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Hylebos Creek and Lower Puget Sound Basins

Current and Future Conditions Report

EVANS

King County
Surface Water
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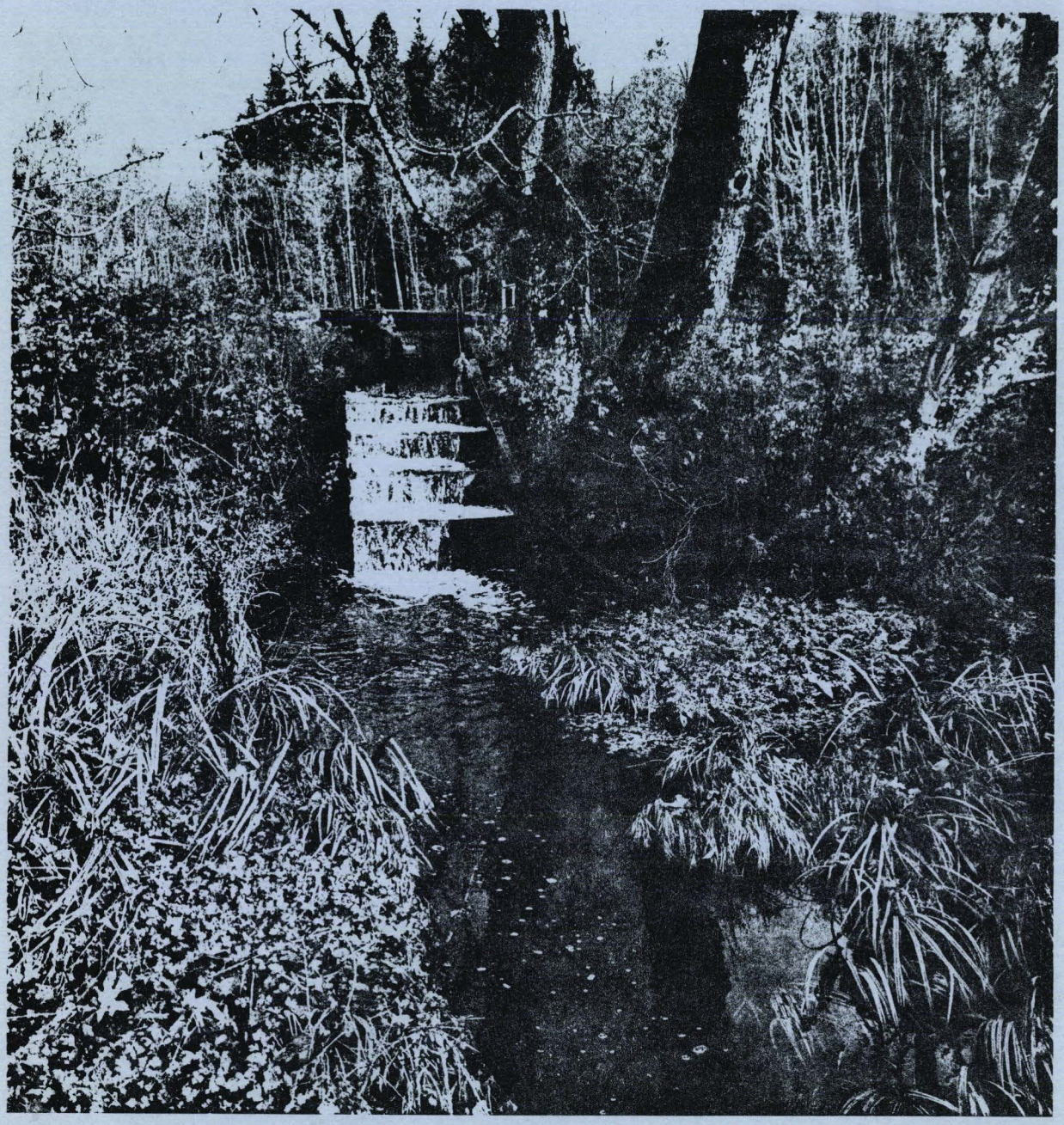
City of Federal Way



In Cooperation with Pierce County and the Cities of Des Moines, Fife, Kent, Milton and Tacoma

July 1990

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HYLEBOS CREEK AND LOWER PUGET SOUND

CURRENT AND FUTURE CONDITIONS REPORT

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JULY 1990

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Executive Summary

CHAPTER 1

EXECUTIVE SUMMARY

INTRODUCTION

This report documents current conditions and predicts the future trends of the freshwater and marine systems in the Hylebos Creek and Lower Puget Sound basins. Its primary purpose is to identify issues to be addressed in the Hylebos Creek and Lower Puget Sound Basin Plan. The draft of this plan is anticipated in February 1991. The basin plan will propose solutions to the observed and anticipated surface water problems in this report and recommend a comprehensive management program for flood protection, channel stabilization, and resource enhancement.

The planning area shown in Figure 1.1 includes the Hylebos Creek basin, which flows south through Federal Way and King County to Commencement Bay in Pierce County, and the eight watersheds flowing west from the plateau between Des Moines and Dash Point State Park, collectively referred to as the Lower Puget Sound basin.

These basins not only overlap jurisdictional boundaries in King and Pierce Counties but also lie within six municipalities, including Des Moines, Federal Way, Fife, Kent, Milton, and Tacoma. Over half of the planning area is within the newly incorporated City of Federal Way. Because the Hylebos basin is tributary to Hylebos Waterway in Commencement Bay, a federal Superfund Clean-up Site, and the Lower Puget Sound basin is directly tributary to Puget Sound, there is a high degree of interest in these watersheds on the part of numerous state and federal agencies and the Puyallup and Muckelshoot Indian Tribes.

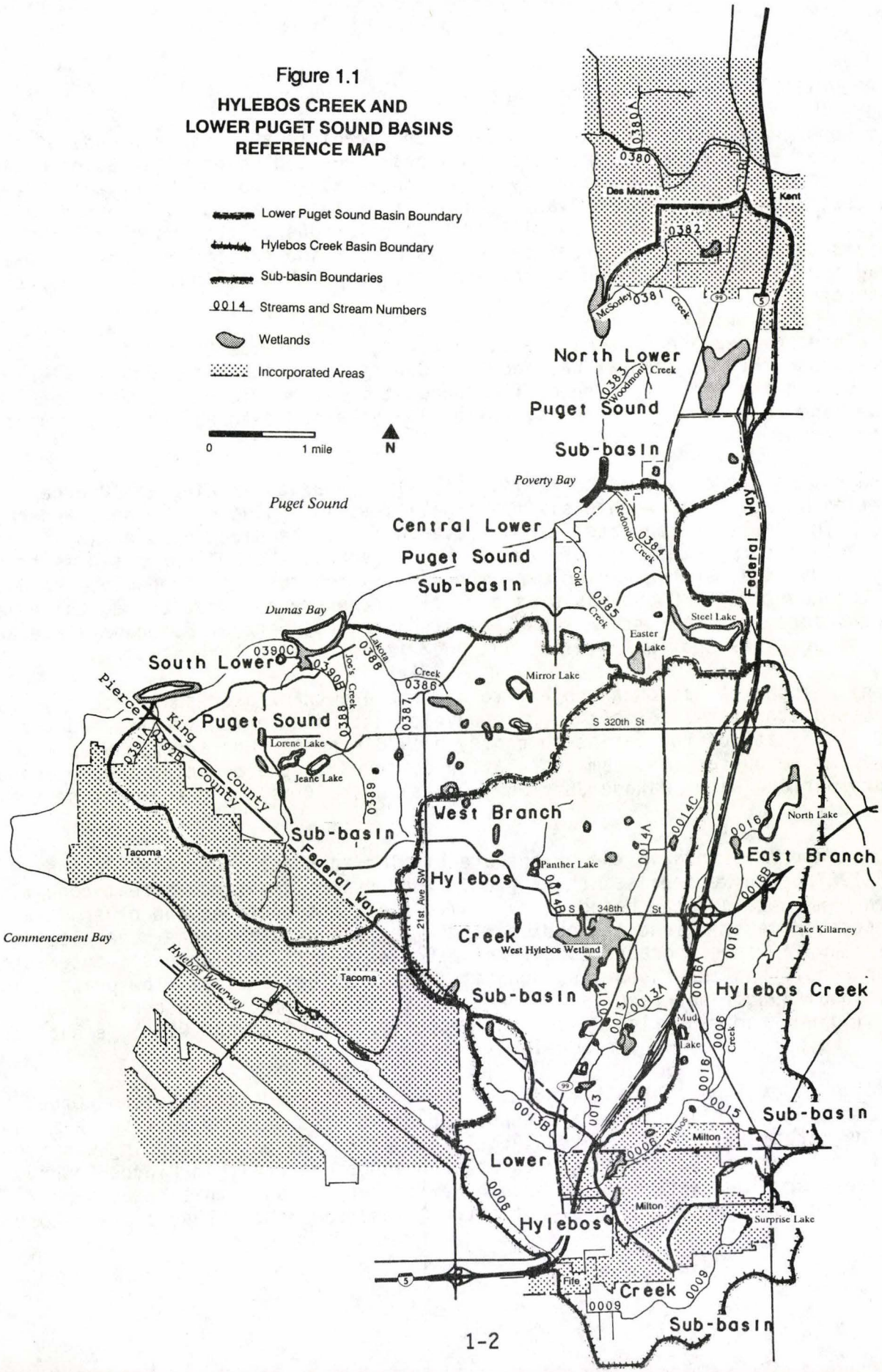
The planning area has been subject to extreme growth pressures in recent years. Increased stormflows associated with development have seriously affected the natural ability of the basins to convey peak discharges and sustain viable fisheries resources. Stream degradation observed in the planning area by King County Surface Water Management (SWM) Division staff is among the most severe in the County.

Conditions and trends in the basins are similar to those documented in the 1986-1987 Basin Reconnaissance Program. That report described stream conditions in the SWM Service Area based on extensive field observations and other data sources. However, since its publication, many new problem areas have also arisen, while some degraded conditions have worsened. Development-induced storm water runoff has increased the intensity and duration of storm flow peaks. The additional runoff has resulted in numerous areas with increased erosion, landsliding, sedimentation, flooding, property loss, fish and wildlife habitat loss, and water quality degradation.

Existing conditions contrast markedly from the historic state--Hylebos Creek, for example, is believed to have supported one of the most productive salmon-bearing stream systems in central Puget Sound. In the past, flooding was probably confined to the floodplain in Lower Hylebos Creek within Pierce County. Erosive stormflows were managed both by extensive wetlands that reduced peak runoff and by an abundant supply of natural instream debris that slowed storm-

Figure 1.1

HYLEBOS CREEK AND LOWER PUGET SOUND BASINS REFERENCE MAP



water velocities. Then, flood damage was only temporary, since the system had time to recover between storm events.

Without the chance to recover between peak flows, stream degradation has become so extensive that only remnants of the once excellent pre-development fish and wildlife habitat remain; but these too may soon be lost as peak flows increase in frequency and magnitude. Given the present condition of most streams in the basins, it is unlikely that full habitat restoration is possible. Without corrective action to stabilize flows, the public and private property losses from flood damage occurring as a result of the January 1990 storm will be paled by future events. On average, it is expected that the future built-out planning area could experience storm flows equivalent to this event every 5 to 10 years.

In addition to the physical causes, these conditions stem from a combination of other underlying factors, including limitations on the effectiveness of federal and state regulatory agencies, insufficient land-use planning and development-impact controls, and the need for more knowledge and attention on the part of the public toward the impacts of urbanization on streams and wetlands.

Choices regarding future actions will be complex and difficult for governments, the development community, and the general public; however, prompt action is necessary to prevent further property damage and resource degradation as the planning area continues to urbanize.

The Hylebos Creek and Lower Puget Sound Basin Plan is one of several surface water management plans currently being developed to control stormwater flows and manage water quality in the basins. This end, however, will require collective commitment among all interests in the basins--governments, community organizations, the business community, and the general public--to a highly coordinated and sustained effort that prevents further deterioration and, where possible, corrects past practices.

SUMMARY OF KEY FINDINGS

Current Conditions

- Recent population growth in the planning area has been among the most rapid relative to other urbanizing areas in unincorporated King County. By 1987, approximately 7400 acres (45 percent) of the two basins were converted from forested to urban uses to accommodate this growth. Stormwater flows, which also rose substantially with this urbanization, resulted from two major factors. The first is the construction of massive impervious surface areas that concentrate and discharge large volumes of stormwater. This is a particularly significant problem in the upper part of West Branch Hylebos Creek where, without adequate stormwater controls, highways and extensive commercial areas boosted flows by over 60 percent from undeveloped conditions. Another example is the upper Joes Creek watershed in Lower Puget Sound. There, several residences surrounding Twin Lakes were flooded during the January 1990 storm from upstream flow increases in areas recently converted from forested to urban uses. The second factor is development covering soils that otherwise infiltrate surface water into groundwater aquifers. This condition is a significant problem in the west-central part of the planning area, where large expanses of impervious surfaces are preventing these soils from performing that function.

- The natural stormwater storage and conveyance elements in many stream segments have been modified to form some of the most extensively altered systems in King County. Substantial filling, piping, and encroachment into streambank areas have had particularly significant effects on Hylebos Creek. Piping most of the creek and filling the headwater wetlands around S 320th Street during its development exemplify the results of these alterations which include increased stormwater volume and velocities, reduced flood storage, destabilized downstream systems, and degraded habitat.

- Stormwater flows are overwhelming natural and constructed flood storage and conveyance systems. During the January 1990 storm, several locations were severely flooded, which in some cases inundated homes and washed out roads. These areas include the channels downstream of Panther Lake, S 356th Street, S 359th Street, S 373rd Street, Saltwater State Park, S 272nd, Twin Lakes, S 363rd Street near SR 161, 5th Avenue in Milton, and along the I-5 corridor between Milton and Fife. Based on experiences in other basins, it is anticipated that these problems will be difficult and expensive to correct.

- Highly erosive geologic deposits underlie the channels in East Branch Hylebos Creek, part of Lakota Creek, most of Joes Creek, and the unnamed tributaries to Dash Point State Park. Where flows have increased significantly, particularly in East Branch Hylebos Creek, channel downcutting and erosion have been dramatic and are accelerating, with channel incisions of up to several feet. Elsewhere in the basins, especially in upper West Branch Hylebos Creek, susceptibility to this type of erosion is not high; however, flow increases have been so great that substantial damage has occurred and is now among the worst found in equivalent stream channels elsewhere in King County. Deposition of sediment has clogged existing infiltrative soils within Panther Lake, diminished or eliminated fish spawning and rearing habitat, and exacerbated flooding by filling culverts and reducing channel capacity.

- Most of the historic resident and migratory fish habitat has been lost due to stream degradation from increased flows, loss or alteration of riparian areas, filling, dredging, and poor water quality. Significant fishery resource losses have occurred especially in the middle and lower reaches of Hylebos Creek, where it is questionable whether extensively damaged habitat can be fully rehabilitated.

- Under base flow conditions, water quality is generally good. During storm events however, nutrient, heavy metal, and bacteria levels exceeding state water quality standards were consistently found throughout the basins. Fecal contamination is of special concern in the Lower Puget Sound basin where bacterial concentrations increase up to 40-fold from non-storm to storm events. High fecal bacteria counts are threatening water-oriented recreational uses and have contributed to decertification of commercial shellfish beds in Puget Sound. Likely sources of this contaminant include failing onsite septic systems, potential sewer line leaks, farm animals accessing creeks, and pet wastes. These same sources, in combination with excessive fertilizers, are also increasing nutrient levels and encouraging nuisance weed growth in lakes.

- Automobile use is the major source of high heavy metal concentrations in the planning area. These pollutants are significant in Lakota Creek and are especially elevated in West Branch Hylebos Creek, which receives runoff from over 1,300 acres of impervious surface primarily from several state highways and the highly commercialized areas around S 320th Street and S 348th Street.

Elevated metal concentrations, together with other pollutants in stormwater, are potentially deadly to already depressed fish populations and are adding to the degraded water quality throughout the planning area, including the sediments in the already contaminated Hylebos Waterway.

Future Conditions

- In the future, the effects of projected population increases in the Hylebos Creek and the Lower Puget Sound basins will continue to degrade stream resources unless mitigation, such as new stormwater storage and control measures, are successfully implemented. If the basins are fully built-out and such mitigation is lacking, flooding will increase in both frequency and magnitude in areas that are currently flood-prone. On average, storm flows are expected to more than double in much of the planning area. Thus, large stormflows that now occur every 10- to 25-years, such as the one in November 1986, will take place almost annually.

- Without suitable flow controls, areas not presently inundated will also be affected, especially during extreme storm events. During these events, peak flows are predicted to double in both the East and West Branches of Hylebos Creek. New areas expected to experience chronic flooding include locations along tributary 0016 downstream of the Weyerhauser Pond and along tributary 0015 in King County and portions of Milton. Increased runoff will also double floodwater entering Pierce County. The frequency and extent of flooding in adjacent communities, including Fife, Milton, Pierce County, and Tacoma, could grow dramatically. In the Lower Puget Sound basins, future flow increases are not expected to be as large as those in Hylebos Creek because these basins are nearly built-out now.

- Without adequate flow management, the processes of streambank erosion, downstream sedimentation, and habitat loss will accelerate. In the Lower Puget Sound basins, the combination of steep gradients and highly erosive soils will continue downcutting sensitive channel reaches along McSorley Creek, Redondo Creek, Cold Creek, Lakota Creek, Joes Creek, and the unnamed tributaries to Dash Point State Park. In addition, these processes will perpetuate the deterioration of East Branch Hylebos Creek.

- Much of the fish habitat in the planning area is on the verge of elimination. The January 1990 storm severely damaged instream resources in the basins. If another storm of the same magnitude occurs before these resources have time to recover, the remaining habitat will likely be lost. With continued urbanization, the likelihood of a large runoff event occurring in any given year can increase dramatically. For example, if the planning area is fully built-out, the magnitude of the runoff from the January 1990 event, a 50- to 100-year occurrence under existing land use, is expected to take place on an average of every 5 to 10 years, a ten-fold increase in frequency.

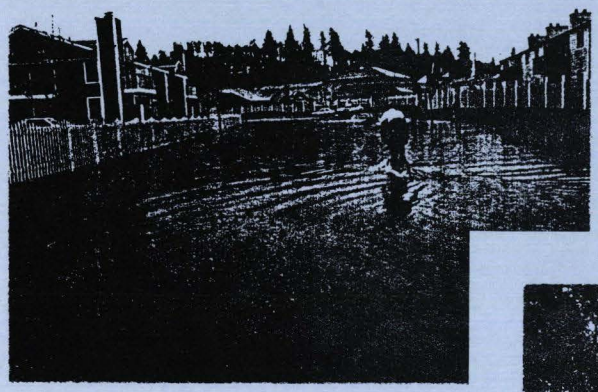
- Much of the wildlife habitat in stream corridor and wetland areas is highly fragmented, which has markedly reduced wildife populations in the planning area.

- Localized landslide activity along the Lower Puget Sound bluffs will accelerate if removal of native vegetation and poor drainage management continues, although several large landslides will persist irrespective of these conditions.

- As the basins approach build-out, sediment levels are expected to decline since development will cover exposed soils. Achieving that state, however, will likely add substantially greater sediment loads to an already overwhelmed system. In additional, impervious surfaces in combination with increased automobile use will accelerate nonpoint pollutant flows and concentrations. Unabated, these contaminants will increasingly diminish and locally eliminate water-oriented recreation, fish populations, and possibly affect the entire food chain in downstream reaches and marine estuaries.

- Development over aquifer recharge areas and heavy pumping for drinking water supplies have already affected and will increasingly reduce groundwater supplies, particularly summertime baseflow, to once-perennial streams that are vital to the West Hylebos Wetland and other downstream reaches.

Introduction



CHAPTER 2

INTRODUCTION

PURPOSE OF REPORT

The purpose of this report is to describe the current and future surface water conditions in those portions of the Hylebos Creek and Lower Puget Sound basins within incorporated and unincorporated King County. The report analyzes existing and expected conditions within these basins from the perspectives of geology, drainage and flooding, water quality, and habitat. This report is the prelude to the Draft Hylebos Creek and Lower Puget Sound Basin Plan that will be published in February 1991. The Draft Basin Plan will propose solutions to the major surface water problems in the basins.

The information in this report is intended to be used by the general public and government officials to better understand the conditions that need to be addressed in the basin plan. This analysis provides the most current and comprehensive assessment of water-related resource conditions available on the basins. Therefore, in addition to serving as the basis for determining significant problems, it is also a technical resource for permitting actions and a foundation for land-use and other growth-related decisions that may impact the resources at risk.

DESCRIPTION OF THE BASINS

The Hylebos Creek and Lower Puget Sound basin planning area, located in southwest King County and northwest Pierce County, comprises over 36 square miles with 35 miles of streams, eleven named lakes, and several hundred acres of wetlands (see Figures 2.1 and 2.2).

To simplify the discussion, the planning area was divided into six sub-basins. Figure 2.2 shows the three sub-basins in the Hylebos Creek Basin: West Branch west of I-5; East Branch, east of I-5; and Lower Hylebos Creek sub-basin in Pierce County. The Lower Puget Sound basin, shown in Figure 2.2, is broken into the North sub-basin, including McSorley (Smith) Creek and Woodmont Creek; the Central sub-basin including Redondo Creek and Cold Creek; and the South sub-basin that includes Lakota Creek, Joes Creek, and the unnamed tributaries to the south. Each sub-basin also includes the adjacent coastal areas and marine receiving waters.

The Hylebos Creek Basin drains 18 square miles of the planning area through more than 25 miles of streams. The headwaters of West Branch Hylebos Creek are in the vicinity of S 320th Street and 16th Avenue S in Federal Way. The tributary from this area (0014A) flows south through the 93-acre West Hylebos Wetland where it converges with several other tributaries, the largest of which is from Panther Lake (0014B). Downstream of SR 99, the creek flows through rather gentle gradients before merging with two other tributaries (0013 and 0013B) prior to reaching the mainstem in Pierce County. In addition to the West Hylebos Wetland and Panther Lake, another significant water feature of the West Branch is an uninventoried 95-acre wetland bounded by SR 99 and 16th Avenue S, S 359th Street, and S 365th Street, commonly known as Spring Valley.

Figure 2.1

HYLEBOS CREEK AND LOWER PUGET SOUND BASINS
LOCATION MAP

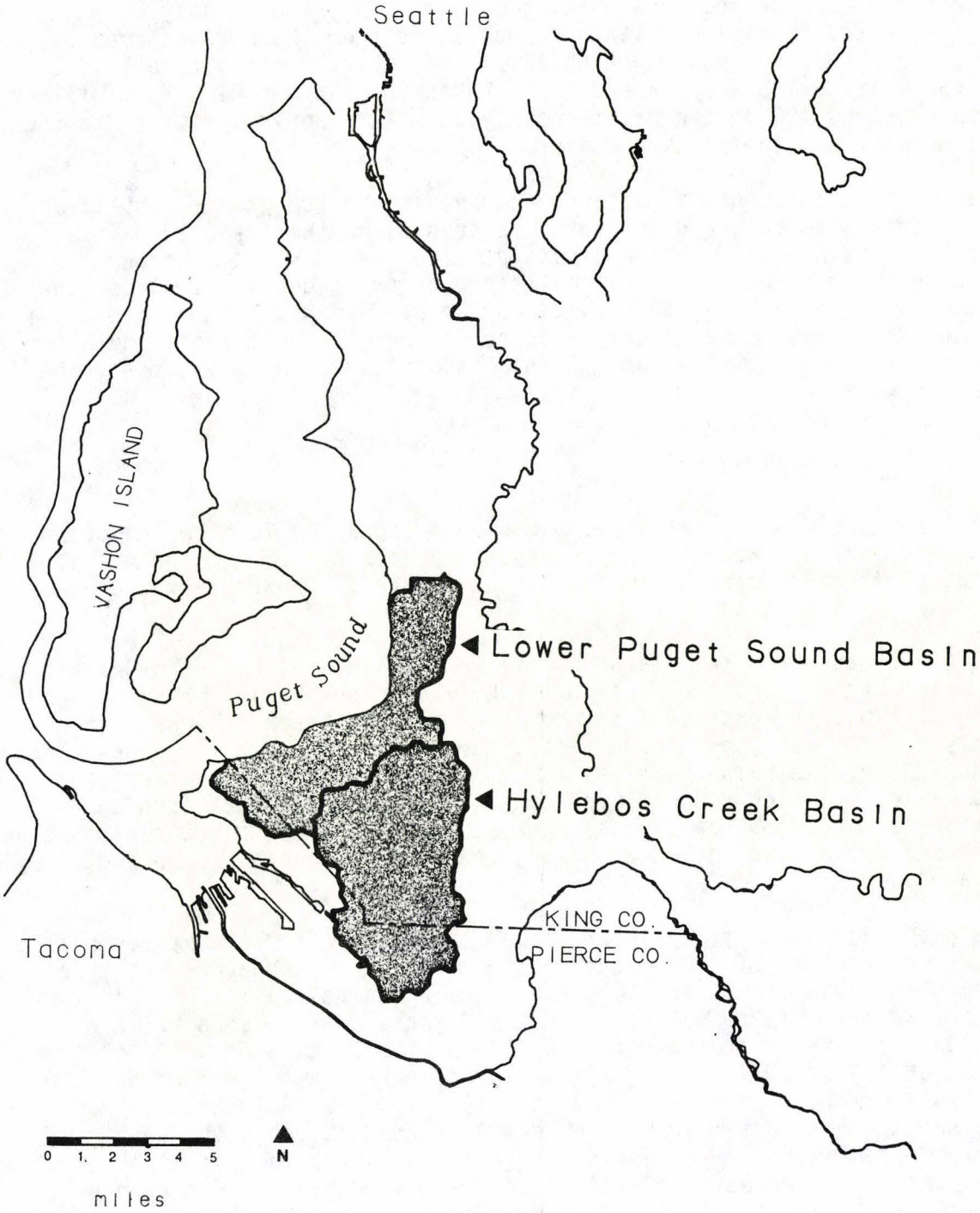
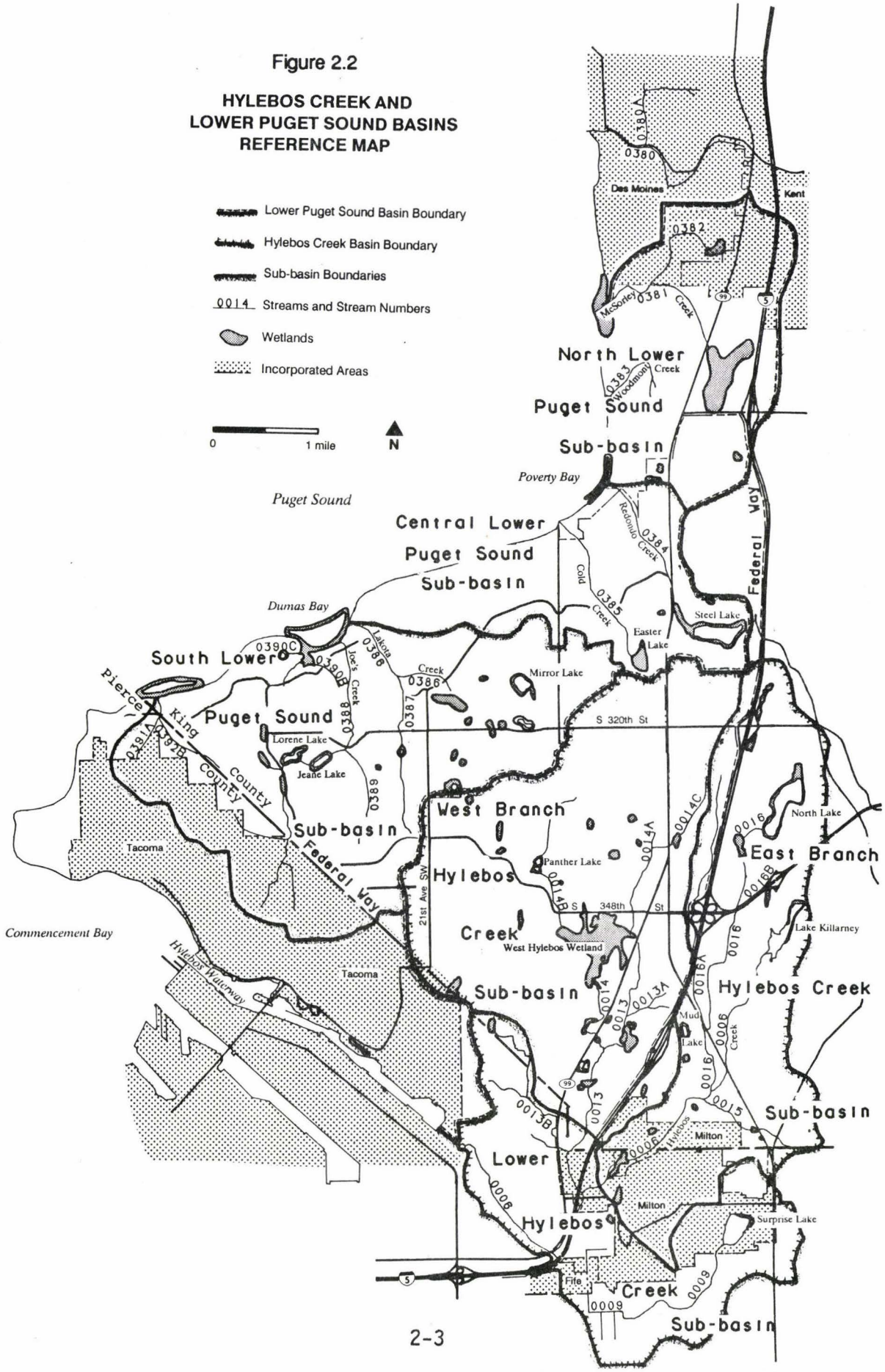


Figure 2.2

HYLEBOS CREEK AND LOWER PUGET SOUND BASINS REFERENCE MAP



East Branch Hylebos Creek begins north of SR 18 in the vicinity of North Lake and Lake Killarney south of SR 18, in unincorporated King County. The creek flows south, at very gentle gradients in the upper portion of the basin where it combines with three tributaries (0006, 0016A, and 0015) south of SR 161. The tributaries combine and flow through a long, steep-gradient reach before entering flatter terrain in Milton and unincorporated Pierce County.

