or District that the City or District can provide operation and maintenance services more efficiently or effectively than the County. County maintenance of these facilities may be conducted under either the existing maintenance service structure or under a service contract between the District or City and the County.

B. The Lake Stevens aerator is a facility with both local and regional aspects. It is anticipated that the City will retain ownership of the aerator and the County will continue to maintain the facility under the existing cost-sharing agreement with the City and District. The potential transfer of maintenance responsibilities and annexation-based changes in the cost-sharing formula will be discussed as part of the operating addendum.

4.9. Transfer of Long-Term Debt and Facilities. Subsequent to this Agreement, the incurrence of future debt shall be first reviewed with the Committee and a protocol for transfer of debt included in an amended Interlocal Agreement. RCW 36.89.120 shall be used as one of the bases for developing the protocol. Transfer of debt incurred or facilities built prior to this Agreement will be resolved as part of the Phase 1 operating addendum. Debt as used in this Agreement shall include only those expenditures which are financed over a period of more than 3 years, and which are greater than $100,000 in amount.

4.10. Regional Service Charges. The District and City shall, in part, establish their storm and surface water service charges or assessments based on the agreed upon costs of the County providing regional storm and surface water services to their respective jurisdictions. These costs shall be developed through the Committee and reviewed and approved by both Councils and the District Commissioners on an annual basis. The full annual amount will be remitted to the County by the respective Jurisdictions on or before November 1 of the fiscal year in which services are provided or in one-half year increments commencing on May 1 and completed on November 1 of the fiscal year in which services are provided.

4.11. Ability to Contract for Services. The County, District and City may each require additional help from time to time that might be supplied from one or both of the other Jurisdictions. In such cases, the County, District or City in using the services of an employee or equipment shall pay the lending Jurisdiction's salary and equipment rental rate plus direct salary overhead currently in effect. This stipulation does not apply to emergency preparation or response services where the Jurisdictions may waive such compensation while acting in emergency response capacities.

4.12 Rates and Assessments. Notwithstanding any term or condition herein contained, and except as limited by statutory authority unless restricted by the terms of the operating addendum, each party to this Agreement shall have the authority to establish rates and/or assessments within its service area without the prior approval of the remaining parties to this Agreement. Providing the District executes this agreement, the City agrees to collect assessments and reimburse the Drainage District for its costs of services to manage the lake level and prevent flooding for properties within the City's service area which front directly on the lake. The amount of reimbursement attributable to the benefit assessment to be paid to the district shall be determined by the District pursuant to applicable law. The amount shall be remitted on or before November 1 of each fiscal year.

Section 5. Upgrading or Expanding the Facilities.

If the County is required by applicable laws or regulations to upgrade or expand its facilities to provide a higher level of water quality protection or to modify the methods and/or locations of storm water discharges under a regulatory requirement of Ecology, the District and City shall pay their proportionate share of these upgrade or expansion costs, PROVIDED, HOWEVER, that the District and/or the City must first approve the method of upgrade/expansion, the costs associated therewith, and the respective Jurisdictions' share of the costs associated therewith.

Section 6. Annexations.

Prior to completion of the Phase I Operating Addendum described in Paragraph 4.1. of this Agreement, and in the event that annexations proposed by either the City and/or the District are consistent with the objectives set forth in Paragraph 4.1.G. of this interlocal Agreement, including any Operating Addendum approved by all of the parties hereto, then no party shall oppose such annexation on the basis of issues pertaining to surface water management. This paragraph will become null and void if the Operating Addendum is not completed within six months of the adoption of this interlocal by all three parties.

Section 7. Dispute Resolution.

In the event of a dispute among the Jurisdictions pertaining specifically to the terms and conditions of this Agreement, the dispute shall first be considered by the Committee and then by the elected decision-making bodies of the Jurisdictions. If the dispute is not settled at this level, a mediator approved by the Jurisdictions will mediate resolution of the dispute. In the event the parties are unable to agree on a mediator, the Federal Mediation and Conciliation Service (FMCS) shall be requested to provide a list of four mediators. Each party shall be entitled to strike one proposed mediator from the FMCS list. FMCS shall select a mediator from the remaining mediators not stricken. If after mediation disputes remain regarding the Jurisdictions' specific rights and obligations under this Agreement, those disputes shall be placed before an arbitrator approved by the disputing Jurisdictions. In the event the parties are unable to agree on an arbitrator, the American Arbitration Association (AAA) shall be requested to provide a list of four arbitrators. Each party shall be entitled to strike one proposed arbitrator from the AAA list. AAA shall select an arbitrator from the remaining arbitrators not stricken and the decision of that arbitrator shall be final and binding on all parties, pending any necessary actions required by the County Council, City Council or District Commissioners to implement an arbitration award. However, the Jurisdictions by agreement may waive arbitration. The cost of mediation or arbitration shall be equally born by all parties.

Section 8. Amendment or Modification.

No amendment or modification of this Agreement, including any addition or deletion thereto, shall be effective unless approved and executed by the Jurisdictions in the same form and manner as, and subject to the remaining provisions of, this Agreement. It is recognized that this is an initial Agreement that does not encompass all the issues of concern to the Jurisdictions. However, the operating and decision-making framework contained herein does establish baseline policies and direction regarding the seamless provision of storm and surface water services within the UGA. Therefore, these outstanding issues will be addressed through the Committee and as agreement on their management is developed through the Committee, specific operating addenda for these issues will be incorporated into this Agreement.

Section 9. Liability.

No liability shall attach to either the City, County or District by reason of entering into this Agreement except as expressly provided herein.

Section 10. Indemnification and Hold Harmless.

Each party hereto agrees to indemnify and defend the other parties, their officers, officials, employees, and agents, from and against any and all claims, actions, suits, liability, loss, expenses, damages, and judgments of any nature whatsoever, including costs and attorney's fees in defense thereof, for injury, sickness, disability or death to persons or damage to property or business, caused by or arising out of each party's acts, errors or omission in the performance of the Agreement. Provided, however, that each party's obligations hereunder shall not extend to injury, sickness, death or damage caused by or arising out of the sole negligence of another party, its officers, officials, employees or agents. Provided further, that in the event of the concurrent negligence of the parties, each party's obligations hereunder shall apply only to the percentage attributable to another party, its employees or agents.

Section 11. Amendments, Extension or Termination.

11.1. This Agreement may be amended, altered, clarified or extended only by written agreement of the parties hereto.

11.2. Each party may terminate this Agreement for any reason upon 360 days written notice, after which the Agreement is void.

Section 12. Direction and Control.

The parties agree that each party will perform the services under this Agreement as an independent contractor and not as an agent, employee, or servant of the other. The parties agree that each party is not entitled to any benefits or rights enjoyed by employees of the other. Each party specifically has the right to direct and control its own activities in providing the agreed services in accordance with specifications set out in this Agreement. The other parties shall only have the right to ensure performance.

Section 13. Compliance with Laws.

This Agreement shall be governed and construed in accordance with the laws of the State of Washington. Each party shall comply with all applicable federal, state, and local laws, rules, and regulations in performing this Agreement including, but not limited to, laws against discrimination.

Section 14. Access to Books/Records.

Each party may, at reasonable times, inspect the books and records of the other parties relating to performance of this Agreement. Each party shall keep all records required by this Agreement for five years after termination of this Agreement for audit or inspection by the other parties.

Section 15. Contingency.

The obligations of each party to this Agreement are contingent upon local legislative appropriation of necessary funds in accordance with law.

Section 16. Limitation on Authority.

The parties understand that this Agreement does not impose on them any obligation to exercise the authority or perform the functions of the others; and that none of the parties is relieved by this Agreement of any obligation or responsibility impressed upon it by law, except to the extent that actual and timely performance thereof is accomplished by the performance of the parties under this Agreement.

Section 17. Integration Clause.

There are no verbal or other agreements which modify this document.

Section 18. Severability.

Should any part, term or provision of this Agreement be determined by a court of competent jurisdiction to be invalid, the remainder of this Agreement shall not be affected, and the same shall continue in full force and effect.

Section 19. Notices.

All notices required to be given under this Agreement shall be delivered to the parties at the addresses listed below. Notices sent by registered mail shall be deemed served when deposited in the U.S. mail.

City of Lake Stevens, Public Works
P.O. Box 257
Lake Stevens, Washington 98258
Attn.: Jim Craig, Public Works Director

Drainage Improvement District 8
P.O. Box 464
Lake Stevens, Washington 98258
Attn.: Ken Withrow, Commissioner

Snohomish County Public Works
Surface Water Management Division
2930 Wetmore Avenue, Suite 101
Everett, Washington 98201-4044
Attn.: Ms. Joan McLee, P.E., Director

Section 20. Effectiveness.

This Agreement shall become effective after the following:

1. Approval of the Agreement by the official action of two of the governing bodies of each of the parties hereto; and

2. Execution of the Agreement by two of the duly authorized representative of each of the parties hereto.

3. This agreement shall be binding only on those parties which have approved and executed it. If one Jurisdiction does not execute this agreement contemporaneously with the other two, it shall only become a party to this agreement if it subsequently executes this agreement within thirty (30) days of initial execution.

Section 21. Filing.

A copy of the Agreement shall be filed with the following public officials:

1. The Lake Stevens City Clerk;
2. Drainage Improvement District 8 Commissioners; and
3. The Snohomish County Auditor.

Section 22. Number and Gender.

Whenever applicable, the use of the singular number shall include the plural, the use of the plural number shall include the singular, and the use of any gender shall be applicable to all genders.

Section 23. Term.

The term of this Agreement shall be for 3 years from its effective date. The Jurisdictions agree to negotiate in good faith towards the continuance of this Agreement prior to its expiration. If during the term of this Agreement, a major annexation occurs eliminating the role of any one of the Jurisdictions as a storm and surface water service provider within the UGA, that Jurisdiction shall be ineligible from Committee membership and will no longer be a party to this Agreement.

Section 24. Interlocal Cooperation Act.

The parties agree that no separate legal or administrative entities are necessary in order to carry out this Agreement. If determined by a court to be necessary for the purposes of the Interlocal Cooperation Act, Ch. 39.34 RCW, an administrator or joint board responsible for administering the Agreement will be established by mutual agreement. Any real or personal property used by any party in connection with this Agreement will be acquired, held, and disposed of by that party in its discretion, and the other parties will have no joint or other interest herein.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement as of the day and year first above written.