The East and West Branches of Hylebos Creek converge within the broad floodplain of Lower Hylebos Creek near the King-Pierce County line, and form the mainstem near SR 514 (Porter Way) in Milton. Mainstem Hylebos Creek then roughly parallels I-5 down to the 70th Avenue overpass northwest of Fife where it is joined by the Surprise Lake tributary 0009 that flows through Milton and Fife. Hylebos Creek then turns northwest, passing through Tacoma and the Port of Tacoma where it is joined by the Fife Ditch prior to entering Hylebos Waterway and Commencement Bay, almost 9 miles from its headwaters in King County.

Eight tributary areas in the Lower Puget Sound basin drain over 17 square miles of the planning area through almost 19 miles of streams. The northern third of the basin is in King County, Des Moines, and Kent. Northwest Tacoma and Pierce County form the basin's southern edge, while the majority of these creeks are in Federal Way. Most of the streams, including Woodmont Creek, Redondo Creek, Cold Creek, Lakota Creek, Joes Creek, and several unnamed tributaries flowing into Dumas Bay, pass through heavily developed areas before flowing into Puget Sound. However, McSorley Creek, which flows through Saltwater State Park, and the tributaries that flow through Dash Point State Park are exceptions. Unlike much of the Hylebos Creek basin, these drainages flow through relatively flat channels upland on a plateau prior to plunging over the bluff before entering Puget Sound. In addition to Puget Sound, the most conspicuous water features in the Lower Puget Sound basin are a 79-acre wetland on the south fork of McSorley Creek, Steel Lake, Easter Lake, Mirror Lake, Lorene Lake, and Jeane Lake.

LAND USE TRENDS

Since the 1950s, population growth has increased in the planning area, especially in the vicinity of Federal Way, more rapidly than most other communities in King County. Through the 1980s growth was explosive, increasing by almost 20,000 to a total current population estimated at 90,000 in the vicinity of Federal Way. Most of the smaller communities in the basins also grew quickly during this period. By the year 2020, population in this area is expected to climb to an estimated 154,000 (King County Planning Division, 1989).

The several state highways crossing the planning area were dominant factors in stimulating growth and the current land-use patterns in the basins. These patterns are strongly related to the quality and quantity of surface water in the basins. This is particularly the case in the Hylebos Creek basin which receives storm flows from Interstate 5 (I-5), State Route 18 (SR 18), SR 99, and SR 161. Most of the commercial and industrial uses in the basins have located on or near these highways. These uses tend to generate more stormwater runoff than residential uses. Thus, the combination of impervious surfaces on the highways, together with the collective effects of this particular land-use pattern, have been significant factors leading to the present degraded condition of Hylebos Creek.

Current and Future Land Use

A computer simulation model was used to determine current and future flows analyzed in this report. Analysis of the basin began in 1988 based on a model that uses 1987 land use patterns as current conditions and the 1986 King County, Federal Way Community Plan and Area Zoning (King County Planning Division, 1986) for future conditions. The following discussion describes the current and future land use patterns used in this analysis. This description includes the jurisdictions in Pierce County for purposes of fully characterizing the planning area; however, only flows in the King County portion of the basins were modeled. A detailed discussion of modeled stormwater flows is in Chapter 3.3, Hydrology.

The 1987 current land use analyzed in the computer model for the planning area is displayed in Figures 2.3a and b. These figures show that the majority of the most highly intensive commercial uses in the basins are located in mid-upper and West Branch Hylebos Creek in proximity to I-5, SR 99, SR 161, and S 320th Street. High intensity development has almost 90 percent site coverage by extensive impervious surfaces including highways, parking lots, and buildings that generate large volumes of stormwater and pollutants compared to other uses. Other highly intensive use areas include portions of the SR 99 corridor that drain into Cold, Redondo, Woodmont, and McSorley Creeks, and scattered locations throughout the Lower Puget Sound basin.

Much of the moderate and high-density single- and multifamily residential development (more than 3 units per acre and 25 to 60 percent site coverage) is in the Lower Puget Sound basin on the plateau, generally east of SR 509. In the Hylebos Creek basin, pockets of high density single-family residential uses are concentrated in the northern and western parts of the West Branch. These uses are also clustered in the vicinity of Milton and adjacent to lakes and major roads in East Branch and Lower Hylebos Creek sub-basins.

The remainder of the planning area is in low density residential and other low intensity uses (fewer than 3 units per acre and less than 25 percent site coverage) such as agriculture, forest, or grassland. Because these uses generate less stormwater per acre, they help to buffer many of the sensitive areas in the basins from more stormwater damage. These areas include the steep slopes along the Puget Sound bluffs and stream corridors tributary to Puget Sound, major wetland systems in the mid- and lower reaches of West Branch Hylebos Creek that provide primary fish and wildlife habitat, and portions of the mid- and lower reaches of East Branch Hylebos Creek that also support salmonid habitat.

Future Land Use

In 1986, King County adopted the Federal Way Community Plan and Area Zoning. The future land use map for modeling the basin was patterned after this plan which was intended to be periodically updated as conditions changed. Since the future land use patterns in the basin model were intended to represent maximum build-out conditions, this 1986 Plan map was modified to project the most intensive land use patterns that could reasonably be expected according to all the plans and zoning maps available for the basins. The storm flows projected under future land use therefore represent the "worst case" conditions.

Figure 2.3a

Hylebos Creek Basin

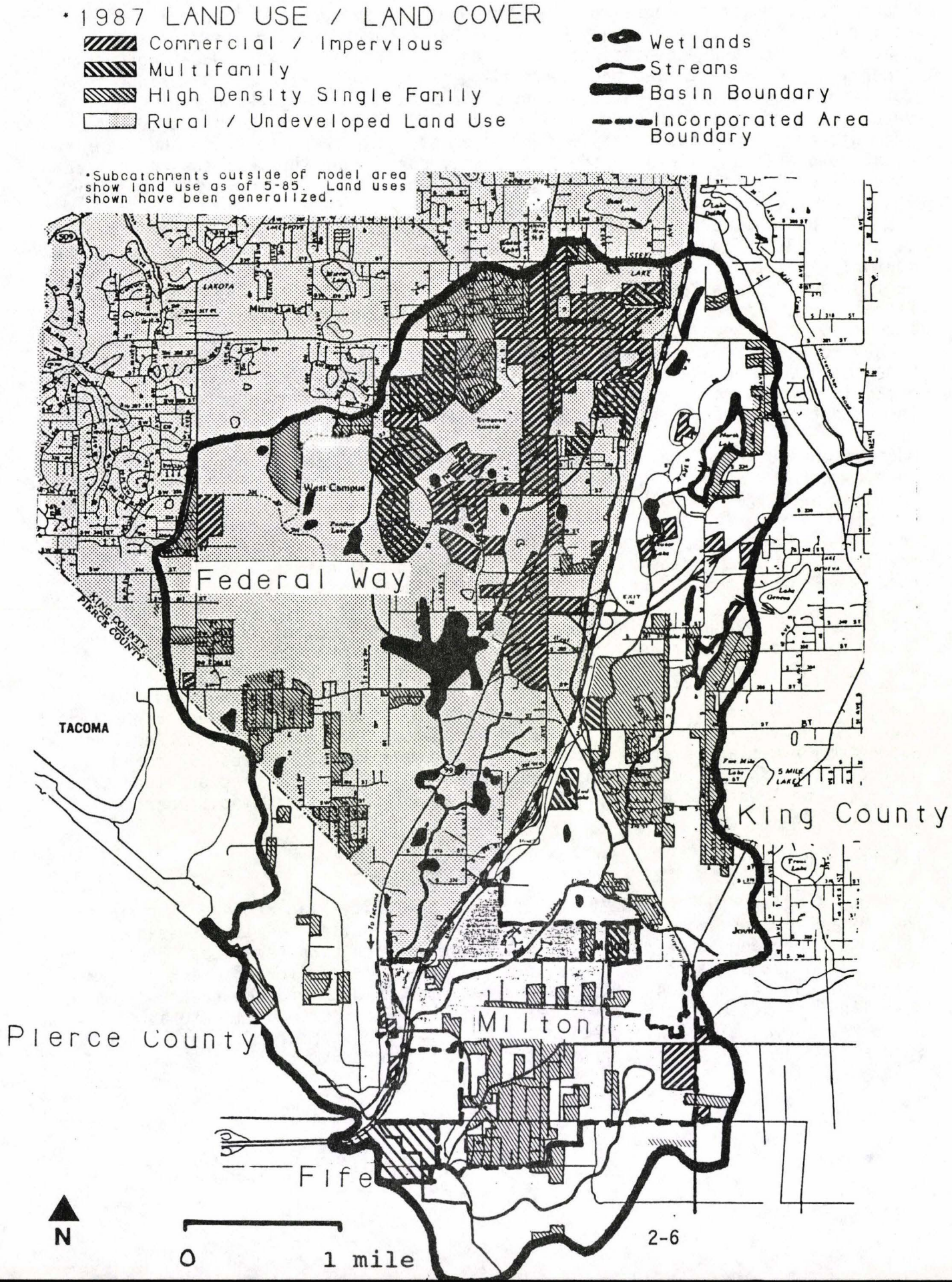
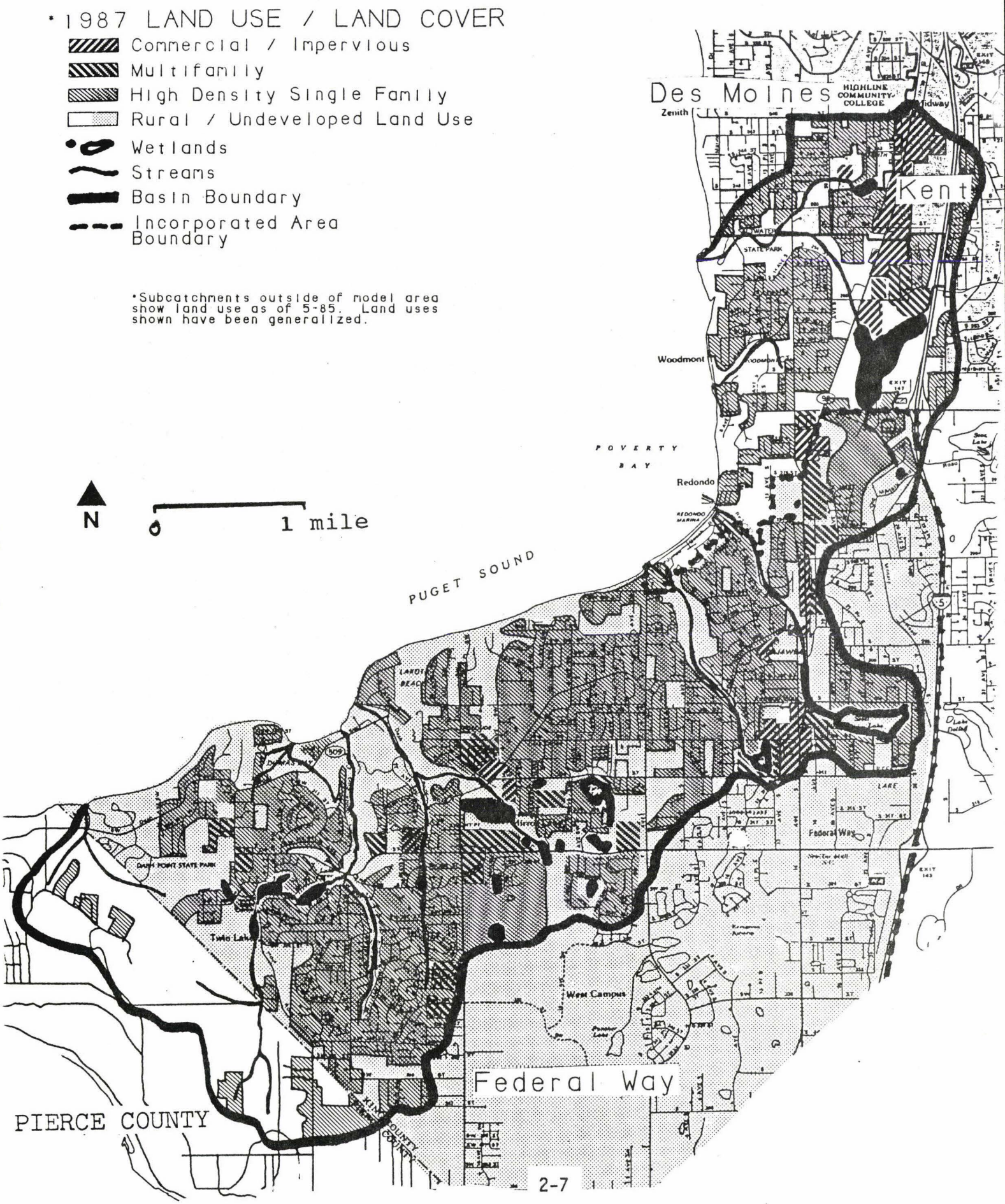


Figure 2.3b

Lower Puget Sound Basin



The 1986 Plan reinforced most of the current land-use patterns already in place. To a great extent, single family residential areas were maintained. Low density residential uses were planned for the sensitive areas in the lower reaches of Hylebos Creek and on the Puget Sound bluffs. Existing commercial, industrial, office park, and multifamily use areas were expanded and new locations for these uses were planned, primarily in the mid- and upper portions of the Hylebos Creek basin.

According to this 1986 Plan, the unincorporated King County portion of the basins, in East Branch Hylebos, Woodmont, and Redondo Creeks, were to continue to develop in low to high single family residential densities. The Plan also projected a combination of manufacturing park, in the upper part of East Branch Hylebos Creek in the vicinity of the Weyerhauser corporate campus, and a range of low to high density residential uses in the remainder of this sub-basin. A portion of the planning area, within Kent and Des Moines, that drains into McSorley Creek is expected to continue to be commercially developed along SR 99, while low to high density single-family residential uses are anticipated to the east and west of this corridor (City of Des Moines, 1981).

In February 1990, the City of Federal Way adopted the Federal Way Comprehensive Plan. This Plan modified the 1986 County Plan somewhat by reducing multifamily and commercial uses in the western portion of the city. However, the general development pattern, projecting the most intensive use areas in West Branch Hylebos Creek is similar to the 1986 County Plan. Figures 2.4a and b represent the future land-use map for the planning area. It is a composite of the 1986 County Plan, which governs unincorporated areas and the 1990 Federal Way Plan that regulates incorporated Federal Way.

Within Pierce County, it is anticipated that the Port of Tacoma will continue to develop with heavy commercial and industrial uses on Commencement Bay and its waterways. The trend away from existing agricultural uses toward heavy commercial and industrial uses along the I-5 corridor in Fife, Milton, and Tacoma is also expected to continue. On the eastern plateau, above the Lower Hylebos Creek valley, land use in Milton and unincorporated Pierce County is expected to remain primarily in commercial uses along SR 161 and in low- to moderate-density residential uses outside of this corridor. The low-density residential area on the west plateau in Fife Heights, is expected to become a mixed low to moderate density residential area in the future (Pierce County, 1964).

REVIEW OF REPORT CONTENTS

Chapter 1: Executive Summary

The Executive Summary provides a synopsis of the key findings of this report.

Chapter 2: Introduction

The Introduction discusses the purpose of this report, the general physical nature of the Hylebos Creek and Lower Puget Sound basins, and land use trends in the planning area.

Figure 2.4a

Hylebos Creek Basin

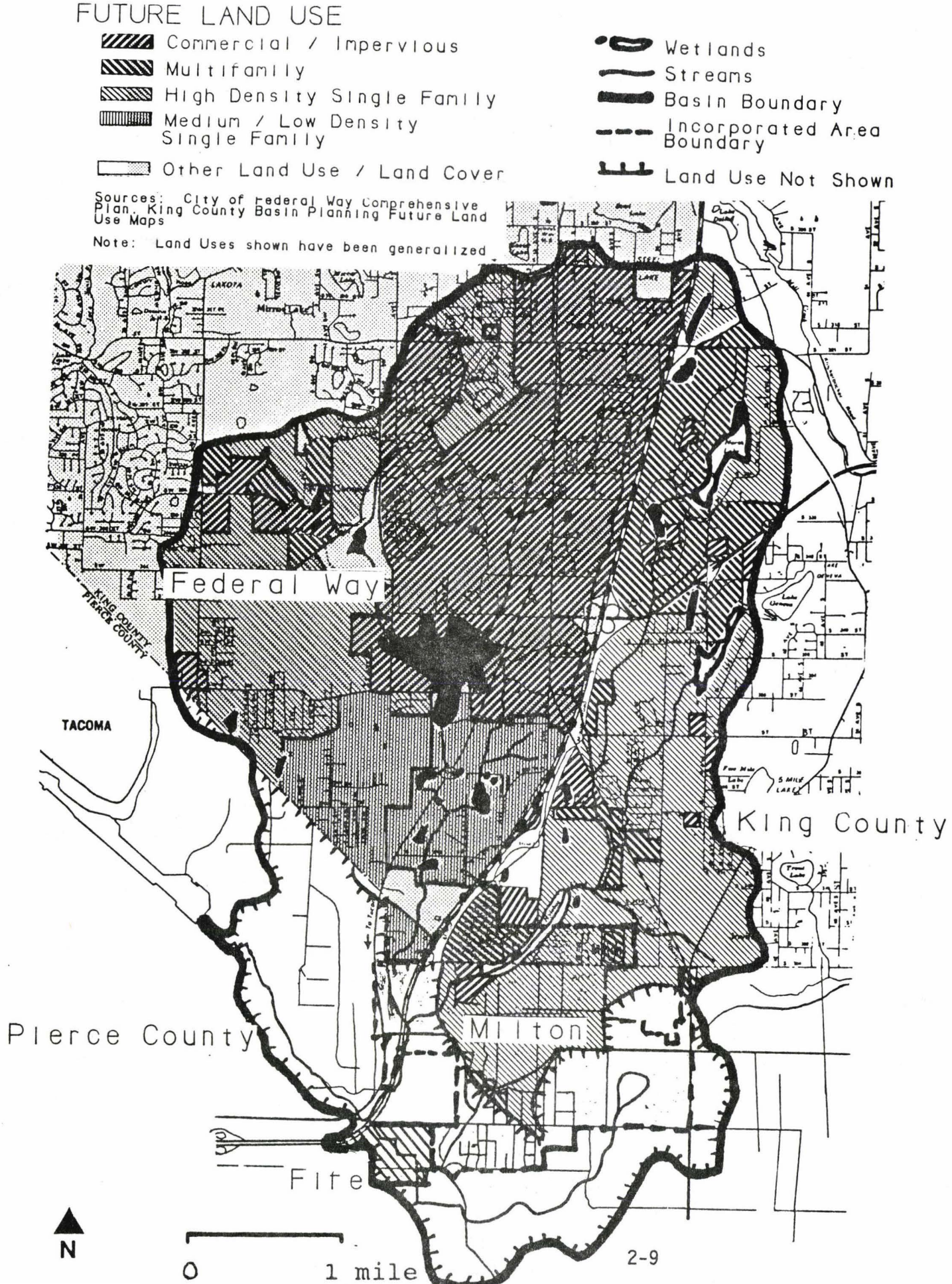
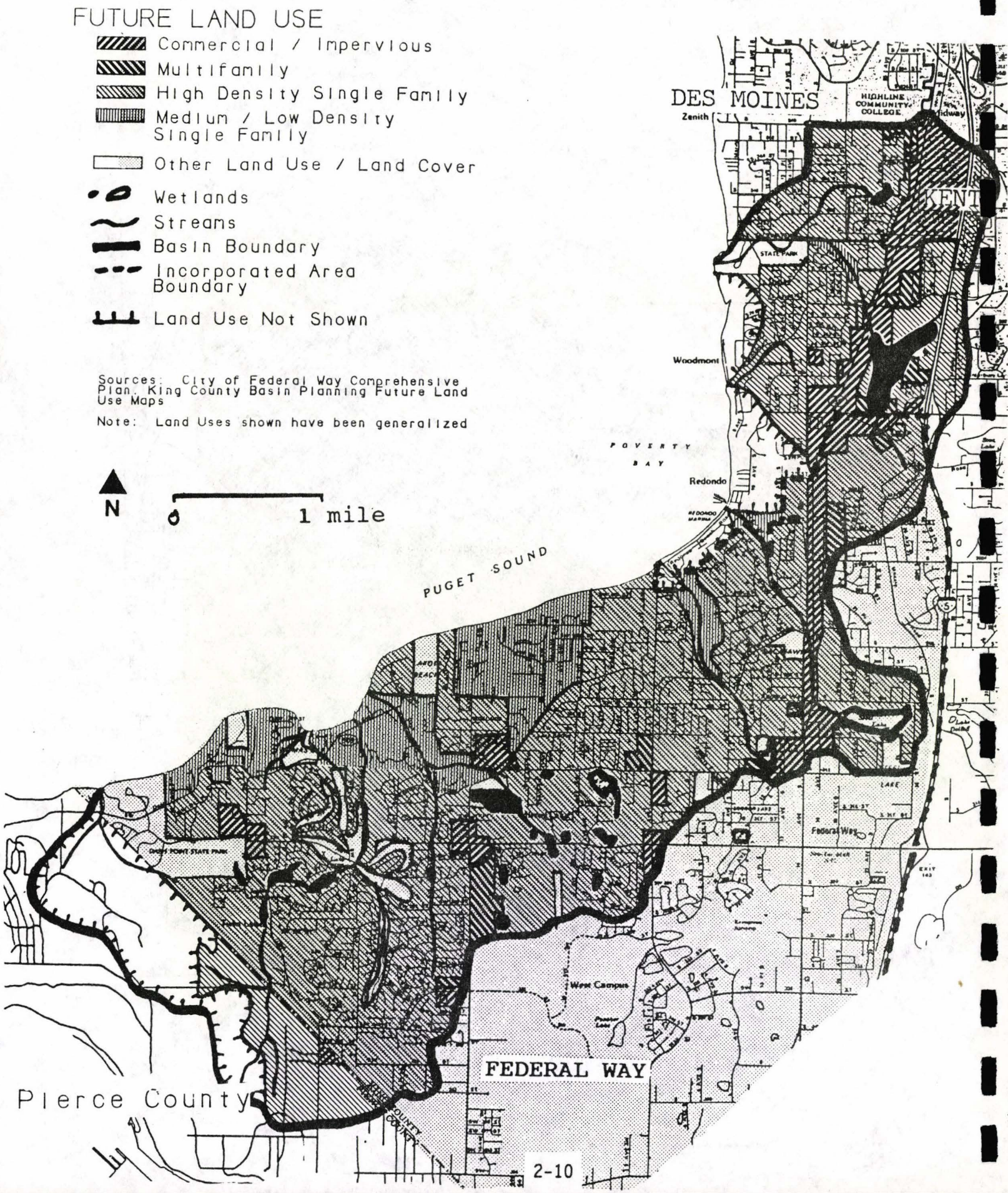


Figure 2.4b

Lower Puget Sound Basin



Chapter 3: Basinwide Conditions

The Basinwide Conditions describe the current and future conditions of the planning area as a whole. This chapter is divided into several sections, each of which discusses a perspective, including geology, hydrology, flooding, groundwater, erosion and sedimentation, water quality, habitat, and public and private sector issues. These sections also discuss data-gathering methods, concepts basic to understanding the analysis, and key findings. The content of each section is summarized below:

- The Introduction (3.1) describes the chapter contents.
- The Geology section (3.2) describes the geology, glacial history, and their effect on drainage basin conditions.
- The Hydrology section (3.3) discusses current and future flow conditions as recorded by stream gages and modeled with a continuous simulation model.
- The Flooding Analysis section (3.4) describes areas currently prone to flooding, where flooding is expected in the future, and why it occurs.
- The Groundwater section (3.5) describes the soils and geologic conditions in the basin that affect aquifers and aquifer recharge, water supply considerations, and the implications of urbanization on these elements in the future.
- The Erosion and Sedimentation section (3.6) addresses erosion and deposition processes in stream channels and the response of channels to current and future flows.
- The Water Quality section (3.7) discusses water quality in the basins during baseflow and storm event conditions, nonpoint source contaminants, and water quality impacts on habitat.
- The Habitat section (3.8) describes the conditions and factors that affect fish and wildlife habitat in the basins.
- The Public/Private Actions and Future Directions section (3.9) discusses the basic elements affecting conditions in the basins, including institutional factors and the activities of the general public, and the role of the basin plan in addressing these issues.

Chapter 4: Sub-basin Conditions

Following the Introduction (4.1), the Sub-basin Conditions Section describes current and future conditions in each of the six sub-basins in the planning area: West Branch Hylebos Creek (4.2), East Branch Hylebos Creek (4.3), Lower Hylebos Creek (4.4), and the North, Central, and South sub-basins in Lower Puget Sound basin (4.5). Each sub-basin is examined through an interdisciplinary analysis that integrates geology, hydrology, flooding, land use, erosion and sedimentation, water quality, and habitat perspectives.

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Appendices

Appendices A and B contain detailed lists of stream conditions in the planning area by river mile and entity. These lists were compiled from stream walks in 1986 and 1987 evaluating erosion, sedimentation, hydrology, habitat, and water quality as part of the King County Basin Reconnaissance Program. They also include recent staff field investigations, other agency observations, citizen observations, and drainage complaints from the public.

Appendix C contains HSPF-modeled flow frequencies and durations by subcatchment under various land use scenarios and schematics of the subcatchment network in each sub-basin.

Basinwide Conditions

CHAPTER 3

BASINWIDE CONDITIONS

SECTION 3.1 INTRODUCTION

Conditions in Hylebos Creek and the Lower Puget Sound basins stem from many interacting factors. Primary among them is the intense land use patterns that generate high volumes of poor quality stormwater to stream systems. When stormwater discharges interact with the stream systems, soils, geology, and habitat in the basins, it profoundly impacts the drainage capacity of these systems, stream channel erosion, sedimentation, habitat conditions, wildlife populations, and groundwater volumes.

This chapter details these land use and stormwater discharge impacts in the planning area as a whole from seven disciplinary perspectives, as follows: Geology (3.2), Hydrology (3.3), Flooding (3.4), Groundwater (3.5), Erosion and Sedimentation (3.6), Water Quality (3.7), and Habitat (3.8). Public/Private Sector Actions and Future Directions (3.9) describes the regulatory and other human factors that underlie the physical conditions. The content of each of these sections is summarized in Chapter 2.2., Review of Report Contents.

SECTION 3.2 GEOLOGY

INTRODUCTION

The Hylebos Creek and Lower Puget Sound basins encompass a variety of geologic terrains. These terrains dramatically influence patterns of surface-water runoff, groundwater flow, and hillslope stability. Long an area of limited population and development activity, rapid growth in the last two decades has resulted in increased concern for the impacts of that development on the land and the constraints that are in turn imposed on human activity. This geologic study provides an overview and a framework for both basinwide streamflow patterns and area-specific hazard evaluation.

DATA SOURCES

This study follows decades of local investigations, initiated by U.S. Geological Survey publications covering all but the most western and southern parts of the area (Waldron, 1961, 1962). Field work for the present study spanned 1988 and early 1989, involving site inspection of all shoreline exposures, all stream channels, and innumerable roadcuts and building excavations throughout the upland areas. Not surprisingly, the distribution of mapped deposits follows closely on the equally detailed work of earlier studies; yet access and exposures have improved dramatically in the last three decades, permitting greater certainty and refinement in identifying geologic materials and the interpretation of their history. Additional data was obtained from well log reports in the vicinity of the Midway Landfill (Applied Geotechnology, 1988), along the coastline (Department of Ecology, 1979), and detailed groundwater investigations in the Federal Way area (Robinson and Noble, written communications, 1988).