SNOHOMISH COUNTY

Snohomish County Executive GARY WEIKEL Executive Director	8-26-98 Date Signed

CITY OF LAKE STEVENS

Lake Stevens Mayor	9-2-98 Date Signed

DRAINAGE DISTRICT #8

District Commissioner	7/22/98 Date Signed

Approved as to Form:

City Attorney	9/10/98 Date Signed
Deputy Prosecuting Attorney	7/13/98 Date Signed

Attest:

City Clerk	9-2-98 Date Signed

D-7

EXHIBIT A

MAP DEFINING SERVICE AREA BOUNDARIES
IN THE LAKE STEVENS AREA

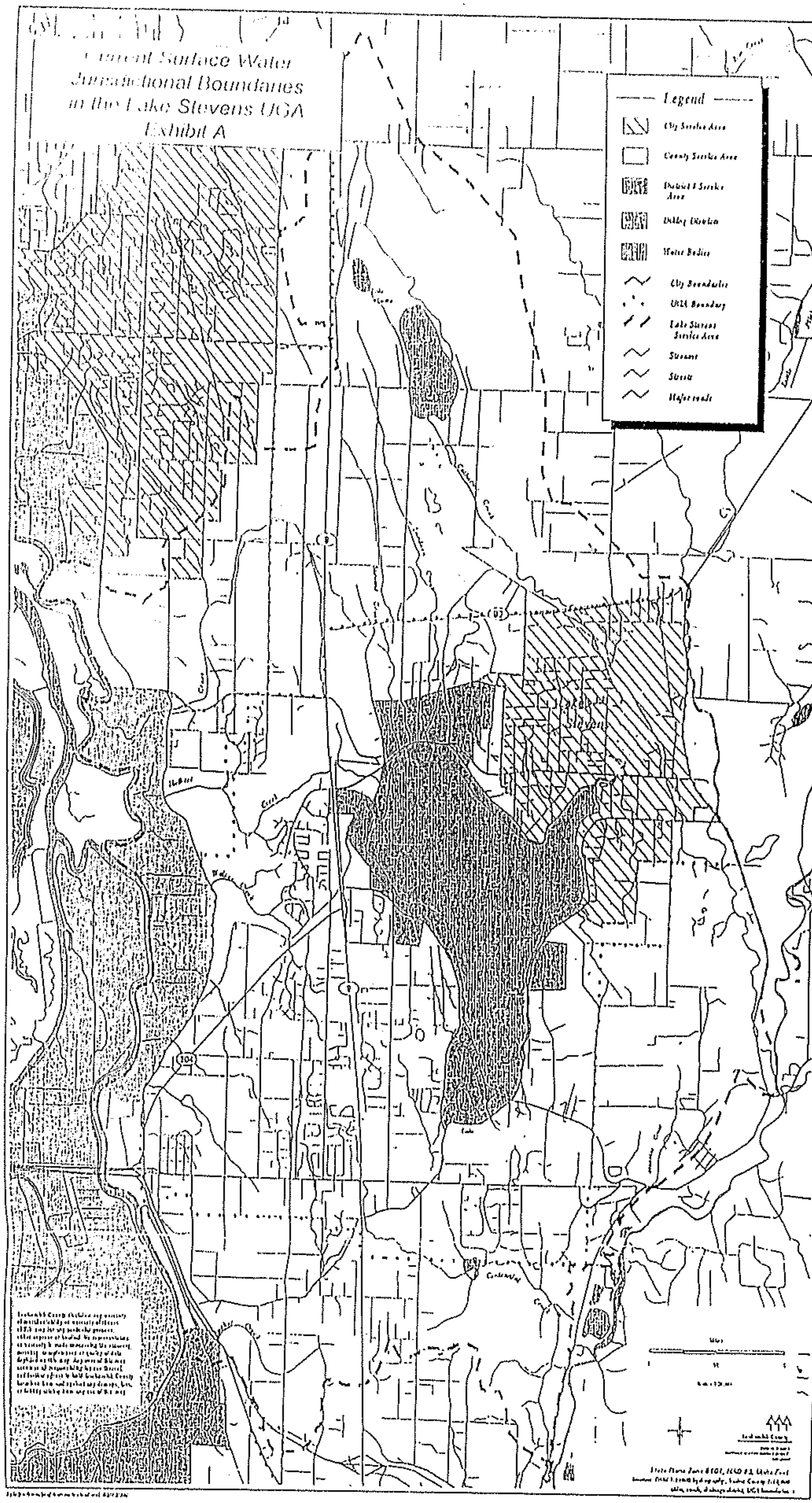
Current Surface Water
Jurisdictional Boundaries
in the Lake Stevens UGA
Exhibit A
Legend
City Service Area
County Service Area
Water Bodies
City Boundaries
UGA Boundary
Lake Stevens Service Area
Streams
Streets
Major roads

EXHIBIT B

URBAN LOCAL STORM AND SURFACE WATER ILLUSTRATIVE GUIDELINES

1. Work with Advisory Committee to recommend additional standards for UGA surface water facilities.

2. Maintain drainage and facilities plans for the urban local system feeding into the regional facilities.

3. Prevent and respond to local flooding conditions.

4. Provide routine maintenance for the urban local system.

5. Cooperate with County on regional capital facilities for quantity and quality control including lake restoration, lake level control and habitat restoration.