CONDITIONS

Physiography

The Hylebos and Lower Puget Sound basins drain an elongated upland plateau known as the Des Moines Drift Plain, bounded on the west by Puget Sound, the east by the Green-Puyallup valley, and the south by the Puyallup River floodplain and (now-filled) estuary. Hylebos Creek drains south over the surface of the drift plain, incising through the surface deposits to reveal the underlying geologic materials only in the lower reaches of the East Branch. In contrast, the Lower Puget Sound drainages have carved rapidly through the lip of the uplands, reflecting their greater steepness and thus greater competence for erosion. Wave action along the shores of Poverty Bay maintains a steep shoreline bluff in many areas and has probably caused significant steepening of these basins by bluff retreat, active since deglaciation of the region about 14,000 years ago.

Glacial History and Stratigraphy

Glacier ice originating in the mountains of British Columbia has invaded the Puget Lowland several times, leaving a discontinuous record of early to late Pleistocene glacial and interglacial periods (Easterbrook, 1986). The ice was part of the Cordilleran ice sheet of northwestern North America; it advanced into the Lowland as a broad tongue referred to as the "Puget lobe" by many authors since Bretz (1913).

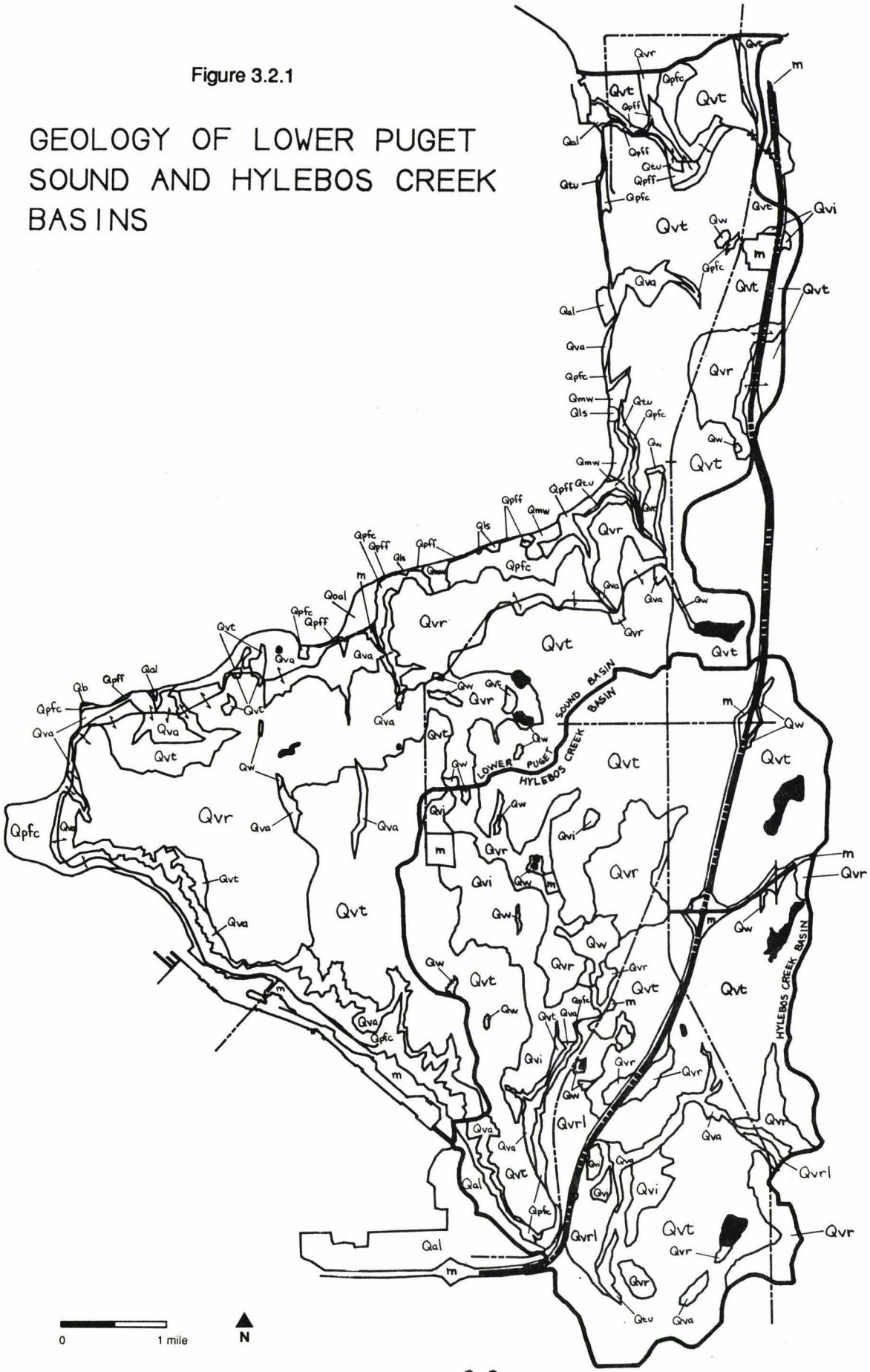
In the study area, deposits of at least two and possibly three glaciations are exposed (Figure 3.2.1). Most widespread are those from the most recent ice advance and retreat, named the "Vashon" by Armstrong and others (1965) because of particularly good exposures on Vashon Island. These deposits underlie the upland plain, now truncated by Puget Sound to the west and the Green River valley to the east.

The most common surficial deposit of Vashon age is till, a compact mixture of silt, sand, and gravel deposited at the base of the glacier. Overlying the till and covering large areas of the southwestern and south-central planning area are broad areas of recessional outwash. These are mainly sand and gravel deposited by rivers emerging from the margin of the retreating ice. The position and surface altitudes of this outwash suggest simultaneous deposition with the extensive outwash terraces in the Soos, Jenkins, and Covington Creek basins some 10-20 miles (15-30 km) east (Mullineaux, 1970; Booth, 1989). Flow of these glacial torrents, controlled and diverted by the position of the steadily retreating glacier margin, was probably south and then across the planning area, draining southwest into what is now Commencement Bay.

Outwash deposited earlier, during advance of the ice sheet, underlies the till and is present throughout the area. In general, however, it is identified most often in well logs; but these advance outwash deposits are well exposed at the ground surface along the northwest- and southwest-facing slopes above Puget Sound and in the incised valleys of Joes Creek and East Branch Hylebos Creek. At Dumas Bay, the Vashon advance outwash is exposed at sea level along 1.5 miles of coastline. This exposure is part of a sub-sea-level channel that extends north through Maury Island and east-central Vashon Island (Booth, in press) and back on to the mainland at Point Pully (3 miles north of the study area; Waldron, 1962). In the south, the channel is traced by numerous water-supply wells, forming the "Milton-Redondo Channel" that yields much of Federal Way's water

Figure 3.2.1

GEOLOGY OF LOWER PUGET SOUND AND HYLEBOS CREEK BASINS



DESCRIPTION OF MAP UNITS (FIG 3.2.1)

HOLOCENE DEPOSITS

POSTGLACIAL DEPOSITS (HOLOCENE) - Divided into:

Modified Land (m)

Beach Deposits (Qb)

Wetland Deposits (Qw)--Localities are compiled from the King County Wetland Inventory (1983).

Alluvium (Qal)

Landslide Deposits (Qls)--Only four are sufficiently large to show at map scale; smaller such features are common along many of the wave-steepened beach cliffs.

Mass-Wastage Deposits (Qmw)--Colluvium, soil, or landslide debris with indistinct morphology, mapped where sufficiently continuous and thick to obscure underlying material.

Older Alluvium (Qoal)--Similar in texture and morphology to unit Qal. May represent a late stage of deposition during the time of Vashon ice recession.

PLEISTOCENE DEPOSITS

DEPOSITS OF THE VASHON STADE OF THE FRASER GLACIATION (PLEISTOCENE) - Divided into:

Recessional Outwash Deposits, Lacustrine (Qvrl)--Laminated to massive silty clay to clayey silt, deposited in standing water during a late stage in the ice recession.

Recessional Outwash Deposits, Undifferentiated (Qvr)--Stratified sand and gravel, moderately to well sorted, with less common silty sand and silt.

Ice-Contact Deposits (Qvi)--Similar in texture to unit Qvr but containing a much higher percentage of silt mixed in with the granular sediment.

Till (Qvt)

Advance Outwash Deposits (Qva)

PRE-FRASER DEPOSITS (PLEISTOCENE)- Divided into:

Pre-Fraser Deposits, Fine-Grained (Qpff)--Laminated to massive silt, clayey silt, and silty clay, with or without interbedded sand and uncommon gravel.

Pre-Fraser Deposits, Coarse-Grained (Qpfc)--Interbedded sand and gravel with at most minor layers and lenses of silty sand and silt; moderately to heavily oxidatidized. Weathering rinds are common but not ubiquitous and range from 0.1-0.3 mm on fine-grained volcanic clasts.

Till, Undifferentiated (Qtu)--Compact, stony diamict, distinguished from its Vashon-age equivalent by oxidation of clasts and matrix, rare weathering rinds on clasts up to 0.5 mm thick, and stratigraphic and topographic position. Includes fluvial, lacustrine, and mudflow deposits too thin to discriminate at map scale.

supply. Its altitude suggests that it may mark a pre-Vashon river valley, estuary, or arm of Puget Sound, offset several kilometers from the present-day location of the waterway in this area.

In addition to recessional outwash deposits of sand and gravel, recessional deposits of silt and clay are also present in the basin plan area. They are concentrated in the Lower Hylebos sub-basin, where they lie at elevations below about 100 feet. These deposits reflect the last stage in the ice recession, when the immediate area was ice-free but the wasting glacier still blocked the northward drainage of lowland rivers out of Puget Sound. As a result, regional lakes formed until the impounded water could spill south into the Chehalis River valley (Thorson, 1980). Deposition into these lakes was limited here to fine sediment, which now forms a low-lying area bounded on the east and west by till-mantled hills and truncated on the south by more recent alluvium of the Puyallup River.

Pre-Vashon glacial advances are expressed by discontinuous, near sea-level till exposures along the shores of Poverty Bay and near Milton; a till lens exposed in the Redondo area at about altitude 150'; and thick, widespread deposits of oxidized sand and gravel that apparently underlie most if not all of the basin plan area at depth. These river-lain deposits are interpreted here as having a glacial origin because deposits of equivalent coarse texture, mixed lithologies, great thickness, and lateral extent are not being deposited in the modern (non-glacial) landscape but are common throughout sediments of unequivocal glacial (namely Vashon) origin and age.

Regional Correlations

Correlation of these pre-Vashon glacial deposits with formally named units farther east (Crandell and others, 1958) or north (Easterbrook and others, 1967) is problematic. The type area for the Salmon Springs Glaciation (Crandell and others, 1958) lies over 6 miles (10 km) to the southeast along the east wall of the Puyallup River valley and has been dated at greater than 750,000 years old (Easterbrook and others, 1981). A layer of air-borne volcanic ash has permitted correlation of this deposit across to the west wall of the Green River valley near Peasley Canyon (Westgate and others, 1987), only a few miles east of the study area. Superficially, these named deposits are similar to those found throughout the study area. Were this correlation correct, however, it would require that the several intervening glaciations that occurred between 750,000 and 15,000 years ago (e.g., Easterbrook and others, 1967; Lea, 1984; Booth, 1990) would have left no record of their passage. Over so broad an area, such a widespread absence of deposits seems implausible. Thus no correlation of these earlier glacial deposits are made in this report with formally named deposits elsewhere in the Puget Sound region. This problem has also been recognized farther south (Noble, 1990).

CONSEQUENCES FOR DRAINAGE-BASIN CONDITIONS

This geologic setting has several consequences for land use, hydrology, and stream-channel erosion and deposition in the Hylebos and Lower Puget Sound basins. Overall, the deposits form a crude 4-element sequence: locally thick and permeable deposits of Vashon recessional outwash or ice-contact deposits, overlying thin and relatively impervious Vashon till, overlying sand and gravel of either the Vashon advance outwash or other older glacial outwash, overlying a

yet-older mixture of clay or till or other impervious sediment. This sequence results in several widespread conditions in the basin plan area (with locations of examples noted in parentheses):

- Landslide susceptibility at and near the contact between the lowermost till/clay deposits and the overlying sand and gravel, caused by the perching of groundwater above this contact and the resultant reduction in slope stability (examples are found throughout the region, but a particularly spectacular one is located above the shores of Poverty Bay, northeast of SW 295th Street between about 8th and 10th Avenue SW);

- Highly erodible stream channels where they pass over the sand and gravel deposits that underlie the Vashon till, because of the lack of either cohesion or coarse sediment in that middle layer (the lower East Branch Hylebos Creek, particularly just above its confluence with tributary 0016);

- Highly infiltrative soils resulting in low or absent surface-water runoff, particularly where thick undisturbed deposits of the recessional outwash are exposed at the ground surface (closed infiltrative depressions west and northwest of Panther Lake, where not impacted by recent construction activity);

- Excellent bearing strength for construction of most of the upland area underlain by Vashon till, coupled with a moderately high potential for release of fine sediment into the stream system during construction activity (the entire Federal Way commercial area bounded by I-5, Steel Lake, Mirror Lake, and Kitts Corner); and

- Widespread areas of wetlands and wetland soils, associated either with shallow groundwater perched on top of the nearly level, undulating till surface, or with Vashon recessional lake-bottom sediments ("Spring Valley", at and just above the confluence of the north fork and West Branch of Hylebos Creek near the County line).

SECTION 3.3 HYDROLOGY

INTRODUCTION

The hydrologic processes in the Hylebos and Lower Puget Sound basins have been severely altered from historic conditions in most areas and are anticipated to be further affected as urbanization continues. Understanding the hydrologic processes that are affected by land-use alterations provides the basis for solving existing and future flow-related problems.

This section discusses hydrologic concepts that influence runoff in the basins, followed by a description of the hydrology of the basins under 1987 land use, future build-out conditions, and pre-developed conditions.

HYDROLOGIC CONCEPTS

Hydrologic Characteristics

Simulating the hydrology of the Hylebos Creek and Lower Puget Sound planning area required grouping soils, topographic slope, and land cover into hydrologically similar categories. This sub-section describes the characteristics of each of these groups.

Soils - Soils were placed into three broad categories: outwash, till, and wetlands (see Section 3.2, Geology, for a complete discussion of soils). Outwash soils consist of sand and gravel deposits that have high infiltration rates. Rainfall in these areas is quickly absorbed and percolates to the groundwater table. Creeks draining these areas typically intersect the groundwater table and receive most of their flow from groundwater discharge, unless they are located in a part of the deposit located above the water table. The response in the creeks after a storm is therefore slow, with the peak flow in the creek often occurring up to several days after a storm.

Till deposits contain large percentages of silt or clay and have low percolation rates compared to the outwash deposits. Only a small fraction of the infiltrated precipitation percolates to the groundwater table. The rest moves laterally through the thin surface soil above the till deposit, often re-emerging at the base of hillslopes. This shallow, subsurface, lateral movement of flow is called interflow. Interflow travels to the creek much faster than groundwater but slower than surface runoff. Soils overlying till deposits may become saturated in large storms and produce significant amounts of surface runoff. The peak runoff rate from till areas is therefore typically much higher than from outwash areas.

Wetland soils remain saturated throughout much of the year. The hydrologic response from wetlands is variable depending on the underlying geology, the proximity of the wetland to the regional groundwater table, and the bathymetry of the wetland. Generally, wetlands absorb runoff in the summer months if they are located above the groundwater table and release groundwater to the creek if it intersects the groundwater table. In winter surface flows are attenuated via hydraulic storage and slow release when soils are saturated.

Land Cover - Three types of cover were considered in analyzing the hydrology of the Hylebos Creek and Lower Puget Sound basins: forest, grass/pasture, and impervious.

Runoff from forested areas produces the least amount of surface runoff. Forest cover is most significant in till areas because it breaks up the structure of the till and its thin surface soils and allows for more infiltration to occur. Interception and evapotranspiration, a factor in most autumn, spring, and summer storms, is also greater in forested areas than with the other cover categories.

Grassed areas produce more surface runoff than forested areas because grass is shallow rooted and does not contribute to infiltration as forested cover does. Grassed areas therefore saturate quicker and produce more overland flow in large storms than forested areas.

Impervious areas produce the most surface flow of all cover categories. The infiltration rate in impervious areas is zero; therefore, precipitation runs directly off to produce high peak flows.

The combination of forest cover on outwash produces the lowest peak flows, with grass-covered outwash producing the next lowest, then forested till, grassed till, and finally impervious cover. Peak flows from wetland soils are variable depending on the characteristics of the wetland and the time of year.

Stream Channels, Lakes, and Wetlands - Receiving creeks, lakes, and wetlands also affect the runoff characteristics from a given area. These features store flows and release them slowly, thus reducing the flow peak. The degree to which these flows are reduced depends upon the roughness, slope, size, and shape of the channel. The most sensitive of these parameters is channel size. Thus, wetlands and lakes by virtue of their larger storage volume are typically more effective than channels at reducing flow peaks.

Slopes - Slopes in till areas were grouped into three broad categories: 0-5 percent, 5-15 percent, and greater than 15 percent. Slopes influence the rate at which interflow discharges to the creek in till soils. Steeper slopes have faster interflow responses than flatter slopes. This allows the thin surface soil in steeper sloping till areas to drain faster than flat sloped till. Because the flat sloped till areas do not drain as well, the soil saturates more quickly in large storm events, producing more significant surface runoff.

HSPF Hydrologic Model

The hydrology of the planning area was analyzed using the Hydrological Simulation Program-Fortran (HSPF) computer model. This model uses mathematical relationships to describe the physical processes controlling the hydrology of the watershed. Using inputs of precipitation and evaporation, HSPF computes the amount of discharge to the creek continuously through time from surface, interflow, and groundwater flow.

The HSPF model was calibrated using two years of stream flow and precipitation records collected by the U.S. Geological Survey (USGS) within the basin for water years 1987-1988. Regionalized calibration parameters developed by the USGS (Dinicola, 1989) initially were used and then refined to better match the conditions in the Hylebos Creek and Lower Puget Sound basins. Using the

calibrated model, a 39-year continuous record of rainfall collected at the Seattle-Tacoma Airport station was input to create a 39-year series of flows at the outlet of each of the 60 subcatchments in the planning area (Figures 3.3.1a and b). Three different land-use scenarios were modeled: 1) Current (1987), 2) future (build-out under existing (1987) zoning and County land-use plans), and 3) pre-developed (forested).

CONDITIONS

Current (1987) Conditions

Land Cover - Simulated flows for the current land-use scenario are based on conditions in 1987 (also used to calibrate the hydrologic model). Table 3.3.1 provides a summary of commercial and residential land uses tributary to each stream outlet. Figures 3.3.2a-e depict 1987 land cover tributary to the outlet of the major creeks. In general, a larger percentage of the land area in the Lower Puget Sound basin has been developed with approximately 30 percent remaining forested as compared to the Hylebos Creek basin where over 50 percent of the basin remains undeveloped under 1987 conditions. The percentage of impervious surface in the West Branch Hylebos sub-basin is comparable to the percentage of impervious surface in the Lower Puget Sound basin, despite the lower level of overall development in the West Branch Hylebos Creek sub-basin. This indicates a much higher density of development, where it occurs, in the West Branch Hylebos Creek sub-basin.

Table 3.3.1

SUMMARY OF (1987) LAND USES TRIBUTARY TO EACH BASIN OUTLET

	1987 LAND USE (ACRES)				
BASIN	COMM.	MULTI-FAMILY	3-7 UNITS/AC	1-3 UNITS/AC	RURAL
West Hylebos	832.4	225.5	613.9	0.0	249.7
East Hylebos	217.6	83.4	791.8	0.0	156.3
McSorley Creek	201.4	141.2	730.6	0.0	19.1
Woodmont Creek	20.2	9.9	161.4	0.0	16.3
Redondo Creek	57.8	46.8	296.8	0.0	0.0
Cold Creek	55.5	37.4	206.9	0.0	0.0
Lakota Creek	82.2	160.0	1045.3	0.0	49.8
Joes Creek	47.2	23.4	802.6	0.0	37.4

Flow Frequencies by Basin - Flows produced by the continuous HSPF model over the 39-year simulation period were used to compute return frequencies for peak annual flows. A Log-Pearson analysis, based on Water Resources Council guidelines (WRC, 17a, 1977) was used to compute the magnitude of peak annual flows over a range of return periods of 1.01-, 2-, 5-, 10-, 25-, 50-, 100-, and 500 years. Flows for the 2-, 10-, 25-, and 100-year flows at the outlet of each

Figure 3.3.1a

Hylebos Creek Basin Planning Area

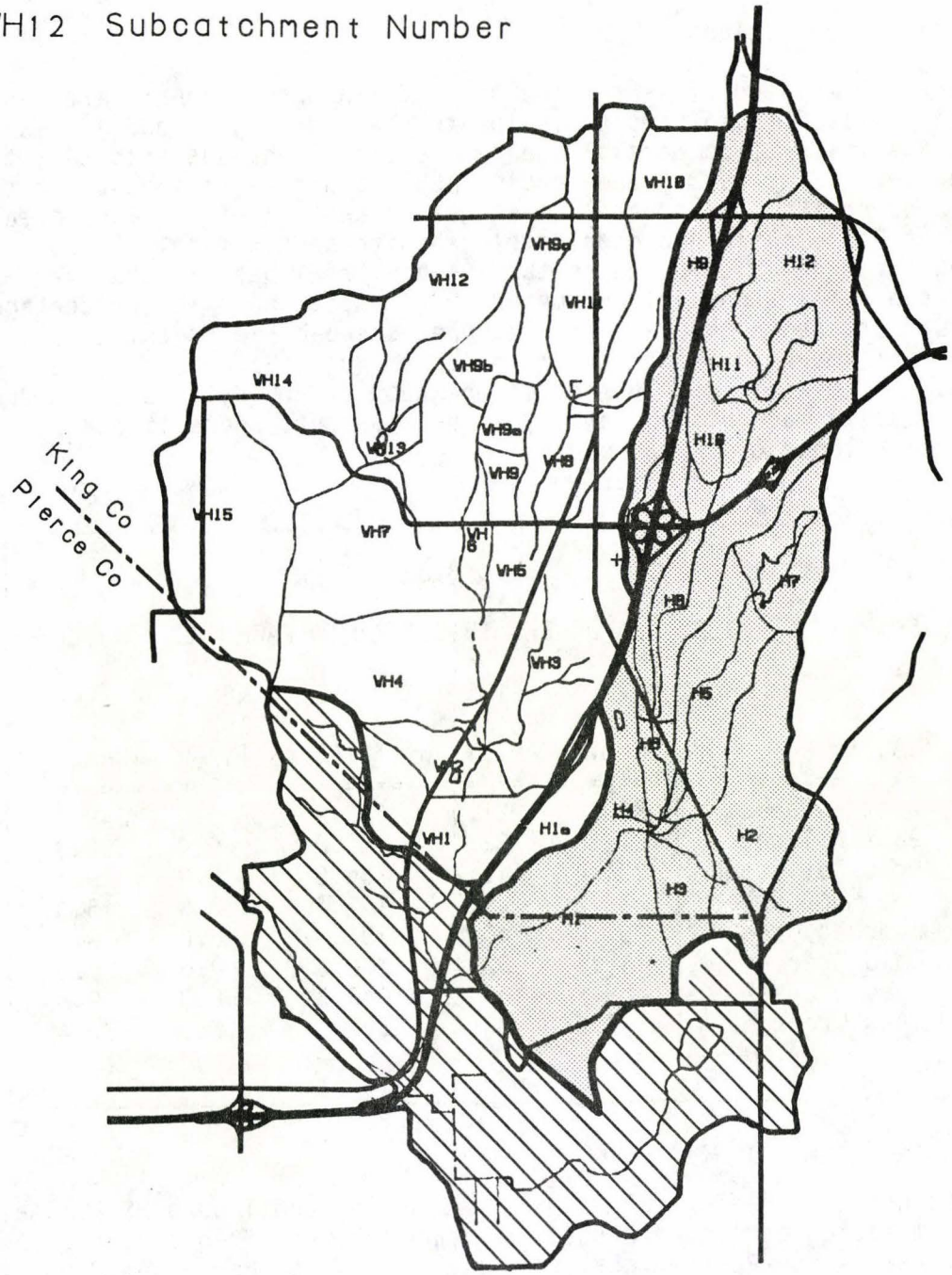
SUB-BASINS IN THE HYLEBOS CREEK BASIN

West Branch Hylebos

Lower Hylebos

East Branch Hylebos

WH12 Subcatchment Number



0 1 2

miles

N

Figure 3.3.1b

Lower Puget Sound Basin

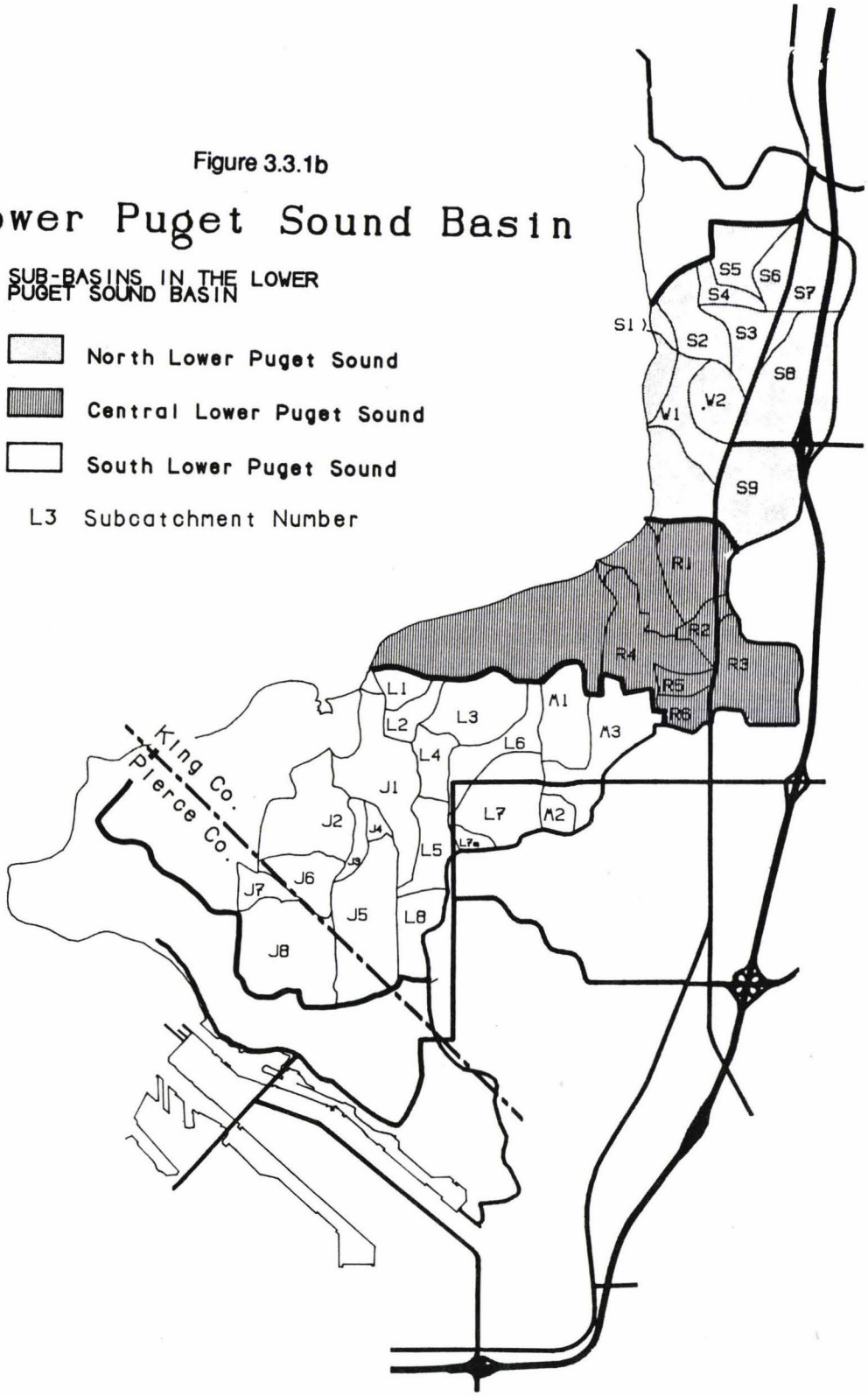
SUB-BASINS IN THE LOWER PUGET SOUND BASIN