6. Provide a first level of response to water quality violations or emergencies.

7. Work with the regional service provider in structuring methods for installing, repairing, or replacing inadequate facilities.

8. Other duties as identified by a Jurisdiction that are consistent with Committee recommendations.

EXHIBIT C

REGIONAL STORM AND SURFACE WATER ILLUSTRATIVE GUIDELINES

1. Major Rivers flood response/prevention/strategic planning.

2. Basin planning for major water basins.

3. Major regional conveyance facilities, water quality, and aquatic restoration-planning design, construction, O & M.

4. Cooperative bank stabilization for major rivers.

5. Public information and education/school programs.

6. Watershed Stewards.

7. Master Drainage plans outside of cities (where drainage basins overlap with cities and districts the county should perform plans cooperatively with these Jurisdictions).

8. Other strategic planning for 6/year CIP, flood hazard management, watershed plans, fish habitat restoration, lake restoration.

9. Maintenance in rural areas for road drainage, facilities and detention ponds, drainage conveyance, levee maintenance, decant station operation, weed control, large regional lakes.

10. Monitoring for water quality, fish habitat assessment, industrial permit tracking, stormwater engineering, NPDES compliance, illicit discharge investigations, pollution complaint response.

11. Business outreach for water quality compliance.

12. Drainage inventory, maintenance history, data management, GIS mapping and analysis.

13. Maintenance of facilities prior to transfer to cities at the time of annexation.

EXHIBIT D

MATRIX OF LOCAL AND REGIONAL SERVICES TO GUIDE WORK PROGRAM DEVELOPMENT

EXHIBIT D

Possible Services Under a Comprehensive Lake Stevens Area Surface Water Management Program

Service Types 1/

R Regional service provided by the County

L Local service provided by the City, District, or County

RL There are both regional and local aspects to this service (a lower case letter denotes a secondary or supportive service)

M Mandatory regional services identified by city managers policy paper

O Optional regional services identified by city managers policy paper

Category	Service	City	Unincorp UGA	Unincorp Rural	City Mgrs. 3/
Admin	Budgeting, management, and clerical support	L	L	L	
Admin	Utility Services	RL	RL	RL	O
System Maintenance	Stream System Management	L	L/r	L	L
System Maintenance	Major Rivers Management and Levee Maintenance	R	R	R	M
System Maintenance	Aquatic Weed Control	L/r	L/r	L/r	
System Maintenance	Local Public & Private stormwater & water quality facility maintenance 2/	L	L	L	L
System Maintenance	Regional public stormwater & water quality facility maintenance	R	R	R	O
System Maintenance	Aeration System/Lake Outlet	RL	RL	RL	
System Maintenance	Decant stations	Rl	Rl	R	
Strategic Planning	Long range regional facility/capital improvement plans	Rl	Rl	R	O
Strategic Planning	Long range urban secondary system facility/CIP plan update & maintenance	L/r	L/r	L	L
Strategic Planning	Comprehensive basin plans	Rl	R	R	M
Strategic Planning	Integrated land use and surface water plans	L/r	RL	RL	
Strategic Planning	Master drainage plan development for the unincorporated area's regional system	Rl	R	R	M
Strategic Planning	Drainage plan update & maintenance for the secondary system	L/r	L	L	L
Strategic Planning	Lake restoration plans	R	R	RL	M
Strategic Planning	Regional Groundwater Planning	Rl	Rl	R	
Strategic Planning	Flood management plans (inc. FEMA)	Rl	Rl	R	M
Strategic Planning	Inventory of aquatic resources	R	R	R	O
Strategic Planning	Fish habitat protection plans	R	R	R	M
Outreach Services	Public information and education programs	R	R	R	M
Outreach Services	Major River Flood Warning and Emergency Response	R	R	R	M
Outreach Services	Local Stream Flooding Emergency Response	L/r	R	L	C
Outreach Services	Drainage complaint response	L	L	L	
Outreach Services	Pollutant Spill and Complaint First Response	L	L	L	L
Outreach Services	Pollutant Spill and Complaint Response Technical Resource	R	L	R	M
Outreach Services	Stream and lake stewardship program	R	R	R	C
Outreach Services	Lake Management Program	R	R	R	
Outreach Services	School programs	Rl	R	RL	M
Outreach Services	Residential volunteer programs	L	Rl	L	
Outreach Services	Business outreach programs	RL	L	R	M
Outreach Services	Farm Outreach and Technical Assistance	RL	R	L	
Outreach Services	Citizen advisory & action committees	RL	RL	RL	
Outreach Services	Septic system repair loans and information	L	L	L	
Outreach Services	Incentive programs	Rl	Rl	Rl	
Policy & Interagency Coordination	Floodplain regulation	L	L	L	
Policy & Interagency Coordination	Police authority for health, safety, welfare	L	L	L	
Policy & Interagency Coordination	Critical areas ordinances	L	L	L	
Policy & Interagency Coordination	Drainage/grading ordinance	L	L	L	L
Policy & Interagency Coordination	Stormwater manual	L	L	L	L
Policy & Interagency Coordination	Drainage system maintenance standards (constructed systems)	L	L	L	L
Policy & Interagency Coordination	Shoreline master programs or plans	RL	RL	RL	
Policy & Interagency Coordination	Zoning code	L	L	L	
Policy & Interagency Coordination	Development review and SEPA	L	L	L	L
Policy & Interagency Coordination	NPDES & state regulatory compliance & permitting	R	R	R	M
Policy & Interagency Coordination	Water quality ordinances	L	L	L	
Policy & Interagency Coordination	Coordination of programs & local stds. with other jurisdictions	RL	RL	RL	
Policy & Interagency Coordination	Interlocal agreements	RL	RL	RL	
Monitoring & Technical Support	Stream and rainfall gages	RL	RL	RL	
Monitoring & Technical Support	Water quality monitoring (including laboratory analysis)	R	R	R	M
Monitoring & Technical Support	Illicit discharge investigation	R	R	R	M
Monitoring & Technical Support	Industrial permit tracking	L/r	R	R	M
Monitoring & Technical Support	Facility performance monitoring	LR	RL	RL	
Monitoring & Technical Support	Fish habitat assessment	R	R	R	M
Monitoring & Technical Support	Hydrologic and flood modeling	R	R	RL	
Monitoring & Technical Support	Evaluation & advice on use of water quality/flood management practices	R	R	R	
Monitoring & Technical Support	Geographic information systems & data management	RL	RL	RL	M
Capital Improvements	Retrofit associated systems	L	L	L	L
Capital Improvements	Regional detention, conveyance, water qual. and habitat facilities & rehab	R	R	R	O
Capital Improvements	Local detention, conveyance, water qual. and habitat facilities and rehab	L	L	L	
Capital Improvements	Regional flood control system	R	R	R	M
Capital Improvements	Localized flood control system	L	L	L	L
Capital Improvements	Conservative bank stabilization	R	R	R	M
Capital Improvements	Acquisition of flood storage, wetland, and habitat sites	L	RL	RL	L

1 = all services are assumed to be conducted within a cooperative process for coordinating city/county/district surface water actions.

2 = bolded services are mandatory elements of the County's National Pollutant Discharge Elimination Program (NPDES) permitted stormwater program.

3 = the city managers proposal covered urban areas including the incorporated city and the unincorporated UGA; a blank means a service was not addressed by city managers.

APPENDIX I

SEPA Checklist

STATE ENVIRONMENTAL POLICY ACT

ENVIRONMENTAL CHECKLIST

Purpose of Checklist:

The State Environmental Policy Act (SEPA), chapter 43.21C RCW, requires all governmental agencies to consider the environmental impacts of a proposal before making decisions. An environmental impact statement (EIS) must be prepared for all proposals with probable significant adverse impacts on the quality of the environment. The purpose of this checklist is to provide information to help you and the agency identify impacts from your proposal (and to reduce or avoid impacts from the proposal, if it can be done) and to help the agency decide whether an EIS is required.

Instructions to Applicants:

This environmental checklist asks you to describe some basic information about your proposal. Governmental agencies use this checklist to determine whether the environmental impacts of your proposal are significant, requiring preparation of an EIS. Answer the questions briefly, with the most precise information known, or give the best description you can.

You must answer each question accurately and carefully, to the best of your knowledge. In most cases, you should be able to answer the questions from your own observations or project plans without the need to hire experts. If you really do not know the answer, or if a question does not apply to your proposal, write "do not know" or "does not apply." Complete answers to the questions now may avoid unnecessary delays later.

Some questions ask about governmental regulations, such as zoning, shoreline, and landmark designations. Answer these questions if you can. If you have problems, the governmental agencies can assist you.

The checklist questions apply to all parts of your proposal, even if you plan to do them over a period of time or on difference parcels of land. Attach any additional information that will help describe your proposal or its environmental effects. The agency to which you submit this checklist may ask you to explain your answers or provide additional information reasonably related to determining if there may be significant adverse impact.

A. BACKGROUND

1. *Name of proposed project, if applicable:*

   Catherine Creek / Lake Stevens Watershed Management Plan

2. *Name of applicant:*

   Drainage Improvement District #8

3. *Address and phone number of applicant and contact person:*

Ms. Angela Busby
District Superintendent
Drainge Improvement District #8
2012 Grade Rd. #205
Lake Stevens, Washington 98258
425-335-0610

4. *Date checklist prepared:*

June 22, 1999

5. *Agency requesting checklist:*

Drainage Improvement District #8

6. *Proposed timing or schedule (including phasing, if applicable):*

As soon as practical. However, it will require coordination and acceptance by Lake Stevens and Snohomish County through the adoption of these recommendations and incorporation into their development standards.

7. *Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal?*

Yes, implementation of recommendations and capital improvements included in the plan.