North Lower Puget Sound

Central Lower Puget Sound

South Lower Puget Sound

L3 Subcatchment Number



0 1 2 miles

N

FIGURE 3.3.2a 1987 LAND COVER

West Branch Hylebos Creek Sub-basin

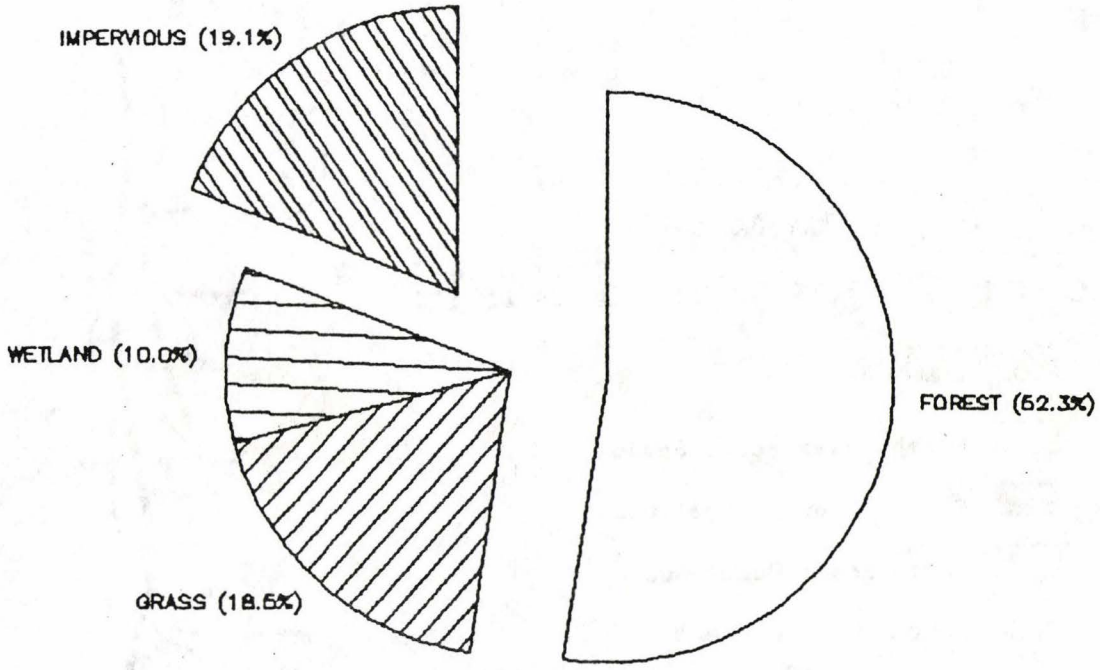


FIGURE 3.3.2b 1987 LAND COVER

East Branch Hylebos Creek Sub-basin

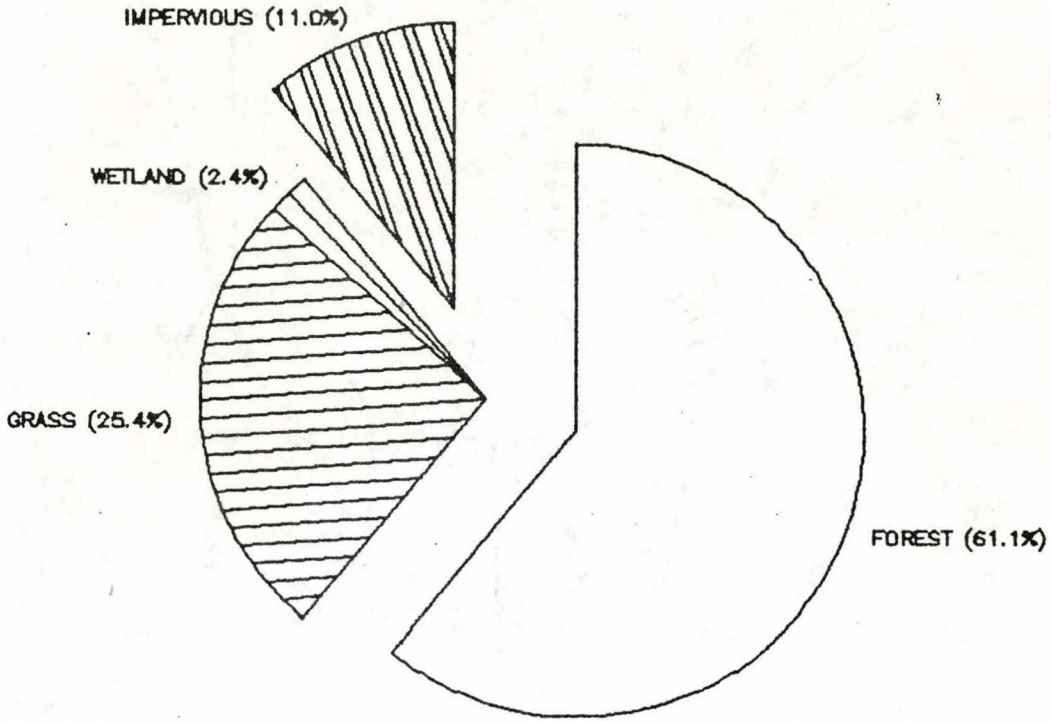


FIGURE 3.3.2c 1987 LAND COVER

North Lower Puget Sound Sub-basin

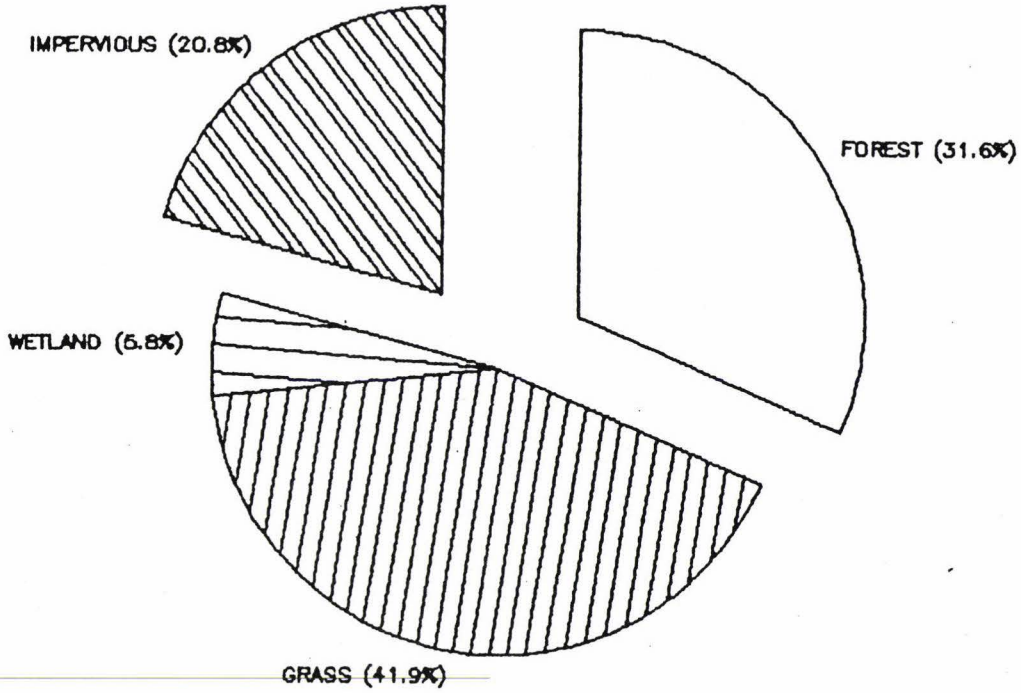


FIGURE 3.3.2d 1987 LAND COVER

Central Lower Puget Sound Sub-basin

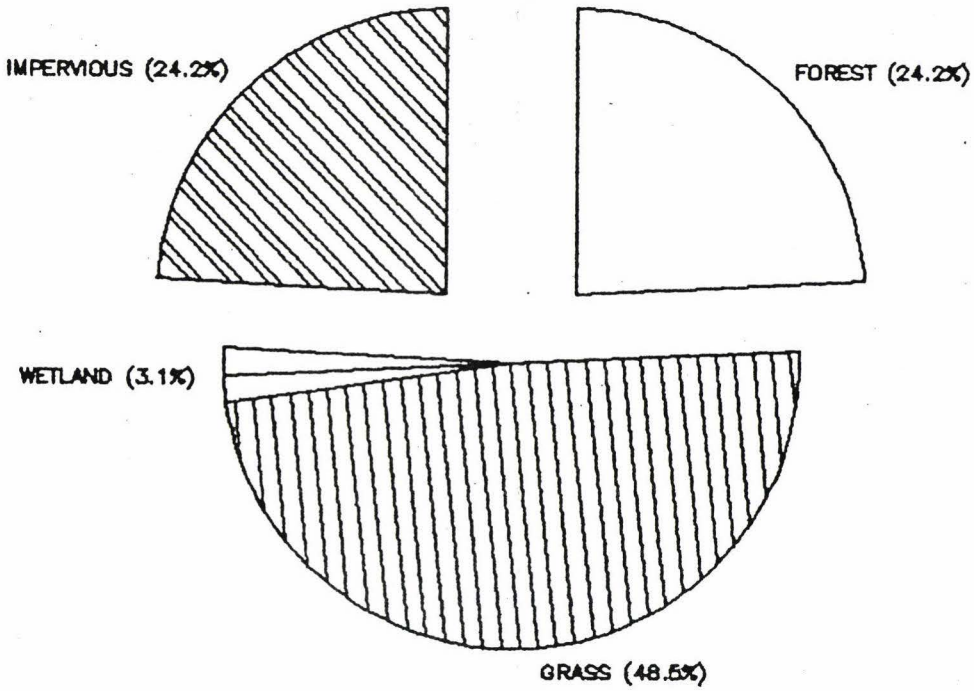
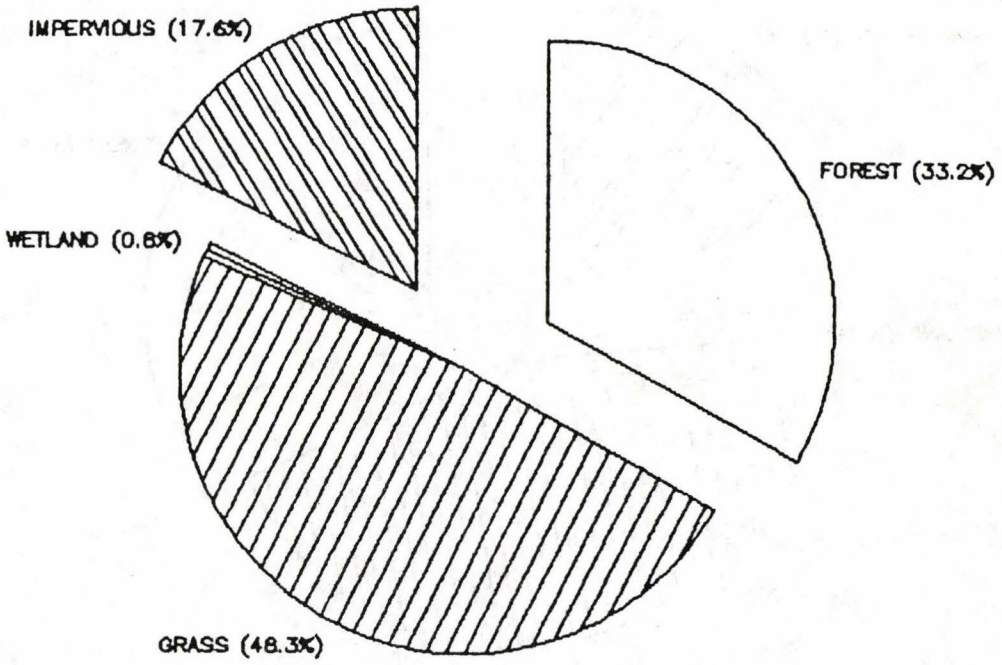


FIGURE 3.3.2e 1987 LAND COVER

South Lower Puget Sound Sub-basin



major stream are shown in Table 3.3.2. The lowest peak annual flow was found to be an outlier in the Log-Pearson analysis and tended to skew the regressions producing a poor fit (Figure 3.3.3). With this lowest point omitted (Figure 3.3.4), the regression was much better. Flow frequencies for the 1987 land use were computed without the lowest peak annual flow. Therefore the flow frequencies for the 1987 land use are based on 38 years of peak annual data.

Table 3.3.2

MODELED FLOW FREQUENCIES AT STREAM OUTLETS
UNDER 1987 LAND USE

BASIN	Peak Annual Flow Frequency (CFS) 2 year	10 year	25 year	100 year
West Hylebos	121	189	227	287
East Hylebos	119	193	231	290
McSorley Creek	107	153	173	199
Woodmont Creek	48	69	79	93
Redondo Creek	60	87	100	117
Cold Creek	38	54	61	70
Lakota Creek	58	81	92	106
Joes Creek	94	134	151	175

Peak Runoff Rates From Each Soil, Cover, and Slope Group - The relative influence of soil type, land cover, and slope is illustrated by the response of the various soil/cover/slope combinations modeled by the HSPF model for the planning area. Table 3.3.3 provides a summary of peak runoff rates, expressed in cubic feet per second per acre, for each pervious and impervious group used in the model. These discharge rates consisted of the sum of surface runoff, interflow, and groundwater.

Although peak runoff rates for the soil groups can be compared on a frequency basis, the actual storm contributing to the peak runoff rates may be different. In other words, the storm that generates the 2-year runoff rate for till soils is not necessarily the same storm that generates the 2-year runoff rate for outwash soils. Peak annual runoff rates for till soils occur from autumn through spring while the peak annual runoff rates from outwash occur exclusively during the winter or early spring. Till soils are more responsive to peak rainfall intensities, regardless of the time of year. Conversely, peak annual runoff rates for outwash soils (especially forested outwash) are affected by groundwater response, thus there is a tendency for the peak rate to occur during periods when the groundwater table is high.

Figure 3.3.3

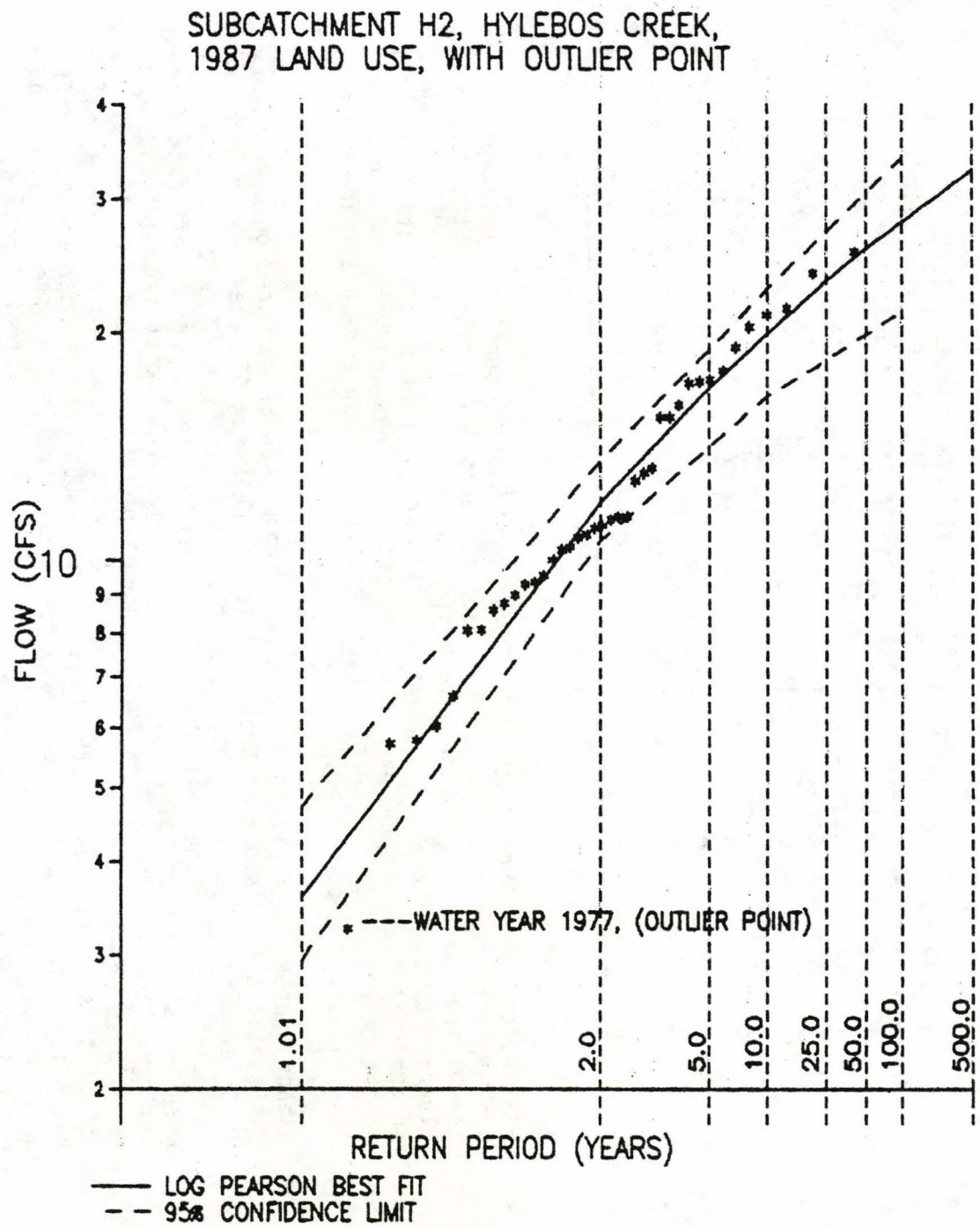

SUBCATCHMENT H2, HYLEBOS CREEK,
1987 LAND USE, WITH OUTLIER POINT
FLOW (CFS)
10
4
3
2
9
8
7
6
5
4
3
2
1.01
2.0
5.0
10.0
25.0
50.0
100.0
500.0
RETURN PERIOD (YEARS)
---WATER YEAR 1977, (OUTLIER POINT)
LOG PEARSON BEST FIT
95% CONFIDENCE LIMIT

Figure 3.3.4

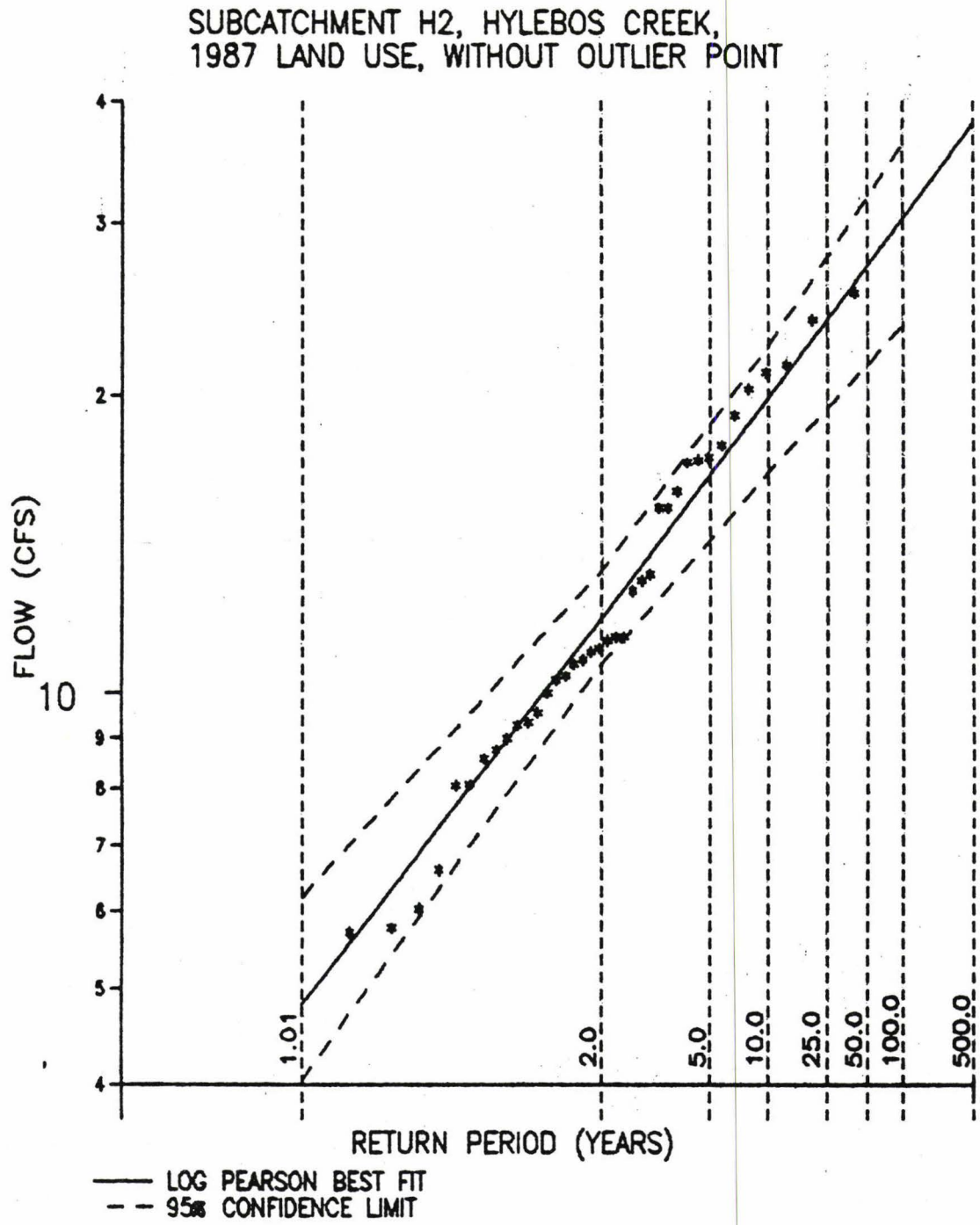

SUBCATCHMENT H2, HYLEBOS CREEK,
1987 LAND USE, WITHOUT OUTLIER POINT
FLOW (CFS)
10
4
3
2
9
8
7
6
5
4
1.01
2.0
5.0
10.0
25.0
50.0
100.0
500.0
RETURN PERIOD (YEARS)
LOG PEARSON BEST FIT
95% CONFIDENCE LIMIT

Table 3.3.3

PEAK FLOW RUNOFF RATES FROM EACH SOIL-COVER-SLOPE GROUP

Segment	Peak Annual Runoff Frequency (cfs/acre) 2-Yr	10-Yr	25-Yr	100-Yr
IMPERVIOUS	0.3489	0.5122	0.6050	0.7623
TILL GRASS FLAT	0.1984	0.2960	0.3352	0.3844
TILL GRASS STEEP	0.1597	0.2561	0.2985	0.3549
TILL GRASS MODERATE	0.1113	0.1936	0.2335	0.2912
TILL FOREST FLAT	0.0557	0.1154	0.1537	0.2222
TILL FOREST STEEP	0.0468	0.0706	0.0811	0.0956
TILL FOREST MODERATE	0.0314	0.0496	0.0585	0.0714
OUTWASH GRASS	0.0227	0.0645	0.0863	0.1174
OUTWASH FOREST	0.0010	0.0030	0.0055	0.0140
WETLAND	0.0390	0.1057	0.1456	0.2089

Unit Area Discharge Rates - Unit-area discharges (peak flow rate divided by upstream subcatchment area) were examined to identify areas that generate uncharacteristically high (or low) runoff rates and determine the hydrologic factors influencing these rates.

Unit-area discharges are influenced by land cover, slope, soil type, and stream reach volume. Land cover, slope, and soil type control the volume and rate of flow entering a stream reach, while the volume of the stream reach controls the amount of peak flow attenuation as the flows travel down the basin.

In general, stream reaches exhibiting the highest unit-area discharges have tributary areas with: 1) relatively high impervious areas, 2) relatively low coverage by forests, 3) predominantly till soils, and/or 4) few lakes and wetlands to attenuate flows.

Unit-area discharges at the outlet of each major basin are listed in Table 3.3.4. The Hylebos Creek basin has lower unit runoff rates than the Lower Puget Sound basin tributaries with the exception of Lakota Creek. The Hylebos Creek basin generates lower peak flows per acre because: 1) the level of urbanization is generally less, 2) there are more lakes and riparian wetlands that attenuate flow, and 3) the channel gradients are typically less than in the Lower Puget Sound basin. The Lakota Creek tributary generates less peak flow per acre because the majority of the runoff from 45 percent of the basin area infiltrates into Fisher Bog and does not contribute to downstream peak flow runoff.

Table 3.3.4

SUMMARY OF (1987) UNIT AREA DISCHARGE RATES
TRIBUTARY TO EACH BASIN OUTLET

BASIN	DISCHARGE PER UNIT ACRE (CFS/ACRE)
Joes Creek	0.073
Lakota Creek	0.049
Redondo Creek	0.131
Cold Creek	0.130
McSorley Creek	0.082
Woodmont Creek	0.216
East Hylebos	0.056
West Hylebos	0.043

Runoff Analysis From The January 9, 1990 Storm - During the analysis of the Hylebos and Lower Puget basins, a large storm event occurred on January 9, 1990 that produced considerable flooding, habitat, and erosion damage. This section describes the precipitation patterns leading up to the peak runoff, the antecedent conditions that contributed to the high runoff rate in the creeks, and a discussion of the simulated runoff flow frequencies on Hylebos Creek at the King-Pierce County line computed by the HSPF model.

Rainfall patterns were examined to determine the precipitation frequency of the storm event. Precipitation data from the Star Lake gage (Figure 3.3.5) were examined to determine the return period of the rainfall. Return periods were computed using a Log-Pearson analysis on the precipitation at the Sea Tac gage for the various durations and translated to the Star Lake gage using isopluvial maps (King County 1989). Return periods for the January storm with durations of 6 hours, 24 hours, and 96 hours at the Star Lake gage are shown in Table 3.3.5. The 24-hour period spanning January 8th to January 9th had a return period of 30 years and contained a 70-year six-hour duration. When the precipitation from the preceding three days are included, the 96-hour total is also about a 70-year event.

Figure 3.3.5

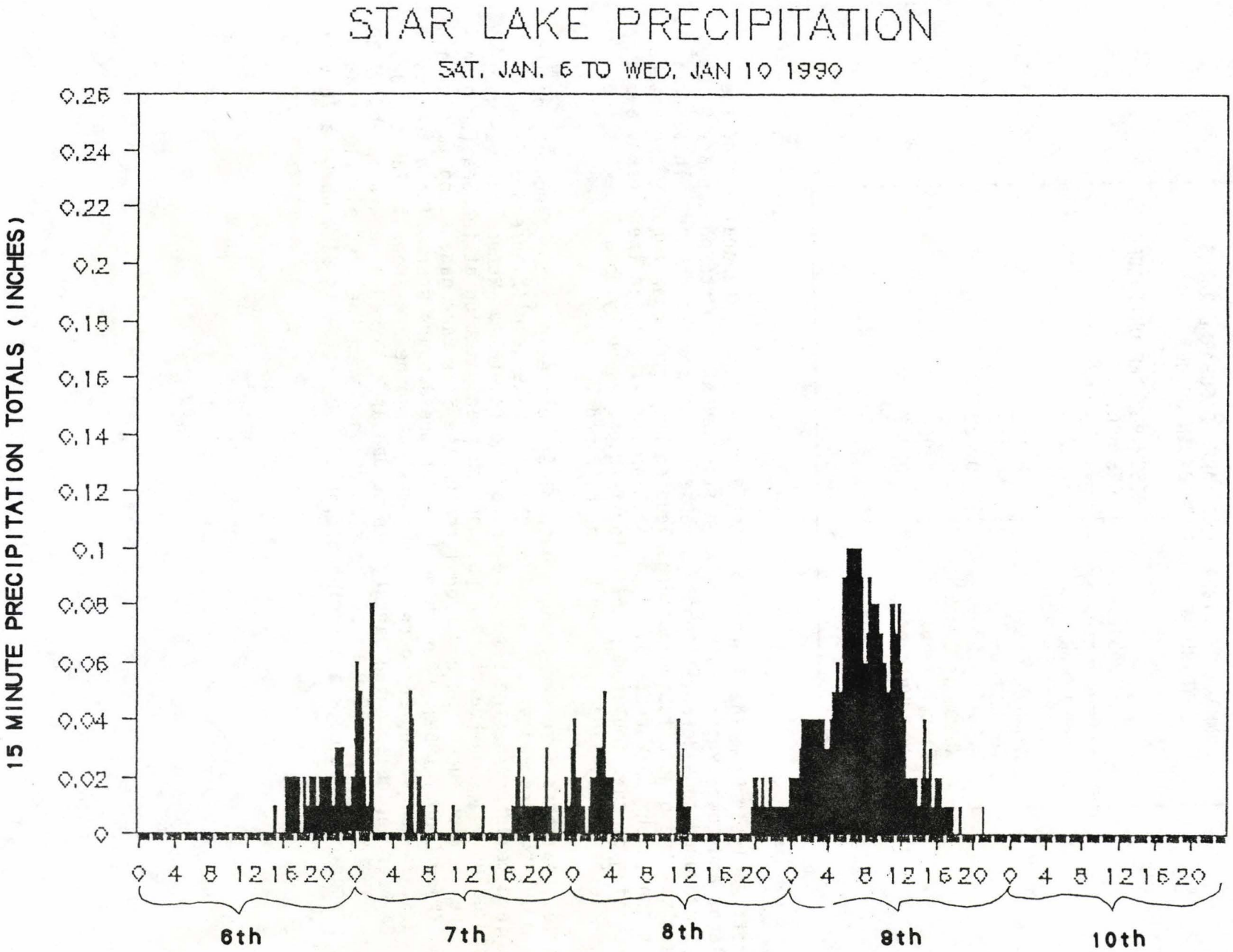

STAR LAKE PRECIPITATION
SAT. JAN. 6 TO WED. JAN 10 1990
15 MINUTE PRECIPITATION TOTALS (INCHES)
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 4 8 12 16 20 0 4 8 12 16 20 0 4 8 12 16 20 0 4 8 12 16 20 0 4 8 12 16 20
6th
7th
8th
9th
10th

Table 3.3.5

RETURN PERIODS FOR THE JANUARY 1990 STORM
AT THE STAR LAKE PRECIPITATON GAGE

DURATION	MAX.PRECIP (INCHES)	RETURN PERIOD (YEARS)
1 HOUR	0.40	5
6 HOUR	1.89	70
24 HOUR	3.50	30
96 HOUR	5.96	70

Because of antecedent moisture in the soil column, lakes, wetlands, and surface depressions, the runoff flow frequency almost never equals the precipitation frequency. For example, had the January rainfall event occurred in September when the antecedent moisture is low, the resulting runoff event would have been much less significant than it actually was.