8. *List any environmental information you know about that has been prepared, or will be prepared, directly relating to this proposal.*

KCM, Inc. Engineers did studies in 1987, 1989 and 1990; Snohomish County in 1991; R.W. Beck Engineers in 1997; Each proposed project will be subject to a separate project SEPA review at the time of construction.

9. *Do you know whether applications are pending for government approvals of other proposals directly affecting the property covered by your proposal? If yes, explain.*

Growth continues in the basins at this time. Applications and proposals are ongoing based on Snohomish County Land Use designations. No applications are pending as a direct result of this Plan.

10. *List any government approvals or permits that will be needed for your proposal, if known.*

Department of Ecology approval of this Watershed Management Plan. Individual projects may require coordination and cooperation between the District, the City of Lake Stevens and Snohomish County. They may also require a Corps of Engineers or U.S. Fish & Wildlife permit.

11. *Give brief, complete description of your proposal, including proposed uses and the size of the project and site. There are several questions later in this checklist that ask you to describe certain aspects of your proposal. You do not need to repeat those answers on this page. (Lead agencies may modify this form to include additional specific information on project description.)*

The Watershed Management Plan assesses existing conditions within the basins, defines causes for water degradation and proposes mitigative efforts for improving water quality and aquatic habitat degradation due to flooding and pollution sources.

12. *Location of the proposal. Give sufficient information for a person to understand the precise location of your proposed project, including street address, if any, and section, township, and range, if known. If a proposal would occur over a range of area, provide the range or boundaries of the site(s). Provide a legal description, site plan, vicinity map, and topographic map, if reasonably available. While you should submit any plans required by the agency, you are not required to duplicate maps or detailed plans submitted with any permit applications related to this checklist.*

The District is located in Snohomish County within the Catherine Creek and Lake Stevens watershed areas. A map of the area is shown in the Report.

B. ENVIRONMENTAL ELEMENTS

1. EARTH:

a. *General description of the site (circle one): Flat, rolling, hilly, steep slopes, mountainous, other ___________.*

b. *What is the steepest slope on the site (approximate percent slope)?*

Slopes vary from zero percent to 50%.

c. *What general types of soils are found on the site (for example, clay, gravel, sand, peat, muck)? If you know the classification of agricultural soils, specify them and note any prime farmland.*

The general soil type in the study area is Tolkul gravely loam. However, given the project site, all soils conditions typical of the area will be found.

d. *Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.*

Erosion resulting from runoff is prevalent throughout both basins.

e. *Describe the purpose, type, and approximate quantities of any filling or grading proposed. Indicate source of fill.*

This project is non invasive and will not result in these activities.

f. *Could erosion occur as a result of clearing, construction, or use? If so generally describe.*

Yes. Construction specification for each project will include erosion control requirements for the construction of individual projects.

g. *About what percent of the site will be covered with impervious surfaces after project construction (for example, asphalt or buildings)?*

This proposal will not directly result in any impervious surfaces.

h. *Proposed measures to reduce or control erosion, or other impacts to the earth, if any:*

Temporary erosion control measures during construction, such as straw bales and silt fences, will be addressed in the construction specifications specific to each project.

2. AIR:

a. *What types of emissions to the air would result from the proposal (i.e. dust, automobile, odors, industrial wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities if known.*

Odors generated by vehicular emissions during construction.

b. *Are there any off-site sources of emissions or odor that may affect your proposal? If so, generally describe.*

No.

c. *Proposed measures to reduce or control emissions or other impacts to air, if any:*

Dust suppression measures will be implemented during construction.

3. WATER:

a. *Surface:*

1) *Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, wetlands)? If yes, describe type and provide names. If appropriate, state what stream or river it flows into.*

Lake Stevens occupies the largest amount of water surface within the area. There are four primary streams in the study area that flow to Lake Stevens. Stevens, Lundeen, and Kokanee Creeks collect flows from areas north of Lake Stevens, and Stitch Creek flows through Stitch Lake and into Lake Stevens. Lake Stevens outlet is located in the City of Lake Stevens, along the northeast end of the lake. The outlet feeds into Catherine Creek, which feeds into the Pilchuck River. There are numerous small unnamed creeks within the study area, many of which have intermittent flows, drying in the summer.

2) *Will the project require any work over, in, or adjacent to (within 200 feet) the described waters? If yes, please describe and attach available plans.*

Yes, implementation of this Plan will require construction adjacent to or passing through wetlands or surface waters. Each project will require separate SEPA checklists. The impacts and descriptions of the projects will occur at the time of project action.

3) *Estimate the amount of fill and dredge material that would be placed in or removed from surface water or wetlands and indicate the area of the site that would be affected. Indicate the source of fill material.*

The amount of fill or dredge material required will be assessed for each project.

4) *Will the proposal require surface water withdrawals or diversions? Give general description, purpose, and approximate quantities if known.*

Yes. Flow bypasses may be established on various tributaries to control erosion and habitat degradation.

5) *Does the proposal lie within the 100-year flood plain? If so, note location on the site plan.*

To be determined on a project specific basis.

6) *Does the proposal involve any discharges of waste materials to surface waters? If so, describe the type of waste and anticipated volume of discharge.*

None.

b. *Ground:*

1) *Will ground water be withdrawn, or will water be discharged to ground water? Give general description, purpose, and approximate quantities if known.*

No..

2) *Describe waste material that will be discharged into the ground from septic tanks or other sources, if any (for example, Domestic sewage; industrial, containing the following chemicals...; agricultural; etc..). Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.*

None.

c. *Water Runoff (including storm water):*

1) *Describe the source of runoff (including storm water) and methods of collection and disposal, if any (include quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.*

The plan will recommend BMPs for these conditions.

2) *Could waste materials enter ground or surface waters? if so, generally describe.*

No.

d. *Proposed measures to reduce or control surface, ground and runoff water impacts, if any:*

Both structural and non-structural measures will be used to control impacts of runoff.

4. PLANTS:

a. *Check or circle types of vegetation found on the site:*

deciduous tree: alder, maple, aspen, other
evergreen tree: fir, cedar, pine, other
shrubs
grass
pasture
crop or grain - None Known
wet soil plants: cattail, buttercup, bulrush, skunk cabbage, other
Water plants: water lily, eelgrass, Milfoil, other types of vegetation

b. *What kind and amount of vegetation will be removed or altered?*

To be determined on a project specific basis.

c. *List threatened or endangered species known to be on or near the site.*

To be determined on a project specific basis. May include various salmon species. Chinook salmon were not found as part of this study.

d. *Proposed landscaping, use of native plants or other measures to preserve or enhance vegetation on the site, if any:*

To be determined on a project specific basis. However, bioswales may be developed to retain and filter runoff and emergent plant growth may be planted within the lake.

5. ANIMALS:

a. *Circle any birds or animals which have been observed on or near the site or are known to be on or near the site:*

birds: hawk, heron, eagle, songbirds,
other: ducks
mammals: deer, bear, elk, beaver,
*other:*______________
fish: bass, salmon, trout, herring, shellfish,
*other:*______________

b. *List any threatened or endangered species known to be on or near the site.*

Eagle nests and Coho salmon are present in the study area.

c. *Is the site part of a migration route? If so, explain.*

N/A

d. *Proposed measures to preserve or enhance wildlife, if any:*

The plan proposes various measures to enhance fish habitat.

6. ENERGY AND NATURAL RESOURCES:

a. *What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed project's energy needs? Describe whether it will be used for heating, manufacturing, etc.*

None.

b. *Would your project affect the potential use of solar energy by adjacent properties? If so, generally describe.*

No.

c. *What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any:*

N/A

7. ENVIRONMENTAL HEALTH:

a. *Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste, that could occur as a result of this proposal? If so, describe.*

None.

1) *Describe special emergency services that might be required.*

None.

2) *Proposed measures to reduce or control environmental health hazards, if any:*

None.

b. *Noise:*

1) *What types of noise exist in the area which may affect your project (for example, traffic, equipment, operation, other)?*

None.

2) *What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example, traffic, construction, operation, other)? Indicate what hours noise would come from site.*

Short-term: Implementation of the Plan would require construction equipment for proposed construction projects.

3) *Proposed measures to reduce or control noise impacts, if any:*

Equipment must meet current State of Washington regulations.

8. LAND AND SHORELINE USE:

a. What is the current use of the site and adjacent properties?

All land uses are present within the study area.

b. Has the site been used for agriculture? If so, describe.

To be determined on a project specific basis.

c. Describe any structures on the site.

N/A

d. Will any structures be demolished? If so, what?

N/A

e. What is the current zoning classification of the site?

N/A - land use maps are presented in the Comprehensive Plan

f. What is the current comprehensive plan designation for the site?

N/A - land use maps are presented in the Comprehensive Plan

g. If applicable, what is the current shoreline master program designation for the site?

N/A

h. *Has any part of the site been classified as an "environmentally sensitive" area? If so, specify.*

To be determined on a project specific basis.

i. *Approximately how many people would reside or work in the completed project.*

N/A

j. *Approximately how many people would the completed project displace?*

None.

k. *Proposed measures to avoid or reduce displacement impacts, if any:*

None needed.

l. *Proposed measures to ensure that the proposal is compatible with existing and projected land uses and plans, if any:*

Projects must coordinate with the proper political entities.

9. HOUSING:

a. *Approximately how many units would be provided, if any? indicate whether high, middle, or low-income housing.*

None.

b. *Approximately how many units if any, would be eliminated? Indicate whether high, middle, or low-income.*

None.

c. *Proposed measures to reduce or control housing impacts, if any:*

The plan recommends to mitigate the impact of housing within the basins.

10. AESTHETICS:

a. *What is the tallest height of any proposed structure(s), not including antennas; what is the principle exterior building material(s) proposed?*

Does not apply.

b. *What views in the immediate vicinity would be altered or obstructed?*

None

c. *Proposed measures to reduce or control aesthetic impacts, if any:*

None required.

11. LIGHT AND GLARE:

a. *What type of light or glare will the proposal produce? What time of day would it mainly occur?*

None.

b. *Could light or glare from the finished project be a safety hazard or interfere with views?*

No.

c. *What existing off-site sources of light or glare may affect your proposal?*

None.

d. *Proposed measures to reduce or control light and glare impacts, if any:*

Does not apply.