To determine the runoff return period of the January 1990 event, the precipitation record from the Star Lake gage was input to the HSPF model using 1987 land-use (the land-use that most closely represents 1990 conditions). Precipitation from the Sea Tac gage for the January storm was not available at the time of this analysis, so Star Lake was used instead. To accurately simulate the moisture conditions prior to the storm, the simulation period spanned October 1, 1989 through January 10, 1990. Flows were computed at the outlet of the East and West Branches and downstream of the confluence of East and West Branch Hylebos Creek (Figure 3.3.6).

Return periods were determined from the simulated 38-year series of peak annual flows plus the flow peak from the January 1990 storm, for a total of 39 years of peak flows. Simulated peak flows from the January 1990 storm were larger than any flows simulated in the previous 39-year series. A Log-Pearson distribution downstream of the confluence of the East and West Branches is shown in Figure 3.3.7. The January 1990 storm is the highest flow peak on the graph and lies just outside the 95 percent confidence interval. Table 3.3.6 lists the simulated magnitude of the January storm and the 50-and 100-year flows at the three locations based on similar Log-Pearson analyses. The runoff event produced by the January 1990 storm therefore had a return period greater than 50 years but less than 100 years, based on 1987 land-use conditions.

Figure 3.3.6

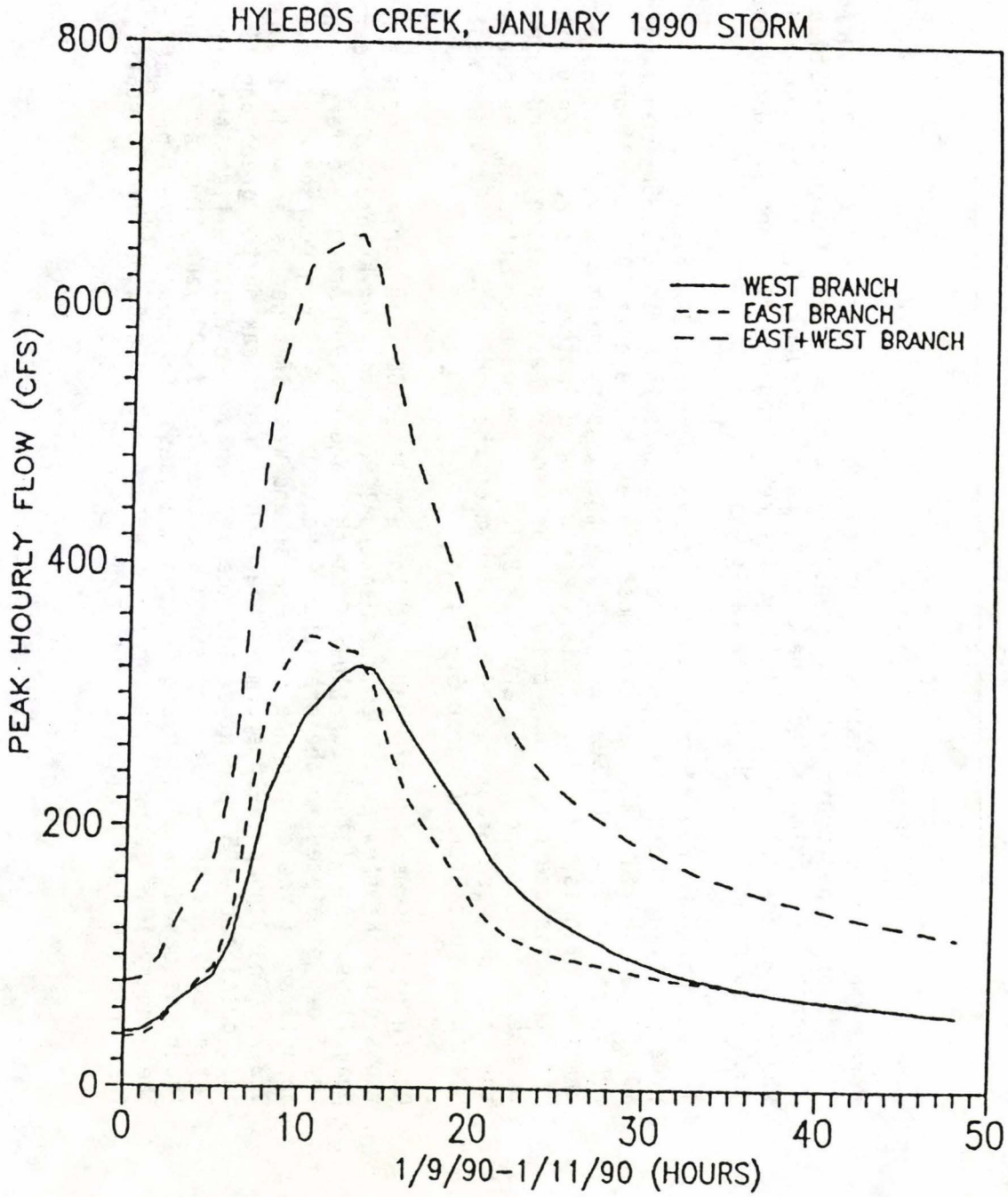

HYLEBOS CREEK, JANUARY 1990 STORM
PEAK HOURLY FLOW (CFS)
800
600
400
200
0
0
10
20
30
40
50
1/9/90-1/11/90 (HOURS)
WEST BRANCH
EAST BRANCH
EAST+WEST BRANCH

Figure 3.3.7

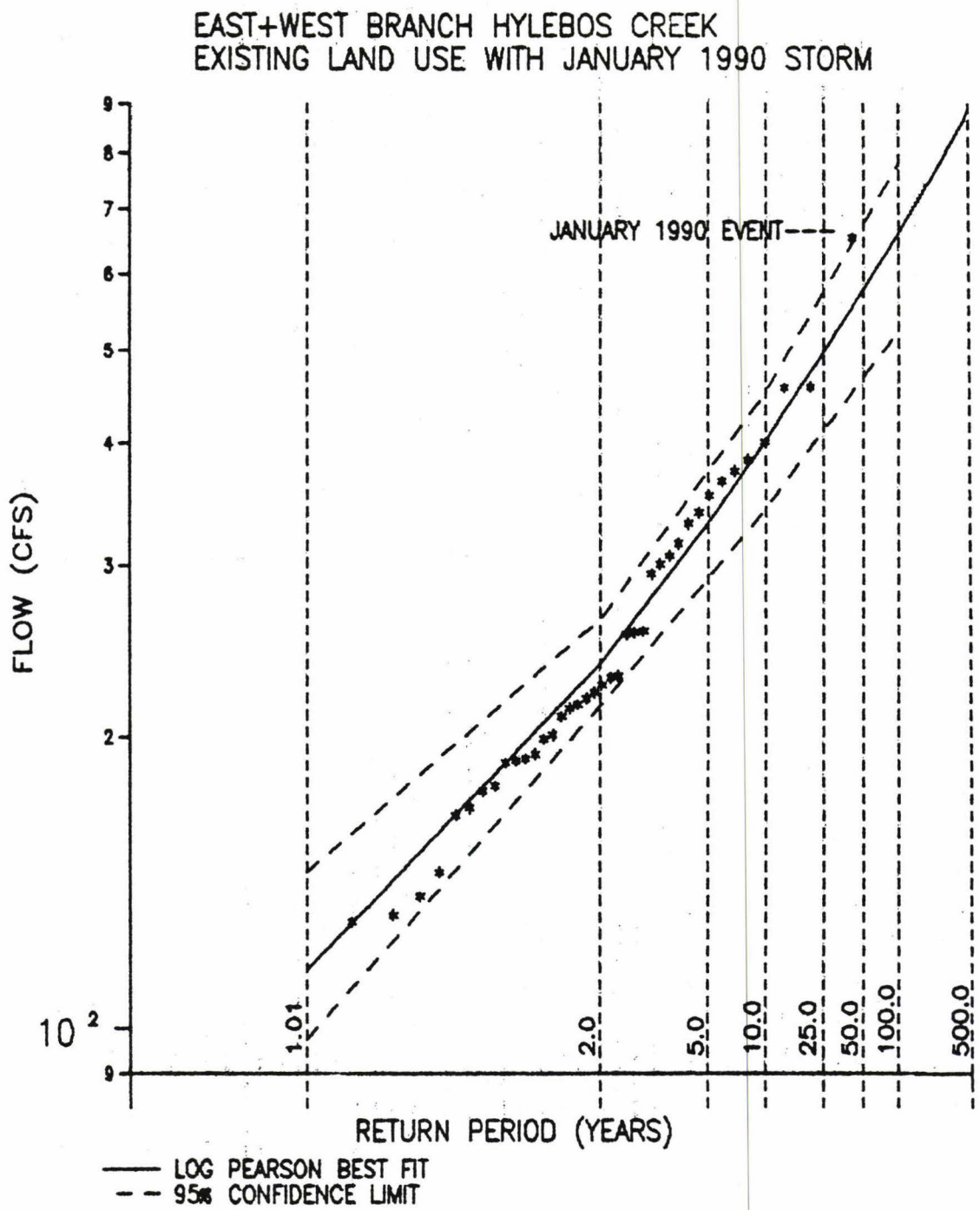

EAST+WEST BRANCH HYLEBOS CREEK
EXISTING LAND USE WITH JANUARY 1990 STORM
JANUARY 1990 EVENT
FLOW (CFS)
9
8
7
6
5
4
3
2
10 2
9
1.01
2.0
5.0
10.0
25.0
50.0
100.0
500.0
RETURN PERIOD (YEARS)
LOG PEARSON BEST FIT
95% CONFIDENCE LIMIT

Table 3.3.6

MAGNITUDE AND RETURN PERIOD OF JANUARY 1990 STORM
AT THE OUTLET OF THE HYLEBOS CREEK BASIN

BASIN	FLOW (CFS) 50 YEAR	100 YEAR	JAN 9, 1990 STORM
WEST BRANCH	293	337	322
EAST BRANCH	303	348	345
EAST+WEST BRANCH	579	663	654

Mean Annual Flow Under 1987 Land Use - Mean annual flow is used to determine whether a project is subject to U. S. Army Corps of Engineers individual permit requirements regarding filling of wetlands (flows greater than 5 cfs), or is considered a "Shoreline of the State" (flows greater than 20 cfs). Currently mean annual flows are determined by gaging records that often span short periods of time or do not represent current land-use conditions. The flows computed by the HSPF model provide a more complete record of flows and produces them at interior locations within the basin. Figures 3.3.8a-f list mean annual flows for the major creeks in the Hylebos and Lower Puget Sound basins. The values on these figures represent the mean annual flow. No shorelines of the State are located in freshwater bodies of these basins and only the lowest subcatchments of the West Branch of Hylebos Creek (WH1 and WH2) are above the 5 cfs Corps of Engineers threshold. These values are based on 39 years of 15 minute simulated flows under 1987 land-use.

Future Conditions

Sources of Future Land-Use Data - Land use for the future model scenario was derived by taking the most dense land use from: 1) existing land use, 2) existing zoning, 3) the King County Comprehensive Plan, and 4) the 1986 King County Federal Way Community Plan and Area Zoning. Regulations governing land use have changed with the incorporation of the City of Federal Way. However, only minor differences exist between the recently adopted 1990 City of Federal Way Comprehensive Land Use Plan and the land-use map used for future modeling. The differences that do exist should only affect flows on a subcatchment level; the cumulative difference at the outlet of the basins should be negligible. Subcatchments where the new land use will produce flows significantly different from the flows predicted in this analysis are listed below.

1. **Business Corridor Expansion Between SR 99 and I-5 (subcatchments WH10 and H9).** The 1990 Federal Way Plan changed zoning from multifamily to business/office and these areas are expected to produce flows higher than predicted in this analysis. This flow increase should be significant downstream to subcatchment WH4 on West Branch Hylebos Creek and downstream to H6 on East Branch Hylebos Creek.

Figure 3.3.8a

West Branch Hylebos Creek

SIMULATED MEAN ANNUAL FLOW

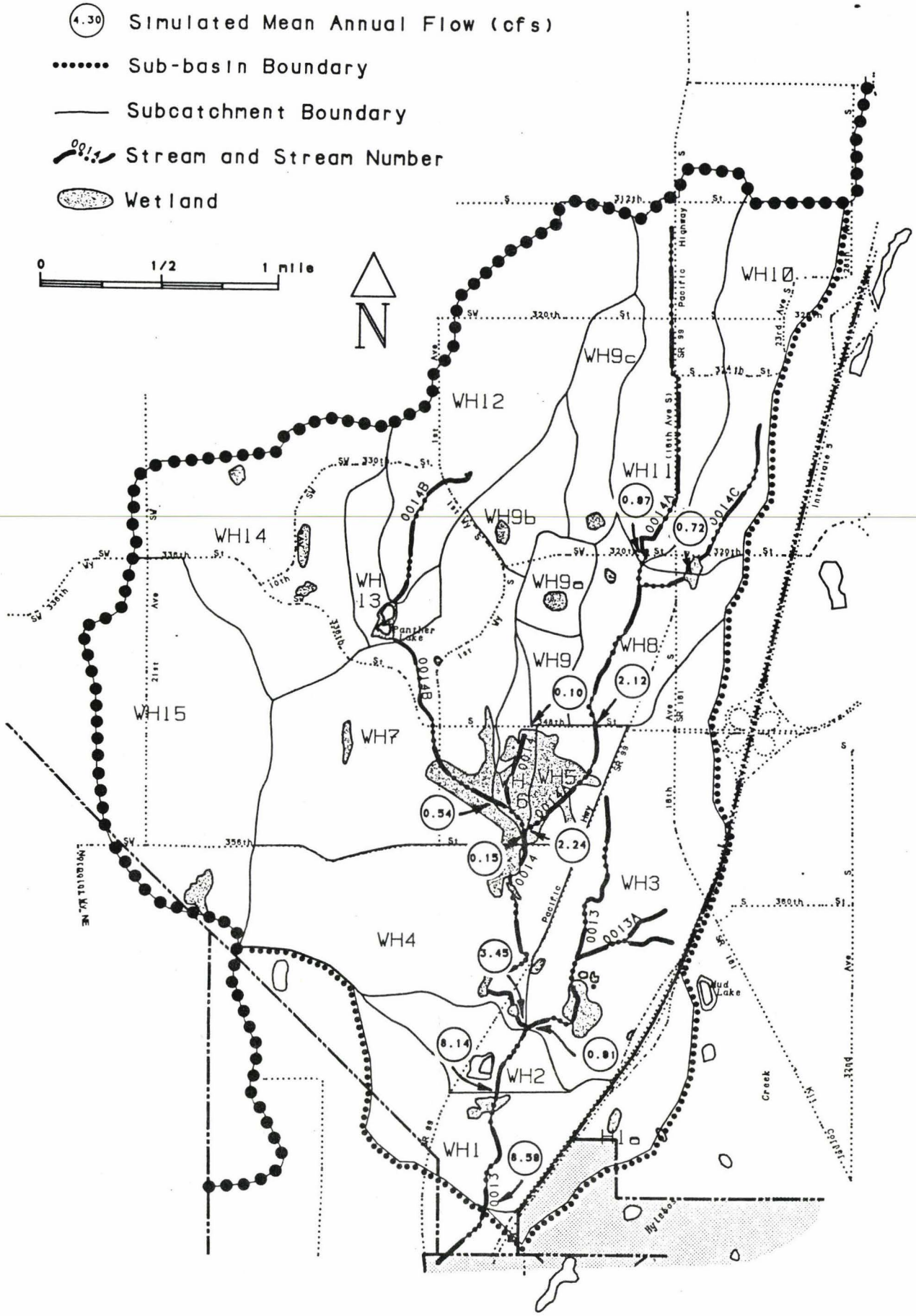


Figure 3.3.8b

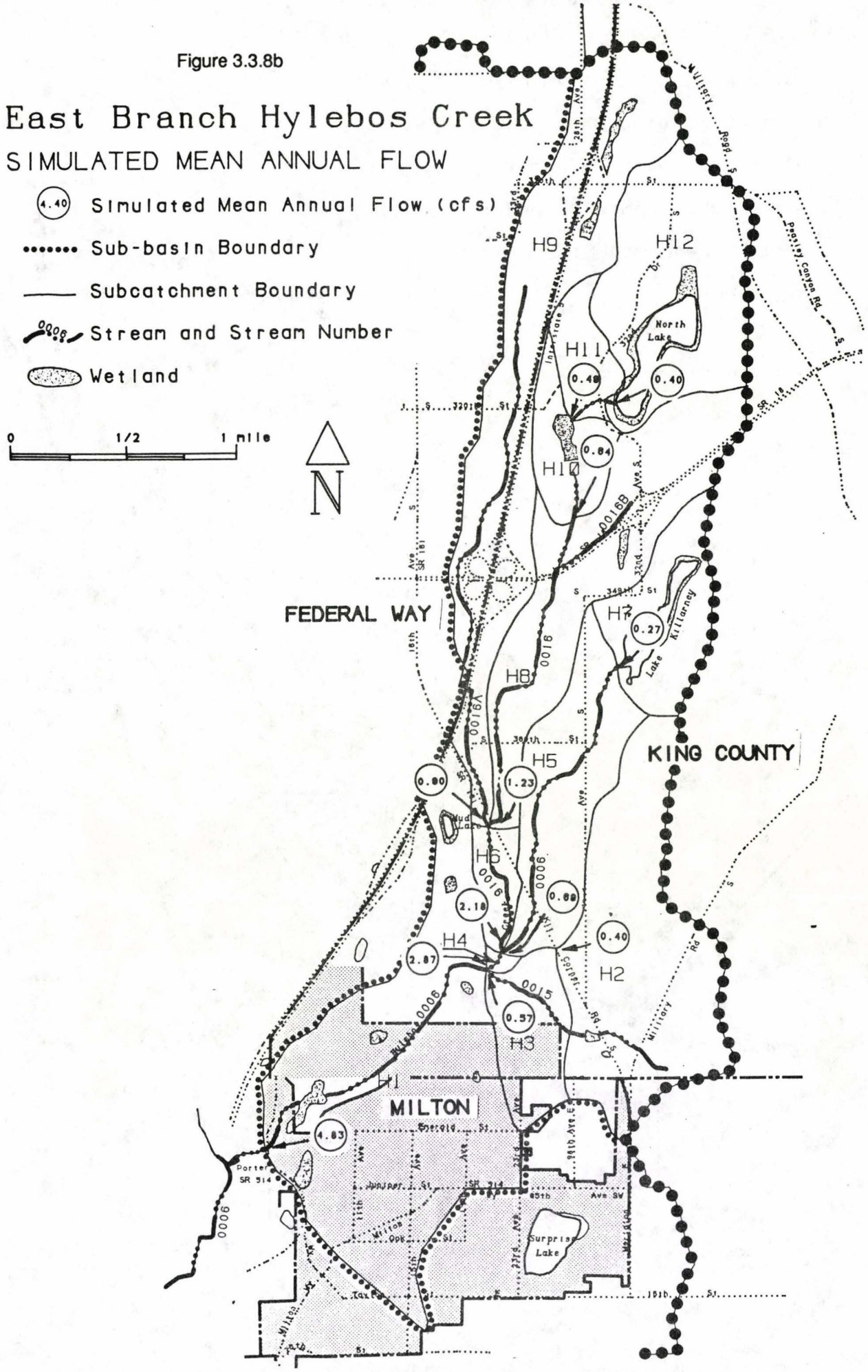

East Branch Hylebos Creek
SIMULATED MEAN ANNUAL FLOW
4.40 Simulated Mean Annual Flow (cfs)
Sub-basin Boundary
Subcatchment Boundary
Stream and Stream Number
Wetland
0
1/2
1 mile
N
FEDERAL WAY
KING COUNTY
MILTON
H1
H2
H3
H4
H5
H6
H7
H8
H9
H10
H11
H12
0.48
0.40
0.84
0.27
0.80
1.23
2.18
0.88
0.40
2.87
0.57
4.83
North Lake
Surprise Lake
Killarney Lake
Mud Lake
Porter
SR 514
0016B
0016
0006
0015

Figure 3.3.8c

Lower Hylebos Creek

SIMULATED MEAN ANNUAL FLOW

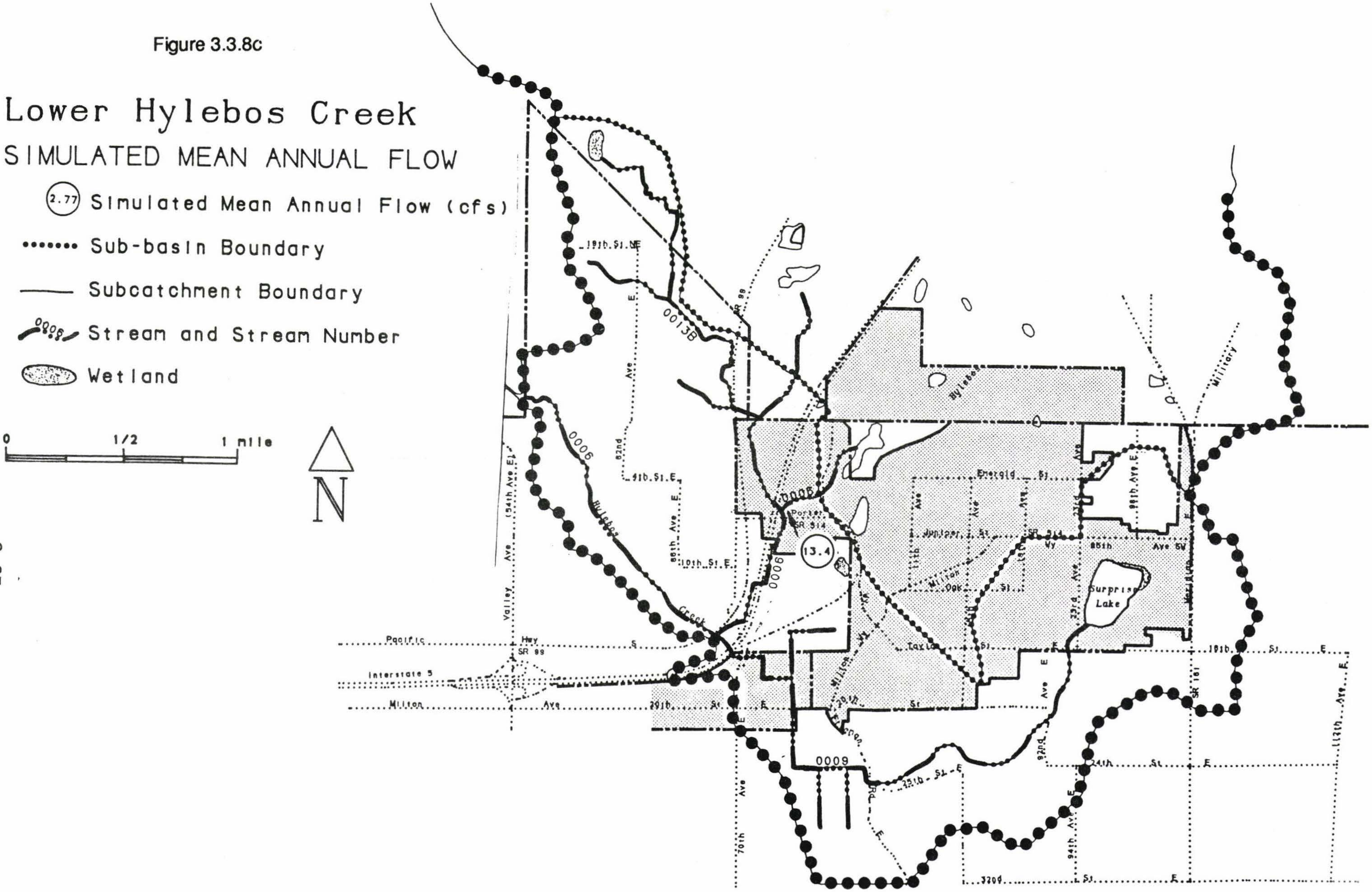


Figure 3.3.8d

North Lower Puget Sound

SIMULATED MEAN ANNUAL FLOW

(0.44) Simulated Mean Annual Flow (cfs)

••••••• Sub-basin Boundary

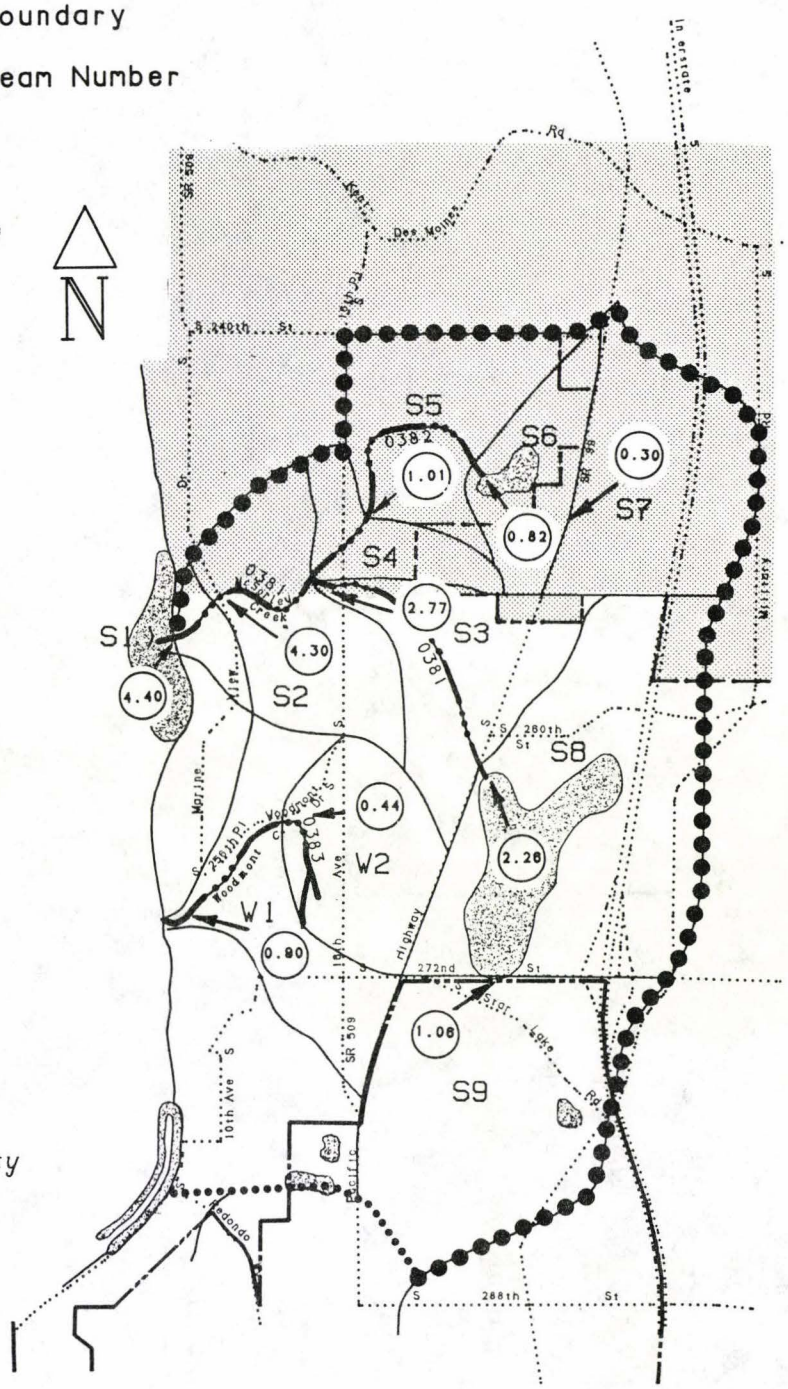
—— Subcatchment Boundary

0381 Stream and Stream Number

Wetland

0 1/2 1 mile

N



PUGET SOUND

Poverty Bay

Figure 3.3.8e

Central Lower Puget Sound

SIMULATED MEAN ANNUAL FLOW

(1.26) Simulated Mean Annual Flow (cfs)

Sub-basin Boundary

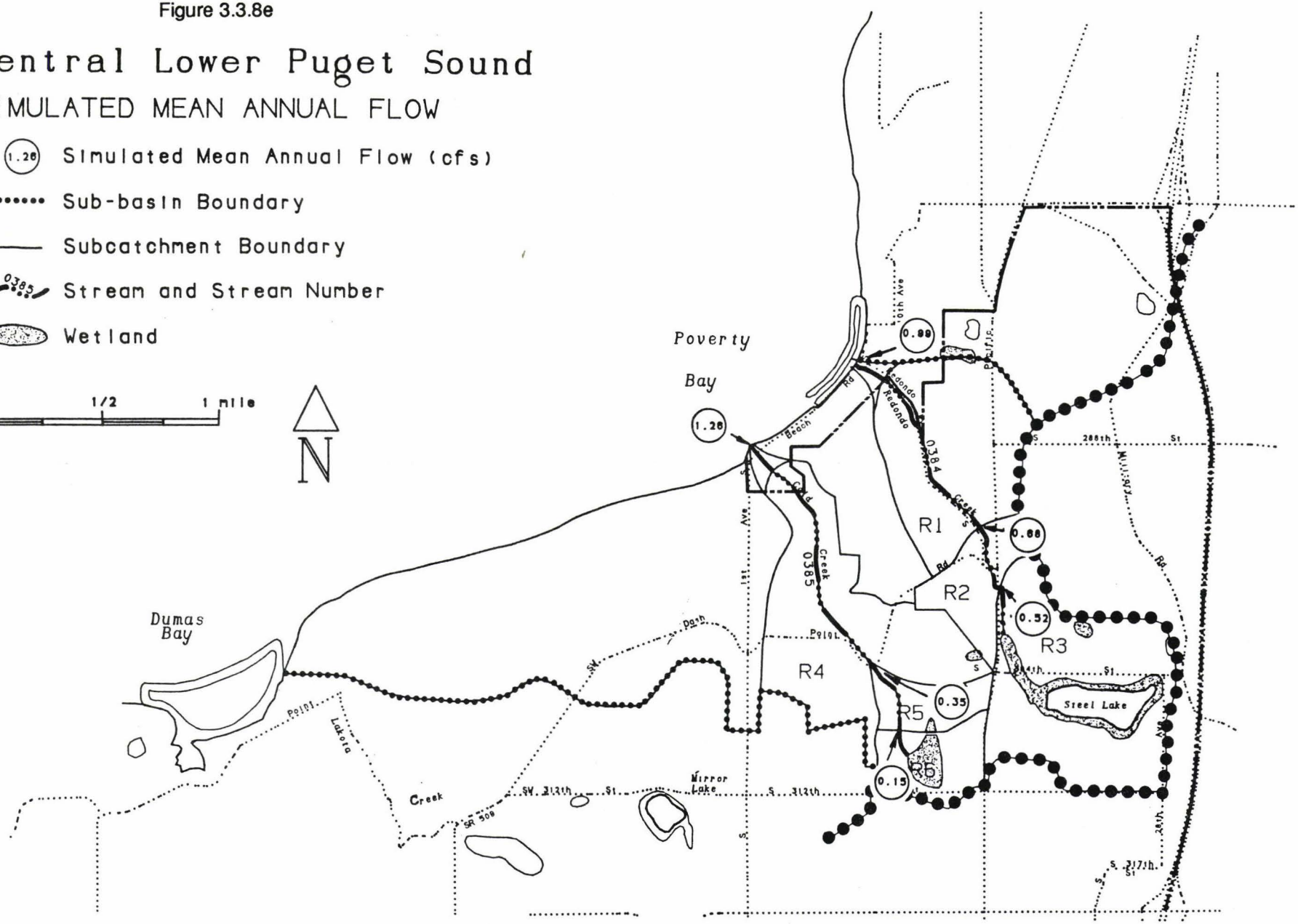
Subcatchment Boundary

0385 Stream and Stream Number

Wetland

0 1/2 1 mile

N



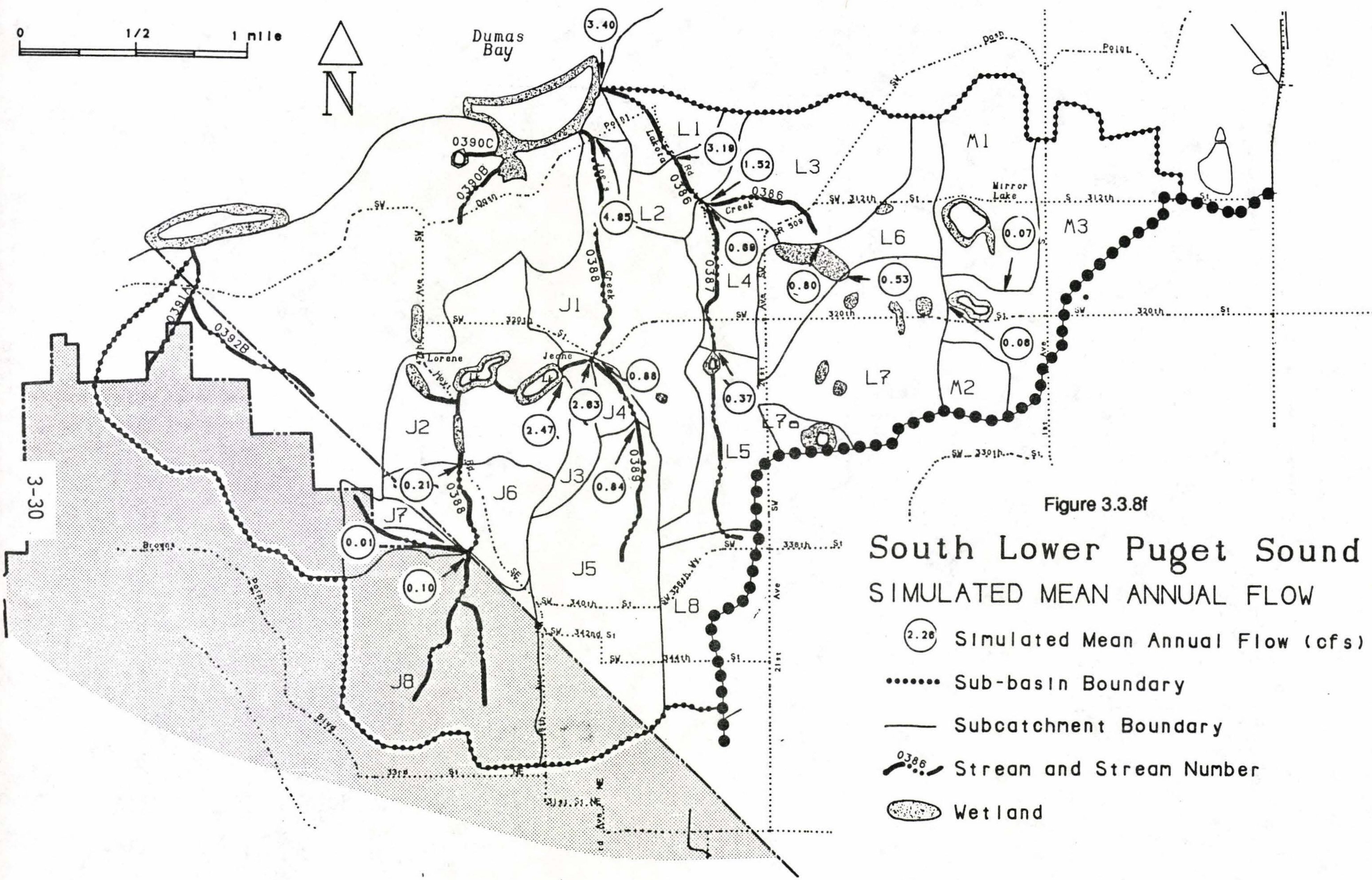


Figure 3.3.8f

South Lower Puget Sound

SIMULATED MEAN ANNUAL FLOW

2. **Open Space Surrounding Panther Lake (subcatchments WH7, WH12 and WH13).** Zoning surrounding Panther Lake was changed from high-density residential to open space. Flows from these areas will be less than simulated in the future land use analysis; however, since the changed area represents a small percentage of the total catchment area, the difference in runoff should be small.

3. **Downzone in the Lower West Branch Hylebos Creek (subcatchments WH1 and WH2).** Zoning in subcatchments WH1 and WH2 was converted from low-density single-family residential to rural land uses. The actual flows from these sub-catchments will be lower than the simulated flows. But again, since these areas represent a small percentage of the total area discharging to the lower reaches, the difference in runoff between the new Community Plan and the modeled land-use should be small.

Differences Between Future and Existing Land Use - Under build-out conditions approximately 94 percent of the Hylebos Creek basin will be developed at urban densities (Figures 3.3.9a and b). The West Branch Hylebos Creek tributary area will continue to be composed primarily of commercial and residential land uses, but the amount of commercial area will nearly double over 1987 land use. The East Branch Hylebos tributary area will continue to be dominated by single-family residential; however, multifamily developments will increase by a factor of ten over 1987 land use and single family residential development will increase by a factor of 2.5 (Table 3.3.7).

Table 3.3.7

SUMMARY OF FUTURE LAND USES TRIBUTARY TO EACH BASIN OUTLET

	FUTURE LAND USE (ACRES)				
BASIN	COMM.	MULTI-FAMILY	3-7 UNITS/AC	1-3 UNITS/AC	RURAL
West Hylebos	1516.5	921.3	1495.4	781.3	28.6
East Hylebos	499.1	917.5	1959.0	103.3	64.4
McSorley Creek	433.3	194.3	922.5	0.0	34.4
Woodmont Creek	74.8	2.3	195.0	12.9	36.3
Redondo Creek	101.9	88.0	366.1	0.0	36.7
Cold Creek	89.6	36.7	229.4	2.8	34.6
Lakota Creek	168.5	265.9	1188.8	101.6	64.4
Joes Creek	88.7	9.4	1411.4	22.7	46.8

In the Lower Puget Sound basin, over 90 percent of the land area is developed under the future land-use condition (Figures 3.3.9c-e). Increases in land-use density are not as dramatic as in the Hylebos Creek basin because the Lower Puget Sound area has already approached build-out under 1987 conditions. There is, however, a significant potential for conversions of developed areas to higher density uses. For example, under the future land-use scenario, multi-

FIGURE 3.3.9a FUTURE LAND USE

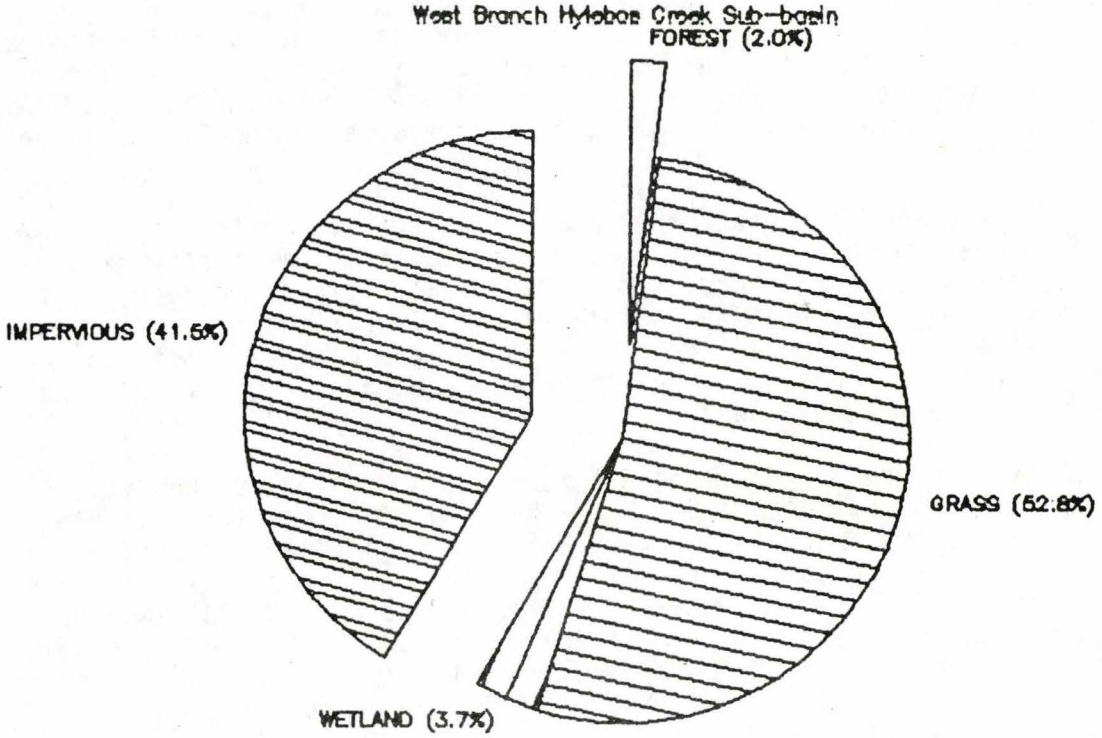


FIGURE 3.3.9b FUTURE LAND USE

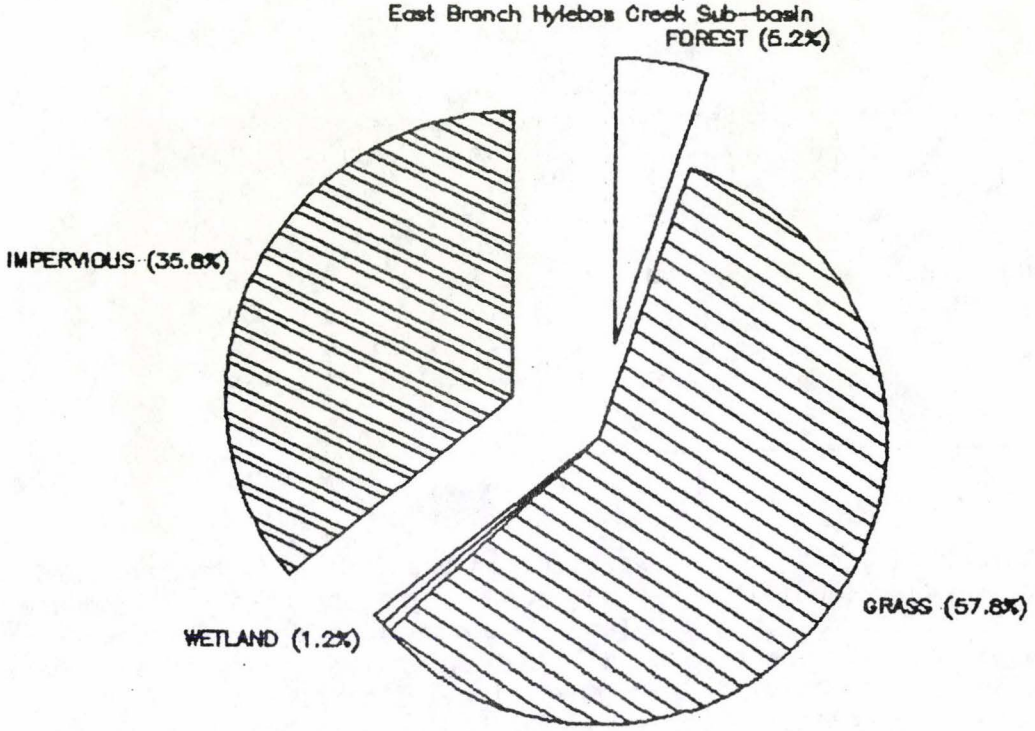


FIGURE 3.3.9c FUTURE LAND USE

North Lower Puget Sound Sub-Basin

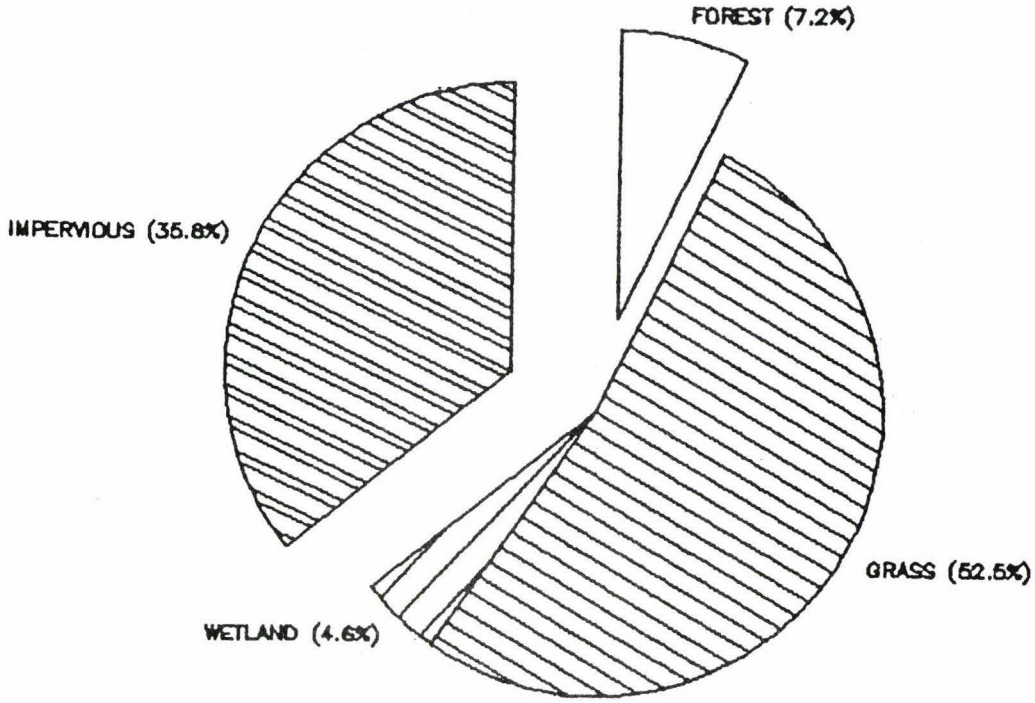


FIGURE 3.3.9d FUTURE LAND USE

Central Lower Puget Sound Sub-Basin

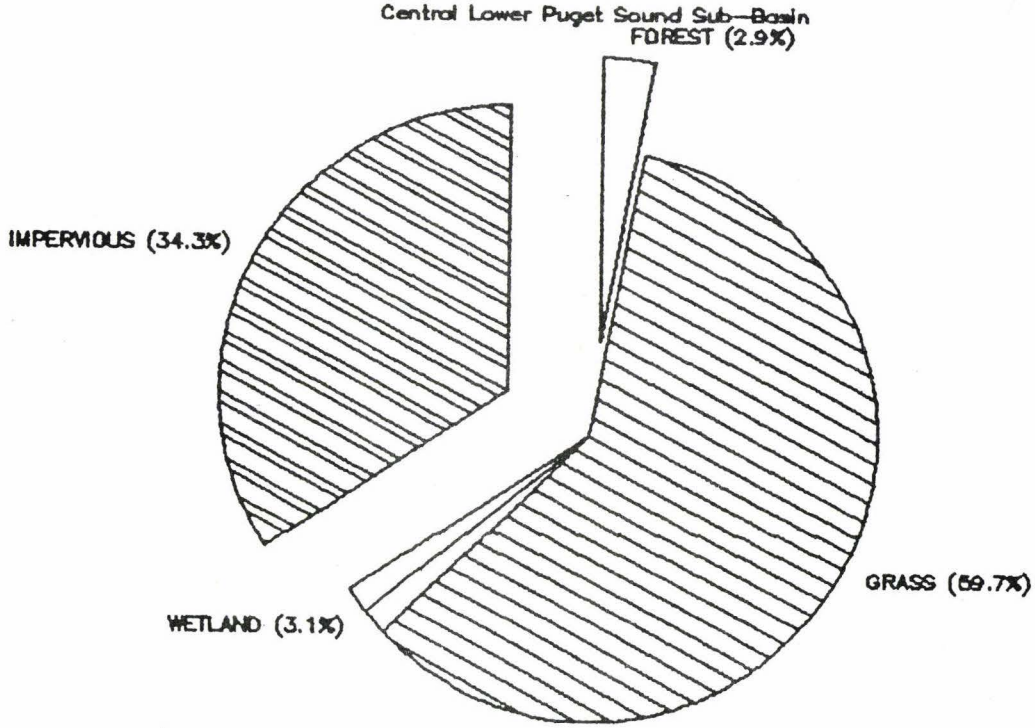
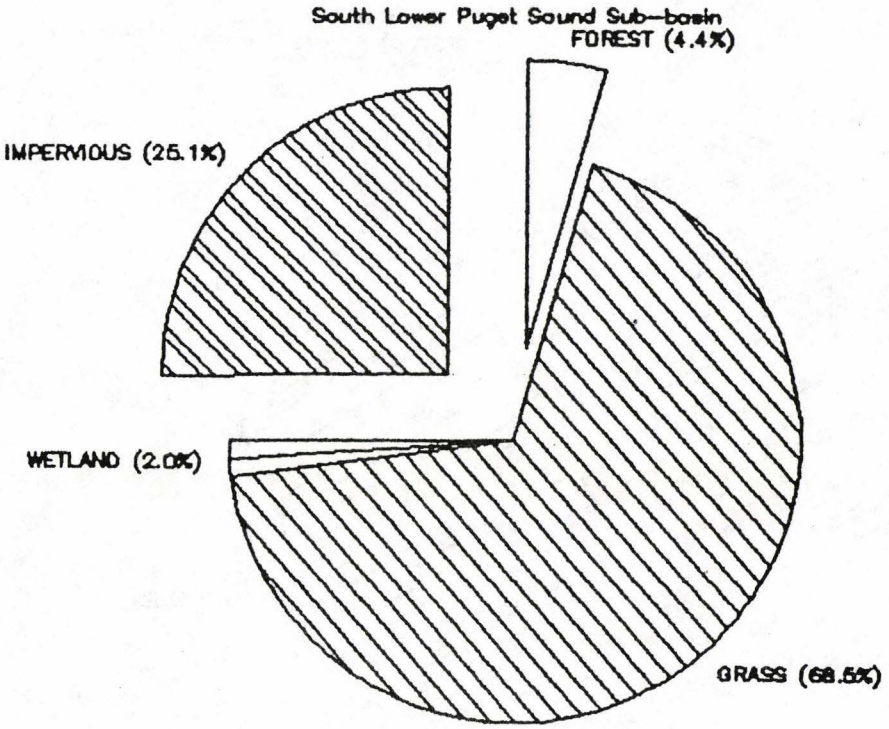


FIGURE 3.3.9e FUTURE LAND USE



family areas in the Joes Creek drainage decreases while commercial land use nearly doubles over the 1987 land-use scenario. Commercial land use throughout the Lower Puget Sound basin nearly doubles over 1987 land use.

As the basins proceed to build-out, there is a potential overall loss of 5,620 acres of forested land (91% of the 1987 total) and 272 acres of wetlands (37% of the 1987 total). The loss of wetlands is the result of development in areas that function hydrologically as wetlands but are currently not inventoried. One of the most significant areas of uninventoried wetlands is along the north fork of Hylebos Creek (tributary 0013). The tributary area (subcatchment WH3) contains 123 acres of wetlands. These wetlands provide significant groundwater discharge to the creek augmenting flows during dry periods. All but 19 acres of the wetlands in this subcatchment are not inventoried and can potentially be developed.

Peak Flow Rates Under Future Land Use - The future land-use scenario was based on an unmitigated condition. This assumed no onsite or regional detention for any part of the basin. This unmitigated assumption together with the land-use assumptions detailed in the previous section, produced a "worst case" future scenario. Unless the land-use plans used to derive the future land-use condition are altered, future flows will not exceed the flows produced by this future land-use scenario. Various flow mitigation techniques will be discussed in the solutions section of the Hylebos Creek and Lower Puget Sound Basin Plan.

Peak annual flow data for each reach were analyzed using a Log-Pearson analysis according to the guidelines presented by the WRC (Bulletin 17a, 1977). Flows were determined for the 1.01-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flows. The lowest ranked peak annual flow, which was an outlier point in the Log-Pearson distributions under 1987 land use, was typically well within the 95 percent confidence interval under the future land use scenario. Therefore the full 39-year record of peak annual flows were used to compute flow frequencies for this scenario.

A listing of the predicted 2-, 10-, 25-, and 100-year flows are presented in Table 3.3.8 for the future land-use scenario at the outlet of each stream system Figure 3.3.10 shows the magnitude of peak flow increases between the 1987 and future land-use scenarios for each of the modeled creek systems in the basins. These percentage increases are based on the average of the predicted increases for the 2-, 5-, 10-, 25-, 50-, and 100-year flows.

Peak flows at the basin outlets increase from 10 percent to 90 percent. Flow increases ranging up to eight-fold were computed at some interior subcatchment points (see Chapter 4, Sub-basin Conditions, for a detailed discussion of these areas). The Hylebos Creek tributaries are predicted to have a much higher increase in peak flow than the Lower Puget Sound tributaries, a reflection of the lower state of development and the higher intensity land-use zoned in the Hylebos Creek basin.

Figure 3.3.10

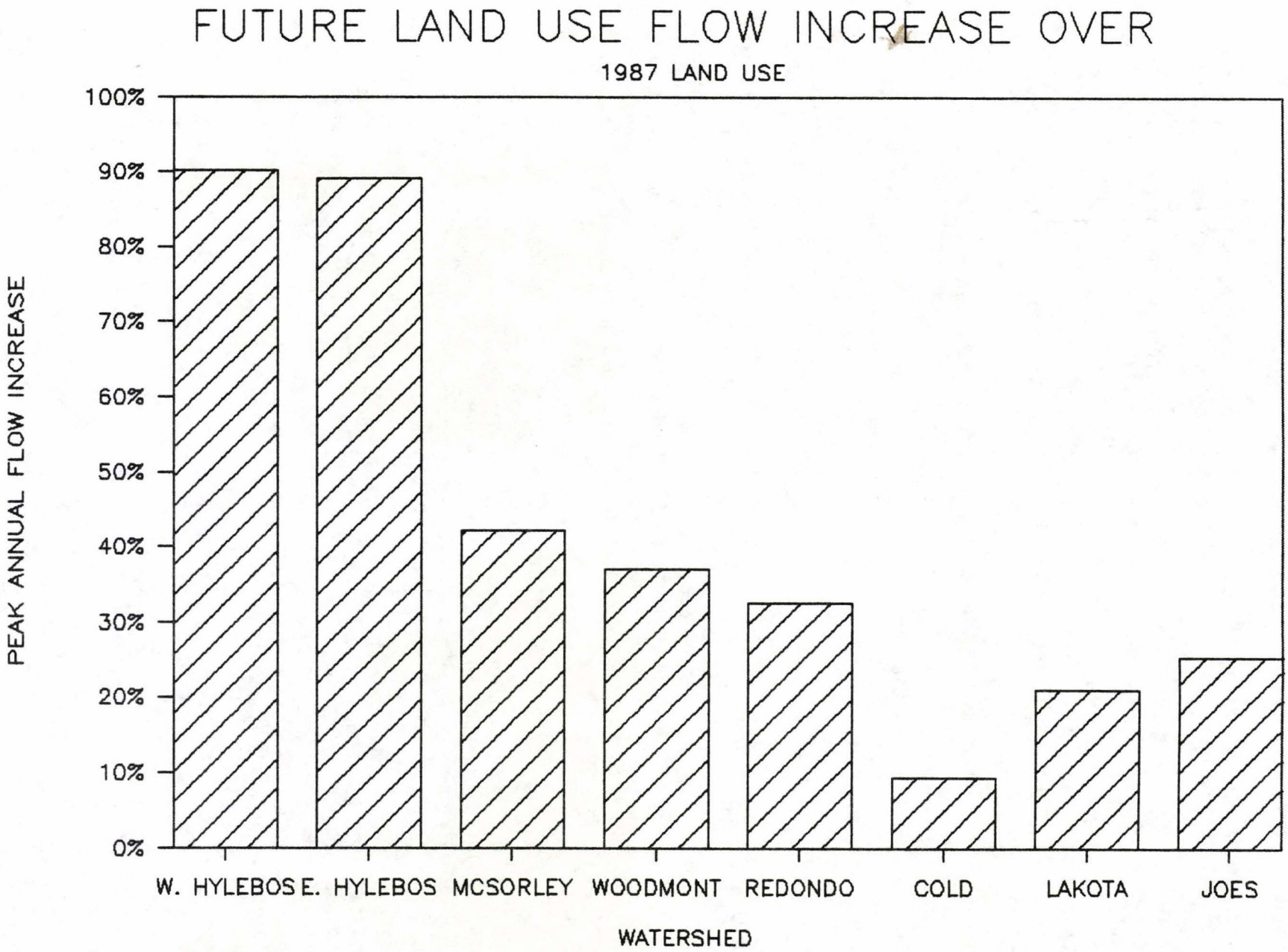

FUTURE LAND USE FLOW INCREASE OVER
1987 LAND USE
PEAK ANNUAL FLOW INCREASE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
W. HYLEBOS
E. HYLEBOS
MCSORLEY
WOODMONT
REDONDO
COLD
LAKOTA
JOES
WATERSHED

Table 3.3.8

MODELED FLOW FREQUENCIES AT STREAM OUTLETS
UNDER FUTURE LAND USE

BASIN	Peak Annual Flow Frequency (CFS) 2 year	10 year	25 year	100 year
West Hylebos	235	363	431	538
East Hylebos	259	375	430	511
McSorley Creek	163	220	243	273
Woodmont Creek	67	95	108	125
Redondo Creek	80	116	132	156
Cold Creek	41	59	67	76
Lakota Creek	71	98	110	128
Joes Creek	115	167	190	222

Forested Land Use

Land Cover - The Hylebos Creek and Lower Puget Sound basins represent one of the most heavily developed areas relative to unincorporated areas in King County. Mitigating existing as well as potential problems identified by the future land-use modeling runs may require reducing flows well below the current (1987) land-use flow level. For example, solving instream erosion problems may require reducing flows to a point where stream channels are stable. Since many of the stream channels in the Hylebos Creek and Lower Puget Sound basins were formed by historic flows when the basin was forested, the stream channel will be stable only under a flow regime similar to what existed under forested land-use conditions. To establish the relative magnitude and examine the statistical characteristics of flows before development occurred in the basins, a model run was performed with all development densities replaced with forest cover.