12. RECREATION:

a. *What designated and informal recreational opportunities are in the immediate vicinity?*

Water recreation at Lake Stevens.

b. *Would the proposed project displace any existing recreational uses? If so, describe:*

No.

c. *Proposed measures to reduce or control impacts on recreation, including recreational opportunities to be provided by the project of applicant, if any:*

None needed.

13. HISTORIC AND CULTURAL PRESERVATION:

a. *Are there any places or objects listed on, or proposed for national, state, or local preservation registers known to be on or next to the site? If so, generally describe:*

None known.

b. *Generally describe any landmarks or evidence of historic, archaeological importance know to be on or next to the site?*

None known.

c. *Proposed measures to reduce or control impacts, if any:*

Does not apply.

14. TRANSPORTATION:

a. *Identify public streets and highway serving the site, and describe proposed access to existing street system. Show on site plans, if any.*

State Route 9, 92 and 204 are all included within the basin areas.

b. *Is site currently being served by public transit? If not, what is the approximate distances to nearest transit stop?*

N/A

c. *How many parking spaces would the completed project have? How many would the project eliminate?*

N/A

d. *Will the proposal require any new roads or streets, or improvements to existing roads or streets, not including driveways? If so, generally describe (indicate whether public or private).*

Not directly.

e. *Will the project use (or occur in the immediate vicinity of) water, rail, or air transportation? If so, generally describe:*

No.

f. *How many vehicular trips per day would be generated by the completed project? If known, indicate when peak volumes would occur.*

N/A

g. *Proposed measures to reduce or control transportation impacts, if any:*

None.

15. PUBLIC SERVICES:

a. *Would the project result in an increased need for public services (for example: fire protection, police protection, health care, schools, other)? If so, generally describe.*

No.

b. *Proposed measures to reduce or control direct impacts upon public services, if any.*

None needed.

16. UTILITIES:

a. *Circle utilities currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, septic system, other.*

To be determined on a project specific basis.

b. *Describe the utilities that are proposed for the project, the utilities providing the service, and the general construction activities on the site or in the immediate vicinity which might be needed.*

Not applicable.

C. SIGNATURE

The above answers are true and complete to the best of my knowledge. I understand that the lead agency is relying on them to make its decision.

Signature Warren W. Perkins

Warren W. Perkins
Gray and Osborne, Inc.

Date Submitted: June 23, 1999

D. SUPPLEMENTAL SHEET FOR NONPROJECT ACTIONS

Because these questions are very general, it may be helpful to read them in conjunction with the list of the elements of the environment.

When answering these questions, be aware of the extent the proposal, or the types of activities likely to result from the proposal, would affect the item at a greater intensity or at a faster rate than if the proposal were not implemented. Respond briefly and in general terms.

1. How would the proposal be likely to increase discharge to water; emissions to air; production, storage, or release of toxic or hazardous substances; or production of noise?

The purpose of this Plan is to reduce the impacts of runoff to the water bodies lying within the watersheds. Each project would comply with SEPA requirements for the individual project.

2. How would the proposal be likely to affect plants, animals, fish, or marine life?

The Plan will be used to enhance fish habitat by increasing fish passage and improving water quality for fish by retaining more water, trapping more pollutants, and decreasing the amount of scour in tributary streams.

Proposed measures to protect or conserve plans, animals, fish, or marine life are:

As mentioned before, the Plan will provide measures that will increase fish passage and improve water quality for fish throughout water bodies within the Catherine Creek and Lake Stevens watersheds. A list of capital improvements can be found in Chapter 8 of the Management Plan.

3. How would the proposal be likely to deplete energy or natural resources?

Not applicable.

Proposed measures to protect or conserve energy and natural resources are:

Not applicable.

4. How would the proposal be likely to use or affect environmentally sensitive areas or areas designated (or eligible or under study) for governmental protection; such as parks, wilderness, wild and scenic rivers, threatened or endangered species habitat, historic or cultural sites, wetlands, floodplains, or prime farmlands?

The intent of the Plan is to reduce harmful impacts on fish and water quality.

Proposed measures to protect such resources or to avoid or reduce impacts are:

Proposed measures include detention systems, the acquisition of wetlands, installing emergent plants within Lake Stevens, education, increasing fish passage in Stitch Lake, and installing treatment systems to help increase water quality. A complete list of proposed capital improvement projects may be found in Chapter 8 of the Watershed Management Plan.

5. How would the proposal be likely to affect land and shoreline use, including whether it would allow or encourage land or shoreline uses incompatible with existing plans?

This plan discourages development that will affect the water quality within the basins however, it provides for measures that will help implement the negative effects of development (such as installing treatment systems and increasing detention standards to provide for larger ponds with slow release rates).

Proposed measures to avoid or reduce shoreline and land use impacts are:

See above.

6. How would the proposal be likely to increase demands on transportation or public services or utilities?

Not applicable.

Proposed measures to reduce or respond to such demand(s) are:

Not applicable.

7. Identify, if possible, whether the proposal may conflict with local, state, or federal laws or requirements for the protection of the environment.

The Plan provides a mean for protecting the environment and will comply with all pertinent laws, as required.