Lack of data describing the physical characteristics of the basin in a pre-developed state necessitated making the following assumptions:

1. The channel cross-sections used in the model to route flows were not changed from either of the other land-use scenarios. This assumption is not expected to significantly alter predicted flows.

2. Culverts and other human-made hydraulic structures were assumed to be present. These structures often act as restrictions during high flow events and provide detention, thus reducing flows. The amount of flow attenuated by this storage is small for most structures and will result in only small discrepancies in the peak flow rates.

3. The amount of wetlands in the system was assumed to be the same as the 1987 land use scenario, even though significant wetland areas have been lost with urbanization in the basins.

4. Tributaries diverted historically, such as 0016A, were left in their current (1987) state.

Peak Flows - Peak annual flow data for each reach were analyzed using a Log-Pearson analysis with flows computed for the 1.01-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flows. The lowest ranked peak annual flow was again an outlier in the Log-Pearson distributions under the forested land-use. This point was dropped in the Log-Pearson analysis, leaving 38 years of peak annual flows to compute flow frequencies. Log-Pearson plots of the peak annual flow data are shown in Figures 3.3.11a and b for selected basins.

Figure 3.3.12 shows the magnitude of peak flow increases between the 1987 land-use and the forested land-use scenarios for each of the modeled creek systems in the planning area. Percentage increases are based on the average of the predicted increases for the 2-, 5-, 10-, 25-, 50-, and 100-year flows.

Peak flow increases between forested and 1987 conditions range from 65 percent to over 300 percent at the basin outlets. Flow increases ranging up to 400 percent were computed at some interior subcatchment points (see Chapter 4 for a detailed discussion of these areas). Peak flows under 1987 land use from the Hylebos Creek sub-basins are between 65 percent and 85 percent higher than they were under the forested condition, with the highest flow increases located in the headwaters where the land use is dominated by commercial development. These increases are still much lower than the Lower Puget Sound drainages, which have 1987 peak flows that are between 120 percent and 300 percent higher than under forested conditions. The high flow increase in Lakota Creek (308% higher than under forested conditions) is attributable to the nearly built-out state of the basin under 1987 land use, and the high percentage of outwash soils in the basin. Conversion of forest cover to high-density residential developments on outwash soils resulted in particularly large flow increases.

The runoff computed from the future and forested land use scenarios represents the extremes of the flow regime in the Planning Area. Figure 3.3.13 shows flows under 1987 land use expressed as a percentage of change between forested and future land use. Zero on this graph represents a forested condition while 100 represents future build-out. For example, the Hylebos Creek Basin has experienced roughly 30 percent of its total possible flow increase, whereas Cold Creek has experienced over 85 percent of its total possible flow increase. Regulatory measures could therefore be effective at controlling flows in the Hylebos Creek Basin, while structural solutions would be more effective in the Cold Creek drainage.

Changes to Flow Durations

Increased urbanization will not only increase the magnitude of peak flows but also will increase their aggregate duration over the simulation period, and the number of flow events, but it will reduce the average length of time per event that flows exceed a given level.

Figures 3.3.14a and b show the difference in flow durations for the three land-use scenarios at the outlet of the Hylebos and Lakota Creek watersheds. In the Hylebos Creek basin, the amount of time the forested 2-year flow is exceeded under 1987 land use is over double what it is under forested conditions. The amount of time the forested 2-year flow is exceeded under future land use is over 10 times as long as under the forested condition. Therefore, in the long term, the flow representing the forested 2-year flow under future land use produces over 10 times the amount of instream erosion and transport as the same flow did under forested conditions.

Figure 3.3.11a

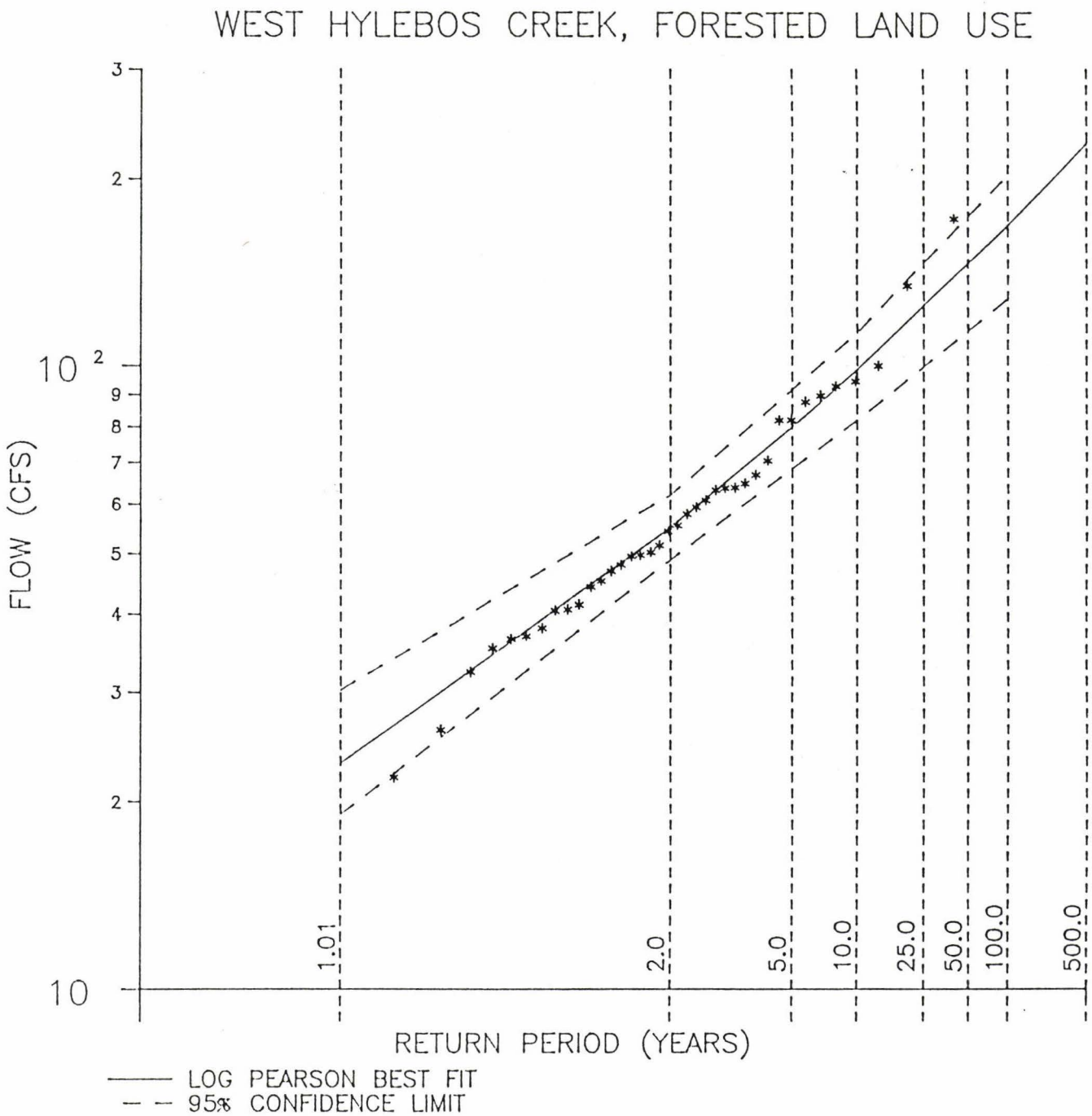


Figure 3.3.11b

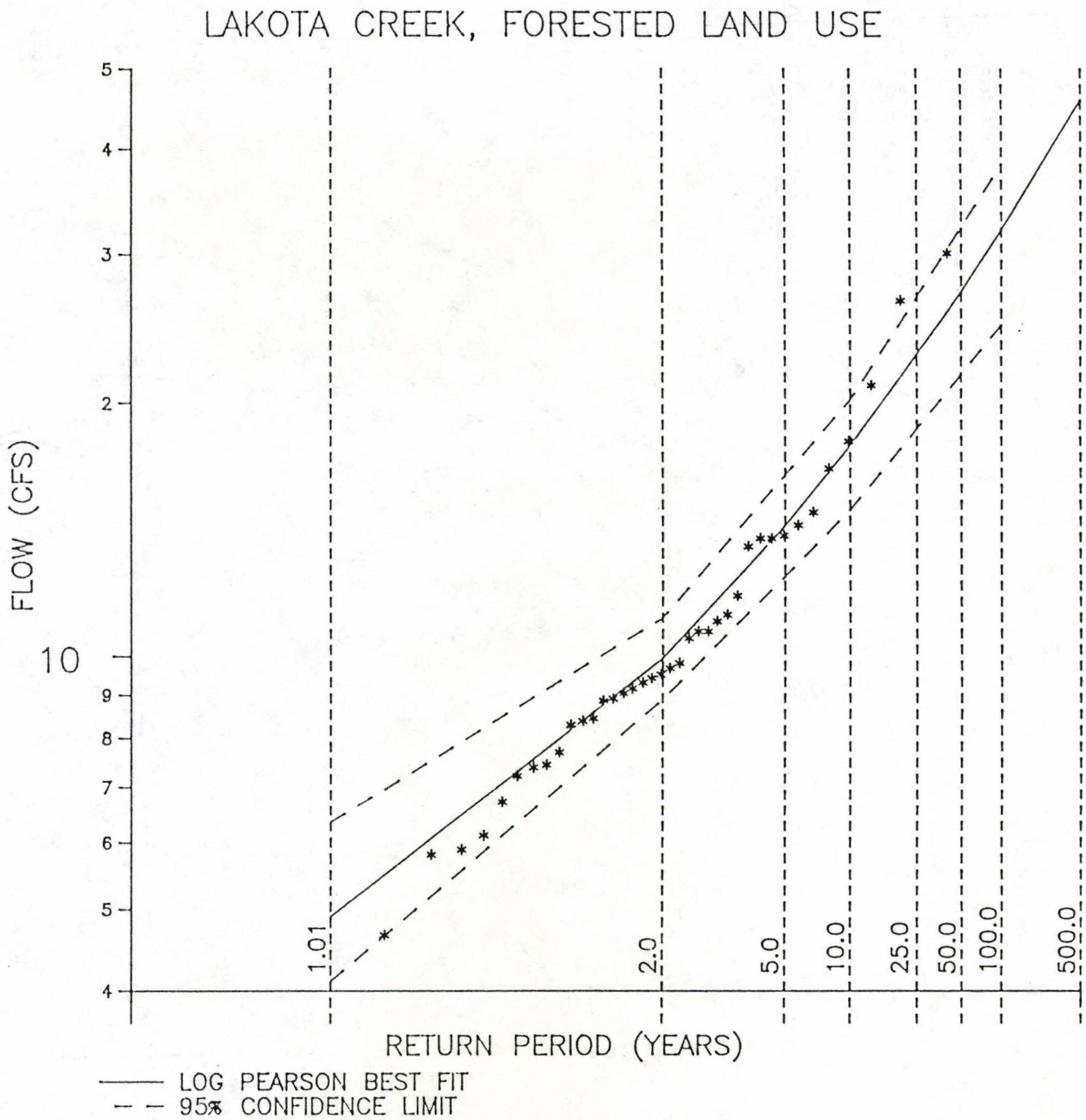


Figure 3.3.12

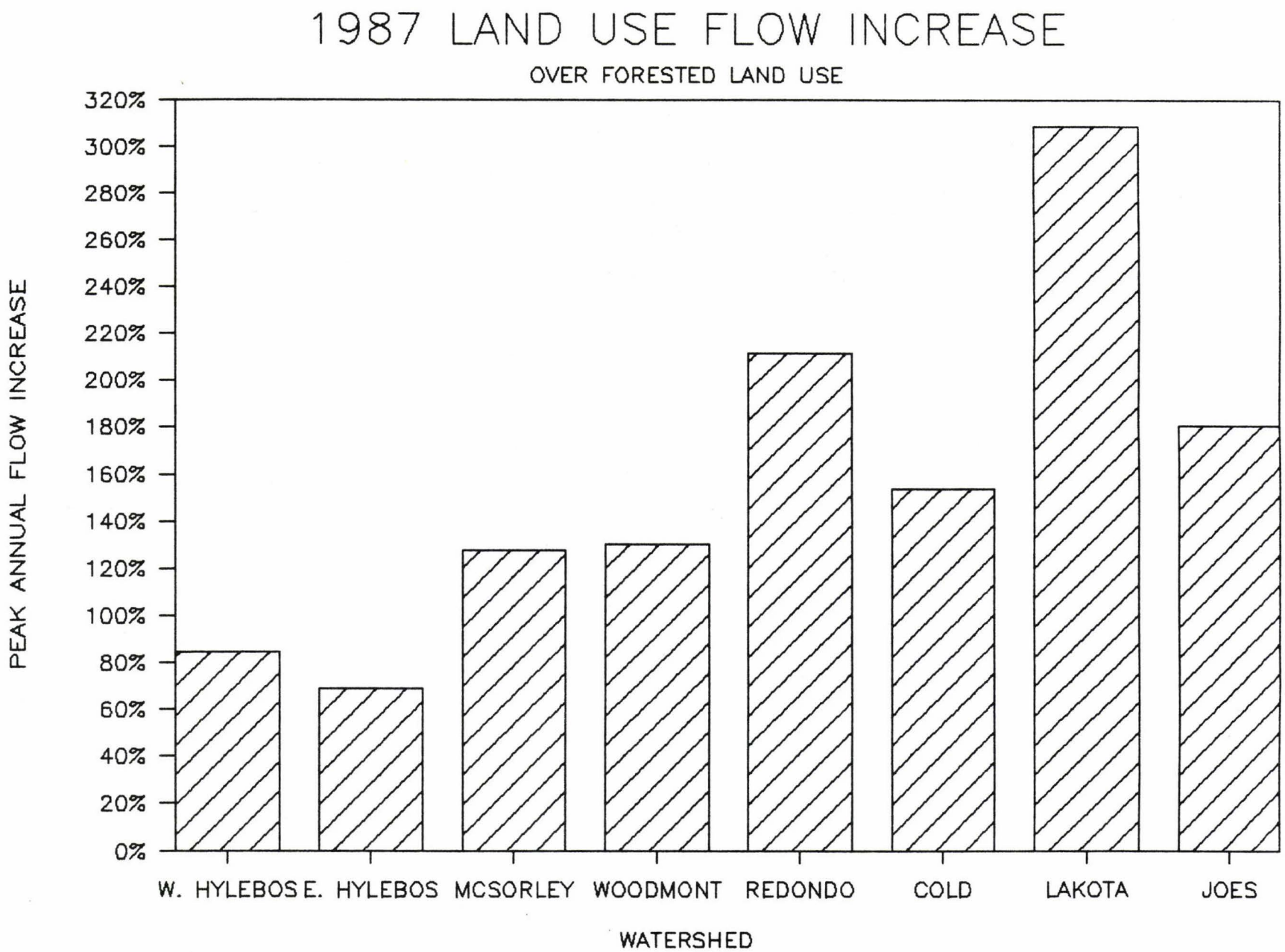

1987 LAND USE FLOW INCREASE
OVER FORESTED LAND USE
PEAK ANNUAL FLOW INCREASE
320%
300%
280%
260%
240%
220%
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
W. HYLEBOS
E. HYLEBOS
MCSORLEY
WOODMONT
REDONDO
COLD
LAKOTA
JOES
WATERSHED

Figure 3.3.13

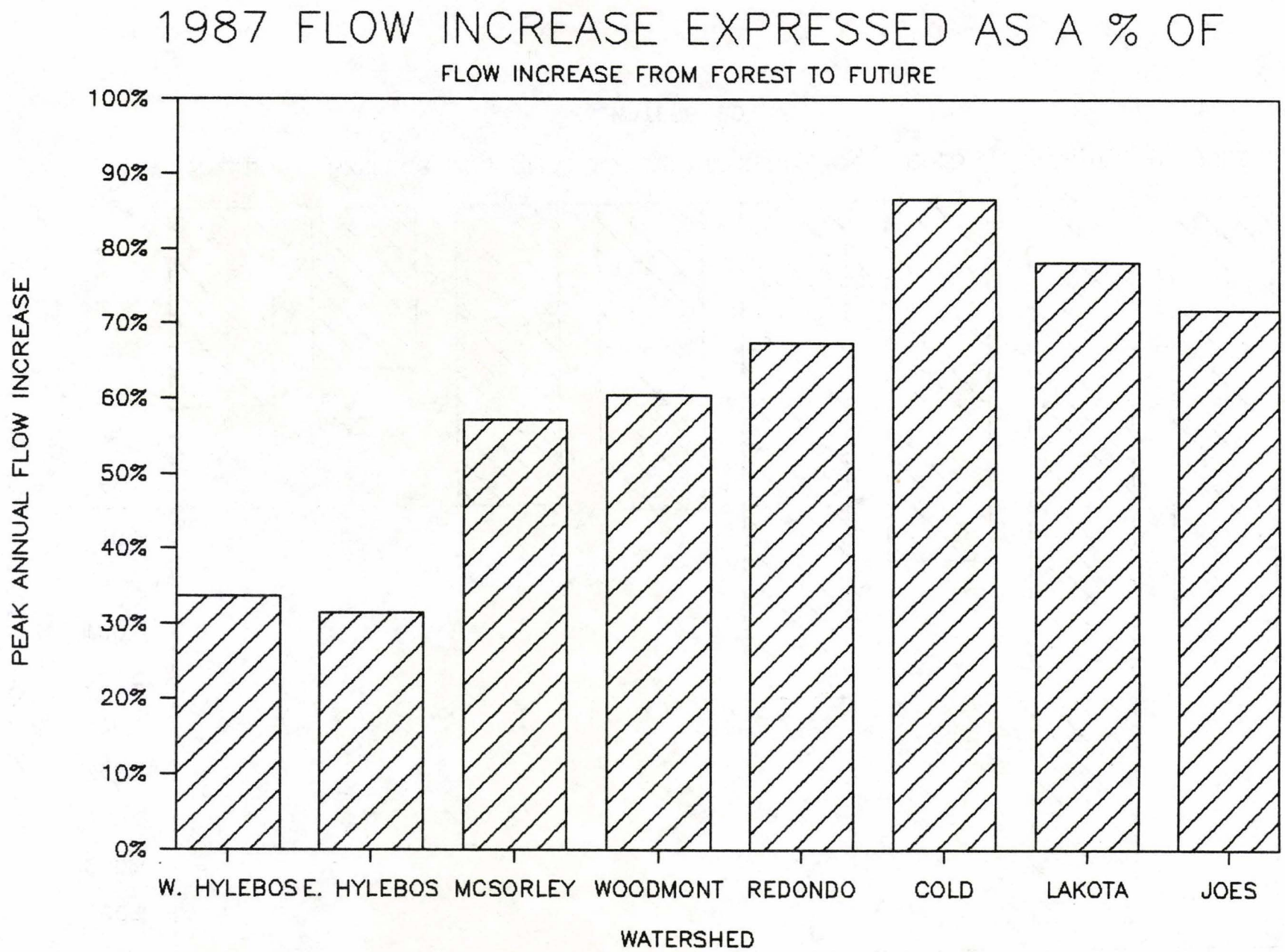

1987 FLOW INCREASE EXPRESSED AS A % OF
FLOW INCREASE FROM FOREST TO FUTURE
PEAK ANNUAL FLOW INCREASE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
W. HYLEBOS
E. HYLEBOS
MCSORLEY
WOODMONT
REDONDO
COLD
LAKOTA
JOES
WATERSHED

Figure 3.3.14a

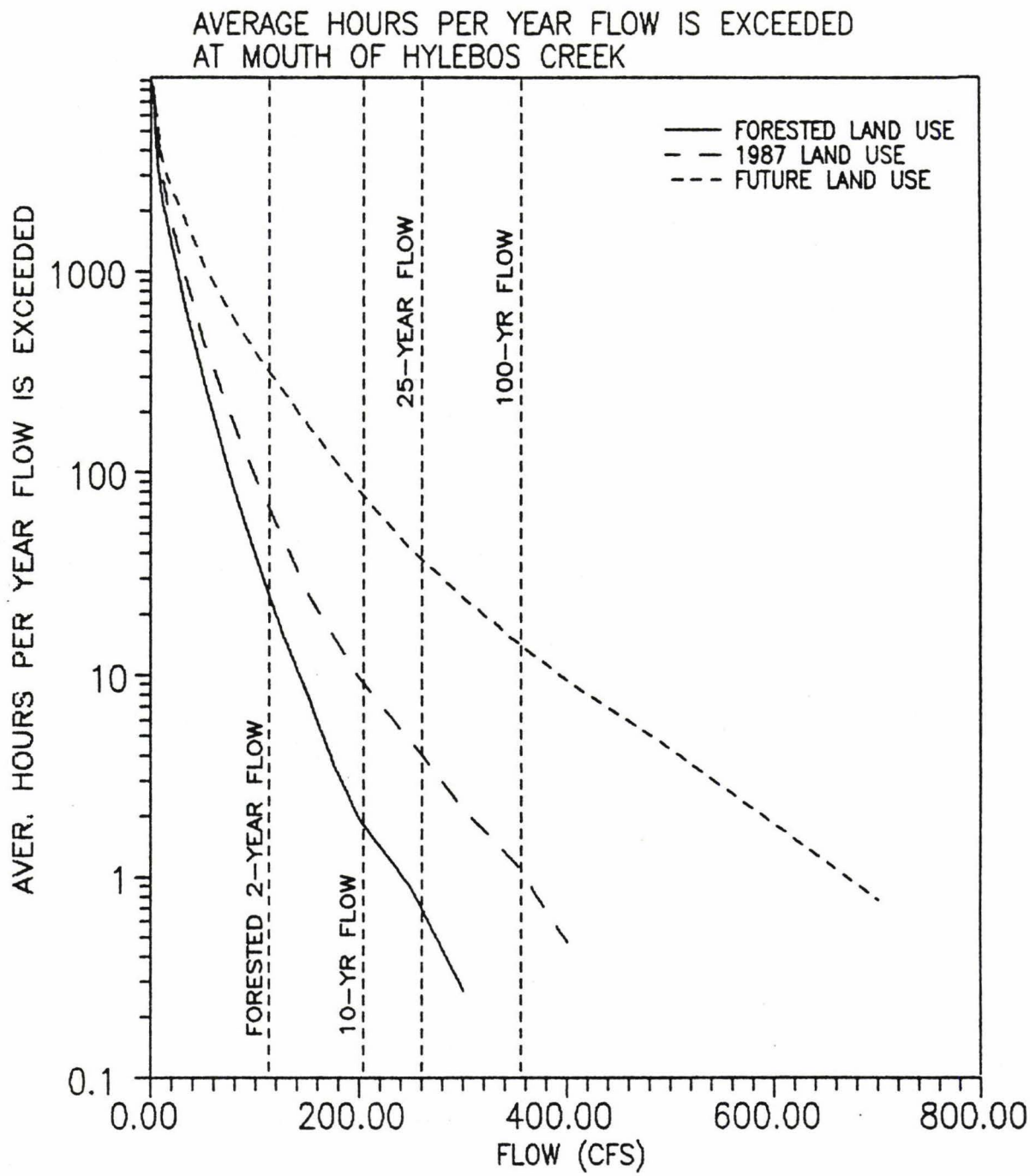
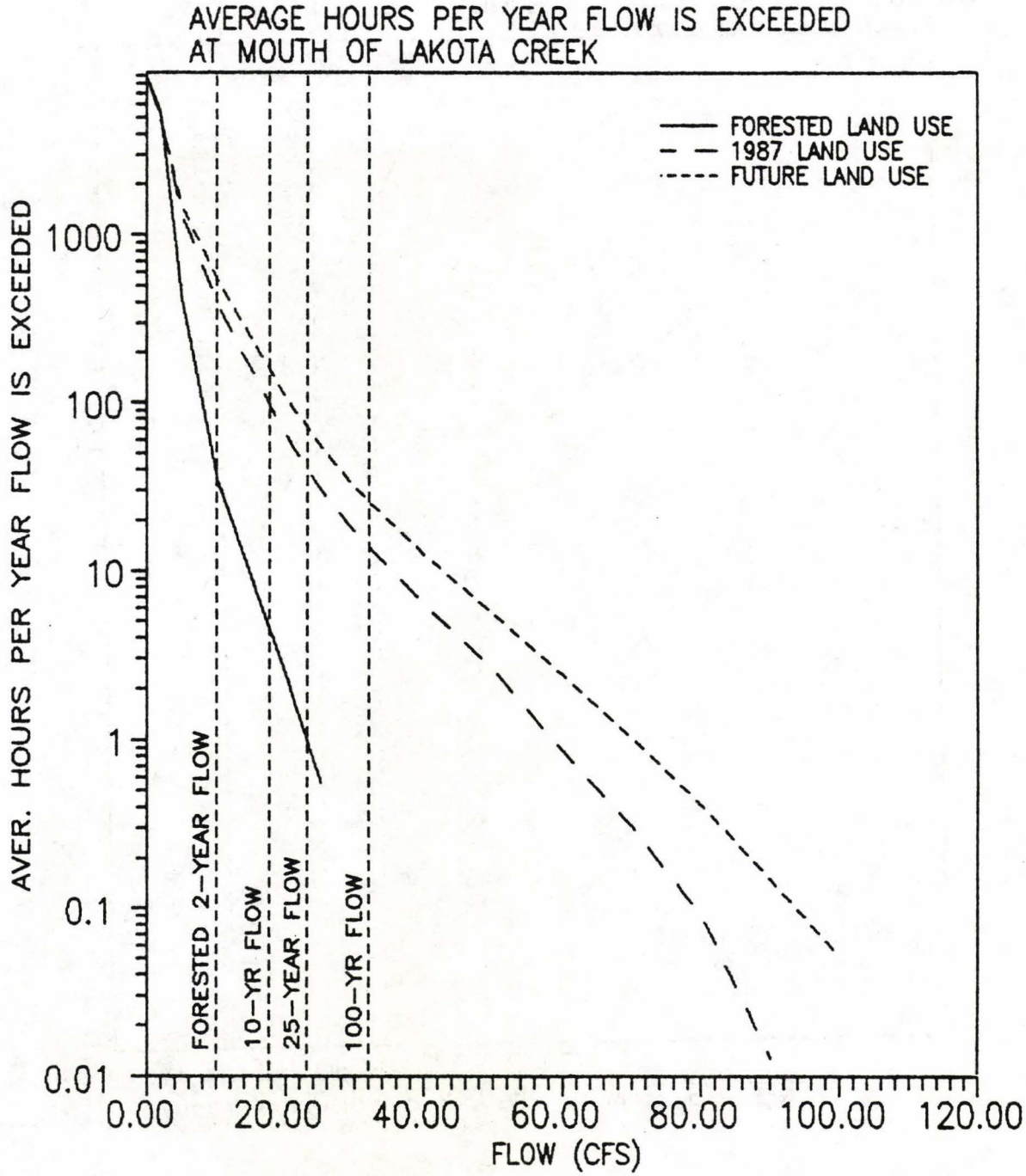


Figure 3.3.14b



Flow durations increase with urbanization because the number of flow peaks increase with urbanization. Figures 3.3.15a and b compare the number of flow excursions for the three land-use scenarios at the outlet of the Hylebos and Lakota Creek watersheds. A flow excursion is defined as the period when the hydrograph rises above a particular flow level, peaks, then drops below that flow level. It provides a rough estimate of the number of peaks that occur during a model simulation run. There are roughly 8-times as many forested 2-year excursions under 1987 land-use conditions as under forested conditions and 30 times as many under future land-use conditions. The difference between future and 1987 land-use is not nearly as great at the outlet of Lakota Creek compared to Hylebos Creek, another indication that the Lakota Creek tributary area is approaching built-out conditions.

Although the number of flow peaks at a given flow level increases with urbanization, each excursion occurs for a shorter period of time. Figures 3.3.16a and b compare the average length of time per excursion for the three land use scenarios. These figures show that the 2-year flow under the forested land use scenario occurs two to four times longer than under the future land use scenario. This is consistent with the concept of "flashy streams" under developed land-use conditions.

KEY FINDINGS

- Peak flow runoff at the 100-year level under 1987 land use ranges from 70 cfs to 290 cfs at the mouth of the creeks, with the East Branch Hylebos Creek producing the highest and Cold Creek producing the lowest discharge. Peak flow discharge per unit area is generally lower in the Hylebos basin, because the Hylebos basin has: 1) less intensive land use, 2) more lakes and wetlands, and 3) lower subcatchment gradients.

- During the analysis of the basins, a large storm event occurred on January 9, 1990 that caused severe flooding and erosion in much of the basin and was determined to be a 30-year 24-hour precipitation event. The recurrence interval for the 24-hour duration precipitation was 30 years and the 96-hour duration precipitation was 70 years. The runoff return period was determined from computer modeling to be between a 50-and 100-year recurrence interval at the confluence of the East and West Branches of the Hylebos Creek.

- Flow increases in the basins under future land use without mitigation ranged up to 200 percent over 1987 land use. The highest relative flow increases were noted along Joes Creek upstream of Twin Lakes, out of Panther Lake, along the West Branch Hylebos Creek, and from tributary 0015 to the East Branch Hylebos Creek. At the mouth of the creeks, higher flow increases were noted from Hylebos Creek than from the Lower Puget Sound creeks, a result of the lower level of current development in the Hylebos Creek basin.

- The Hylebos Creek and Lower Puget Sound basins represent one of the most heavily developed areas relative to other unincorporated areas in King County. Peak flows under 1987 land use have increased from 65 percent to 300 percent over the forested conditions that existed prior to this urbanization. Differences in peak flow runoff between the forested and 1987 land-use condition were greatest in the Lower Puget Sound basin, a function of the higher existing land use there.

Figure 3.3.15a

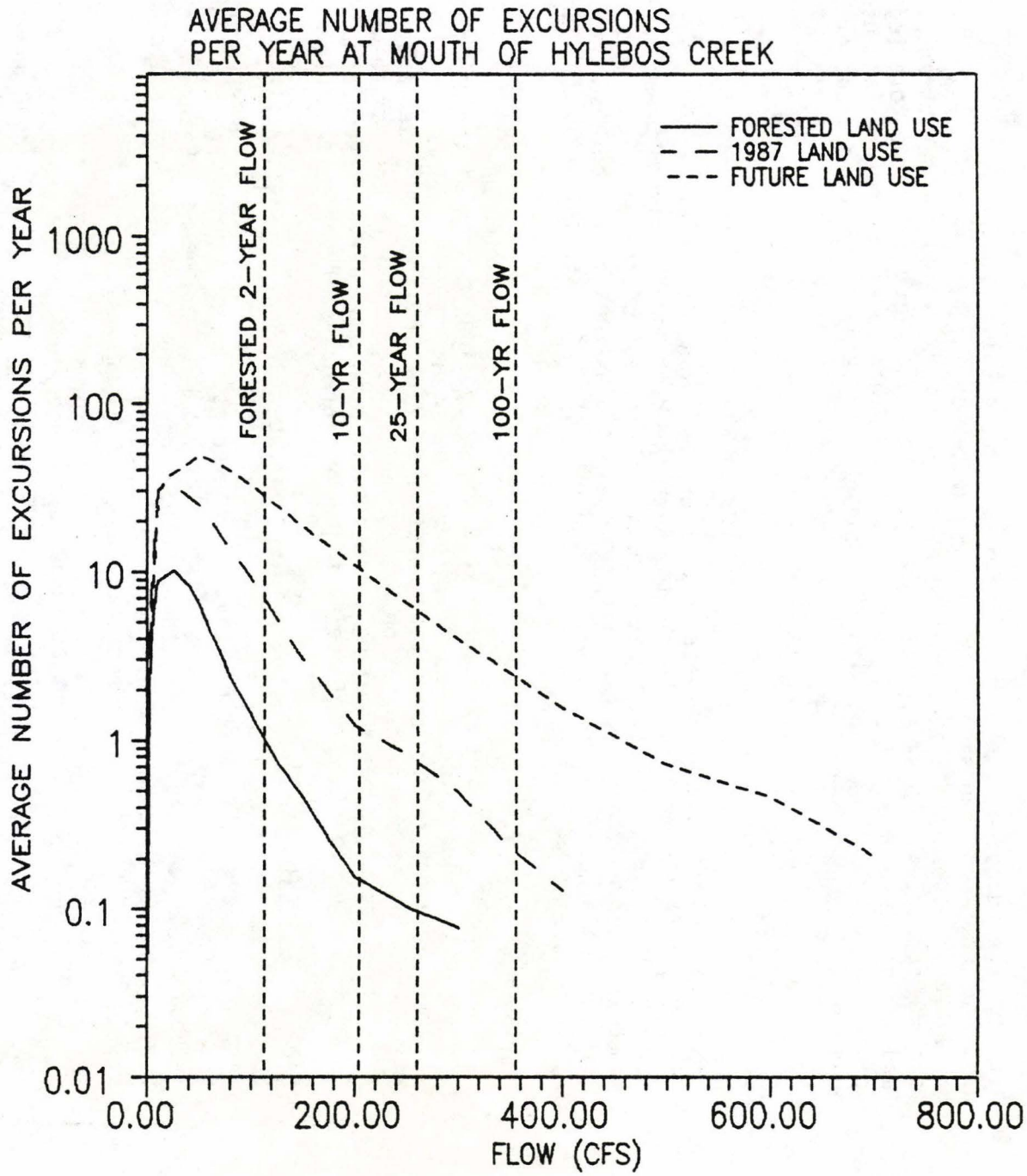


Figure 3.3.15b

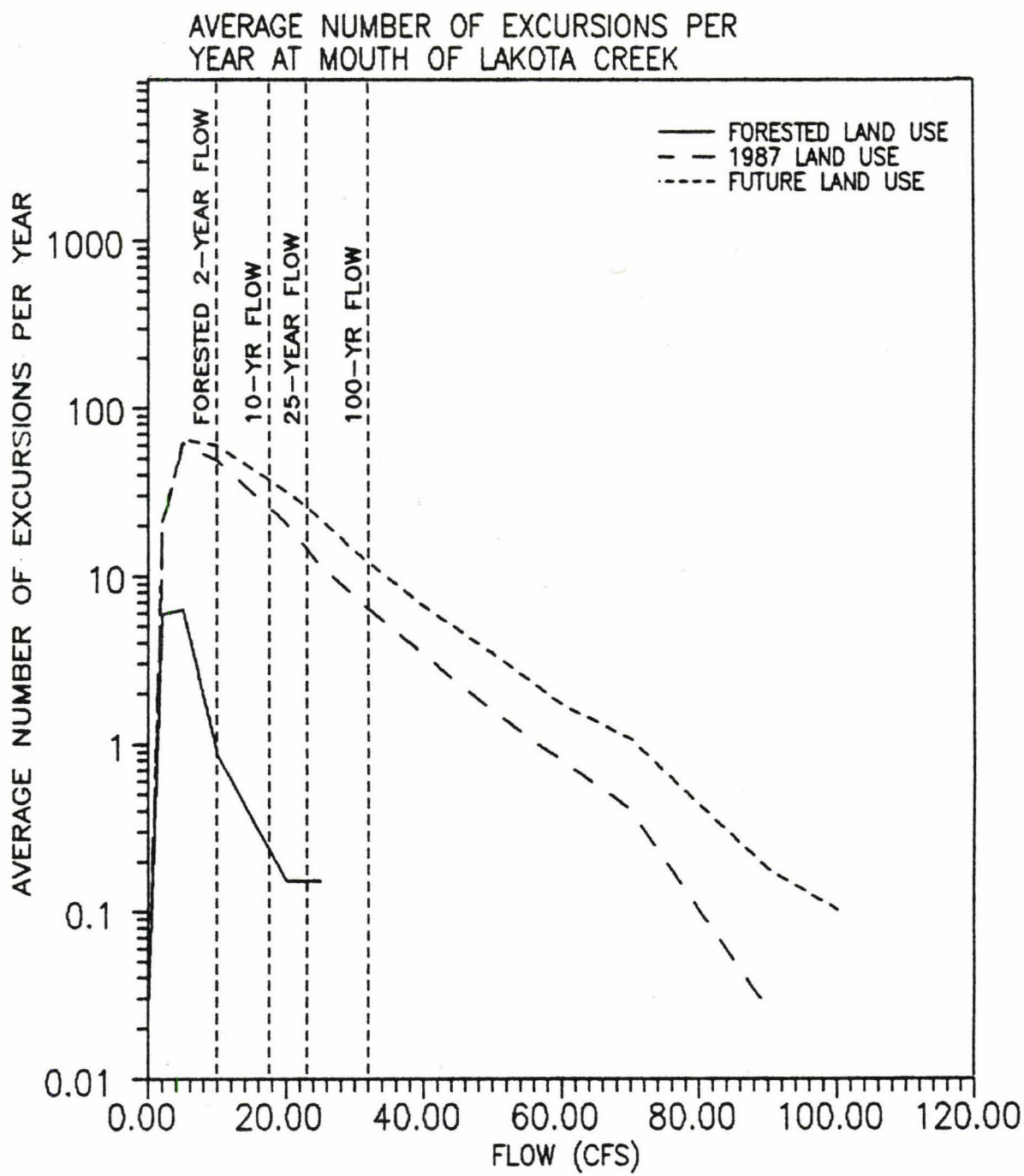


Figure 3.3.16a

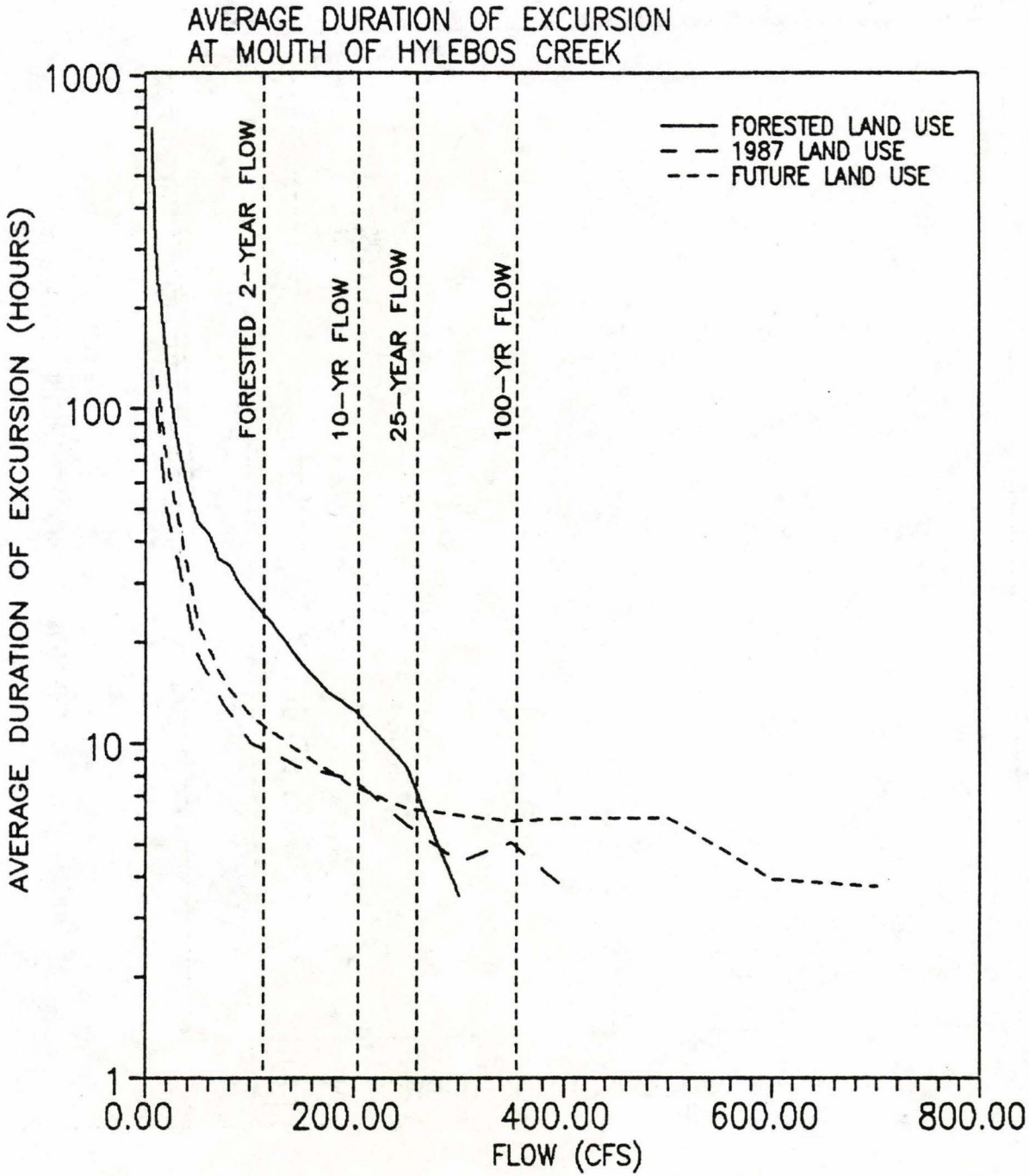
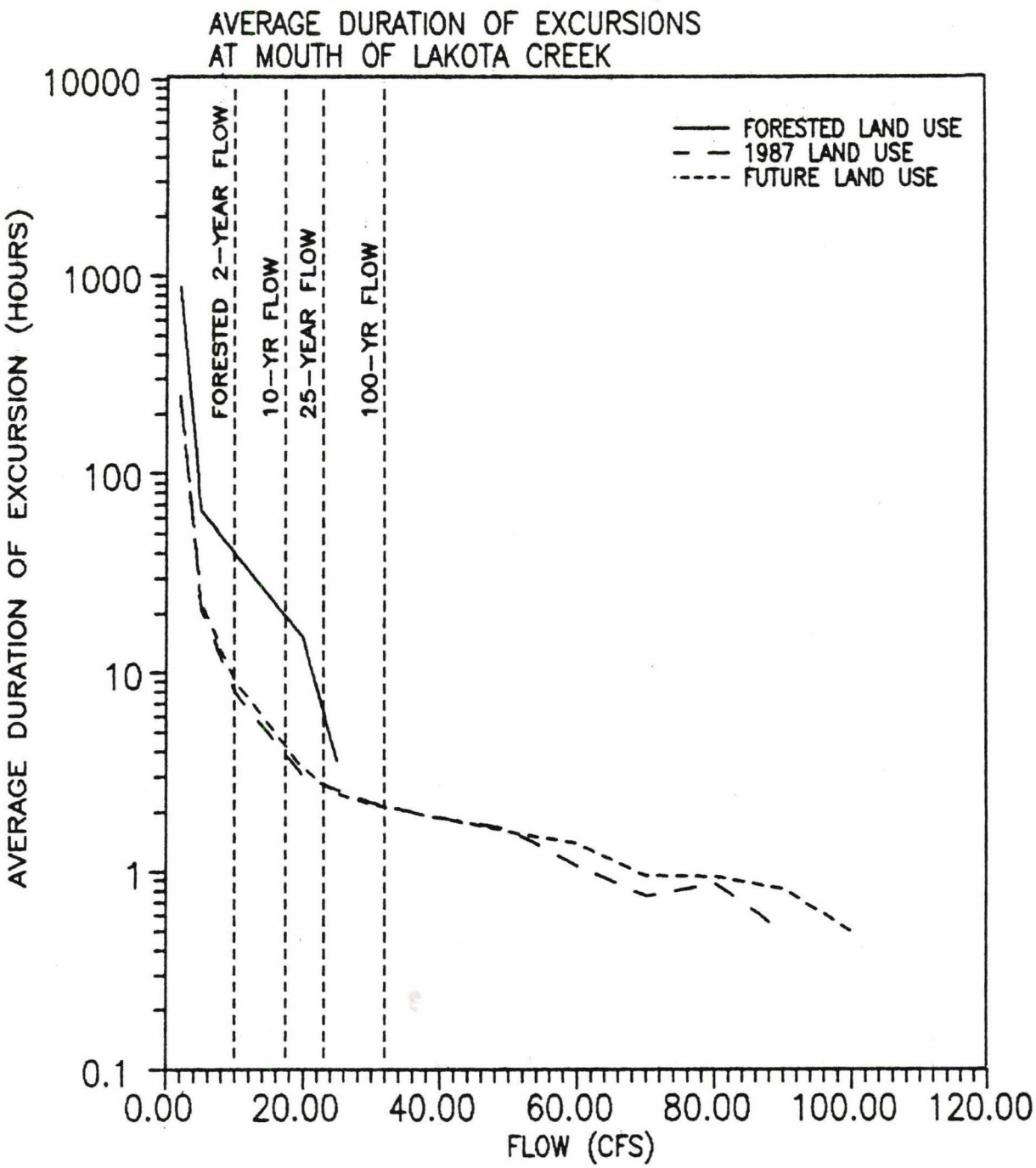


Figure 3.3.16b



SECTION 3.4 FLOODING

INTRODUCTION

The occurrence and extent of flooding in the Hylebos and Lower Puget Sound streams has been severely affected by urbanization. Overbank areas that were once available to accommodate high flood flows have been encroached upon, eliminating natural floodplain areas. The filling of wetlands has displaced water and eliminated off-channel storage areas. The capacity of soils to infiltrate has been greatly reduced by deposition of fine sediments as well as by the impervious surfaces of urbanization. As urbanization has continued, ever-expanding portions of the natural stream system are modified into a network of culverts, catch basins, and artificial ponds.

BASIC CONCEPTS

Types of flooding

Three types of flooding may occur in a basin: 1) regional - systemic, 2) local - systemic and 3) local - nonsystemic. Regional systemic flooding occurs when a large stream or river is the principal source of the flood waters. Typically, the stream or river has a large amount of tributary area that drains into a flat, broad floodplain. In an extreme flood event, the valley area would be inundated along a considerable length of its channel. The lower portion of Hylebos Creek from the upper end of the Hylebos Waterway to the confluence of the East and West Branches experiences this type of regional flooding. The portion of the West Branch in the vicinity of S 373rd Street also has a broad floodplain area that is susceptible to regional flooding. Regional flooding may be prevented by regulatory measures only if a basin has a considerable amount undeveloped land area. Reduction of existing regional flooding in a moderately urbanized basin such as Hylebos Creek would probably entail very expensive, complex projects such as large dams or levees.

Local flooding is characterized in two ways: small-scale, systemic flooding and nonsystemic drainage problems. Systemic flooding of small streams is similar to regional flooding but at a reduced scale. As with regional flooding, local systemic flooding is influenced by changes in land use. Flooding impacts may also be reduced with regulatory measures or the implementation of more limited-scale projects such as retention/detention (R/D) ponds and adequately sized culverts, bridges, or other structures. In the urbanized areas of Hylebos and the Lower Puget Sound basins, local flooding may be caused by increased runoff draining to undersized or debris-clogged culverts, or by channel diversions that supply additional volumes of water to streams that, under stable conditions, were naturally sized for smaller flows.

Urban areas also experience numerous drainage problems such as ponding at low points along gutters or parking lots, clogged inlets to catch basins, unmaintained private driveway culverts and downspout outlets that may temporarily pond water in yards. These types of drainage problems can also occur during storm events, but are not necessarily related to the stream system. These area-specific local nonsystemic problems are typically solved by localized improvements to the constructed drainage system.

Designated Floodplain Areas

Since the passage of the National Flood Insurance Act of 1968, the Federal Emergency Management Agency (FEMA) has identified many floodplain areas nationwide on Flood Insurance Rate Maps (FIRMs) (FEMA, 1985). No "Special Flood Hazard Areas" (areas within the 100-year flood boundary) have been identified on the King County FIRM in the Hylebos Creek and Lower Puget Sound basins. These basins have been designated as "Zone X". Zone X is considered an "area of moderate or minimal hazard from the principal source of flood in the area" (FIA 2, 1987). This designation applies to areas that lie outside the mapped 500-year floodplain.

Based on the flooding caused by the January 1990 storm, this designation appears to be appropriate. Flows calculated by computer modeling of the January storm were the most severe in the 39-year period of simulated flow record, and have been estimated as a 50- to 100-year runoff event. A Zone X designation does not exclude the possibility of flooding caused by storms that exceed the design capacities of the existing local drainage systems. Local stormwater drainage systems are not normally considered in flood insurance studies. However, the "failure of a local system creates areas of high flood risk within these rate zones" (FIA 2, 1987).

Flood insurance studies (FIS) of Hylebos Creek within Milton and unincorporated Pierce County were completed in 1981 and 1987, respectively. Each study used a 100-year discharge of 310 cubic feet per second as the flow just downstream of the confluence of the East and West Branches. This 100-year discharge is substantially less than the HSPF-estimated discharge of 556 cfs, which is the sum of the two branches under 1987 land-use conditions. The FIRM mapping shows I-5 as flood-free for the 100-year event. Recent experience indicates that the mapping does not reflect the actual flood boundaries. Although a measured discharge for the January storm is not available for a direct comparison, the recurrence interval was estimated to be less than a 100-year event and yet did cause flooding of two lanes of the freeway.

New flood analysis of the Pierce County portion of Hylebos Creek is included in the Stormwater Master Plan currently in preparation by James M. Montgomery and Associates for Pierce County Surface Water Management. The final plan is expected to be available in August 1990.

DATA GATHERING METHODS

The initial data gathering effort was focused on collecting and reviewing the existing drainage information about the basins. This information included King County SWM Reconnaissance Reports, currently proposed King County projects and studies, drainage studies from other agencies, such as Pierce County's 1974 Hylebos Basin Drainage Plan, FEMA Flood Insurance Studies, and anecdotal information from staff and citizens. Drainage complaints for the Hylebos Creek and Lower Puget Sound basins that are on file with the King County Drainage Investigation (DI) Section were reviewed and plotted on basin maps (1 inch = 1000 feet). Groupings and patterns of complaints were examined in an attempt to reveal systemic problems in the basins. Field investigations were conducted to examine the current physical state of the stream system. In some stream locations, limited topographic surveys were completed as an aid in understanding the hydraulic conditions of specific problem sites.

The most valuable source of information on flooding conditions in the planning area was the January 9, 1990 storm. In the Hylebos Creek and Lower Puget Sound basins, several roadways and homes were damaged by the flood waters. The storm was a first-hand demonstration of how the existing stream systems function under extreme flood conditions. During the flood event, King County SWM personnel toured throughout the basins to observe the flooding. Photos were taken at numerous locations and are on file in the SWM Basin Planning office. Area-specific locations of significant flooding problems are identified in the following discussion.

CONDITIONS

The Hylebos Creek basin has stream reaches that are prone to regional and local systemic flooding, whereas the Lower Puget Sound basin is mainly afflicted by numerous nonsystemic drainage problems. The Hylebos Creek basin suffered greater property damage and had more significant flooding problems in the recent flood events than the Lower Puget Sound drainages. In most cases, flooding during the storm not only was a result of increased volumes of water but also was caused by large cobbles and woody debris clogging culverts. Overall, areas typically plagued by flooding were once again inundated but to a much greater extent. New locations of flooding occurred in the Twin Lakes area and in the reach between Panther Lake and the West Hylebos Wetland. Since the last major storm event, which occurred in 1986, the upstream tributary areas of these two locations have had large amounts of recent development.

Based on past occurrences and the recent January storm event, several locations throughout the Hylebos Creek and Lower Puget Sound basins have been identified as significant problem areas. The areas are located on Figures 3.4.1a and b also are listed below. These problem areas are deemed significant because public safety was jeopardized and/or considerable property damage occurred. The numerous locations of ponded water in streets and yards where public safety was not significantly affected or property damage was slight are not enumerated in this report.

Current Significant Problem Areas

Fifteen locations have been identified as significant problem areas and are described below. Three regional flooding areas (Problem Numbers 1 - 3) are listed first and followed by the remaining twelve areas (Numbers 4 - 15) that are local systemic flooding problems. Further information is provided in this report in Chapter 4, Sub-basin Conditions.

1) Tributary 0006 near Interstate 5

   This is an area of regional flooding in the broad valley of the Lower Hylebos sub-basin in Pierce County, Milton, and Fife. During the January storm event, the two southbound lanes on the west side of I-5 were flooded for several days. Flow in this portion of the stream, approximately RM 4.6, is constricted by I-5, SR 99, the 70th Avenue E. bridge, and a recent fill of the right bank. This constriction, in combination with the moderately high tides that occurred during the storm (12.1 and 12.7 feet on January 9th and 10th, respectively), most likely increased flood levels throughout the valley.

Figure 3.4.1a

SIGNIFICANT FLOODING AREAS IN THE HYLEBOS CREEK BASIN

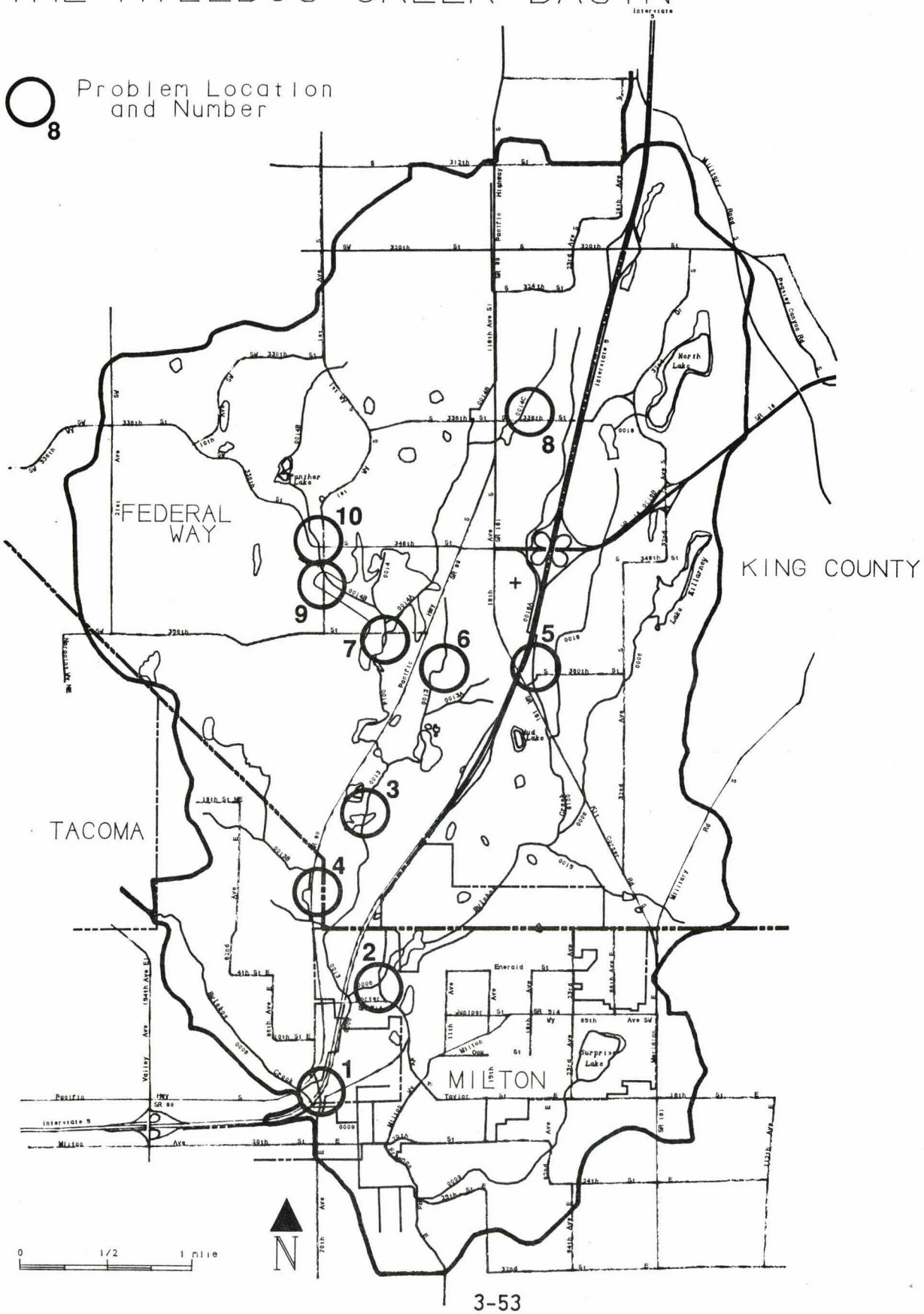
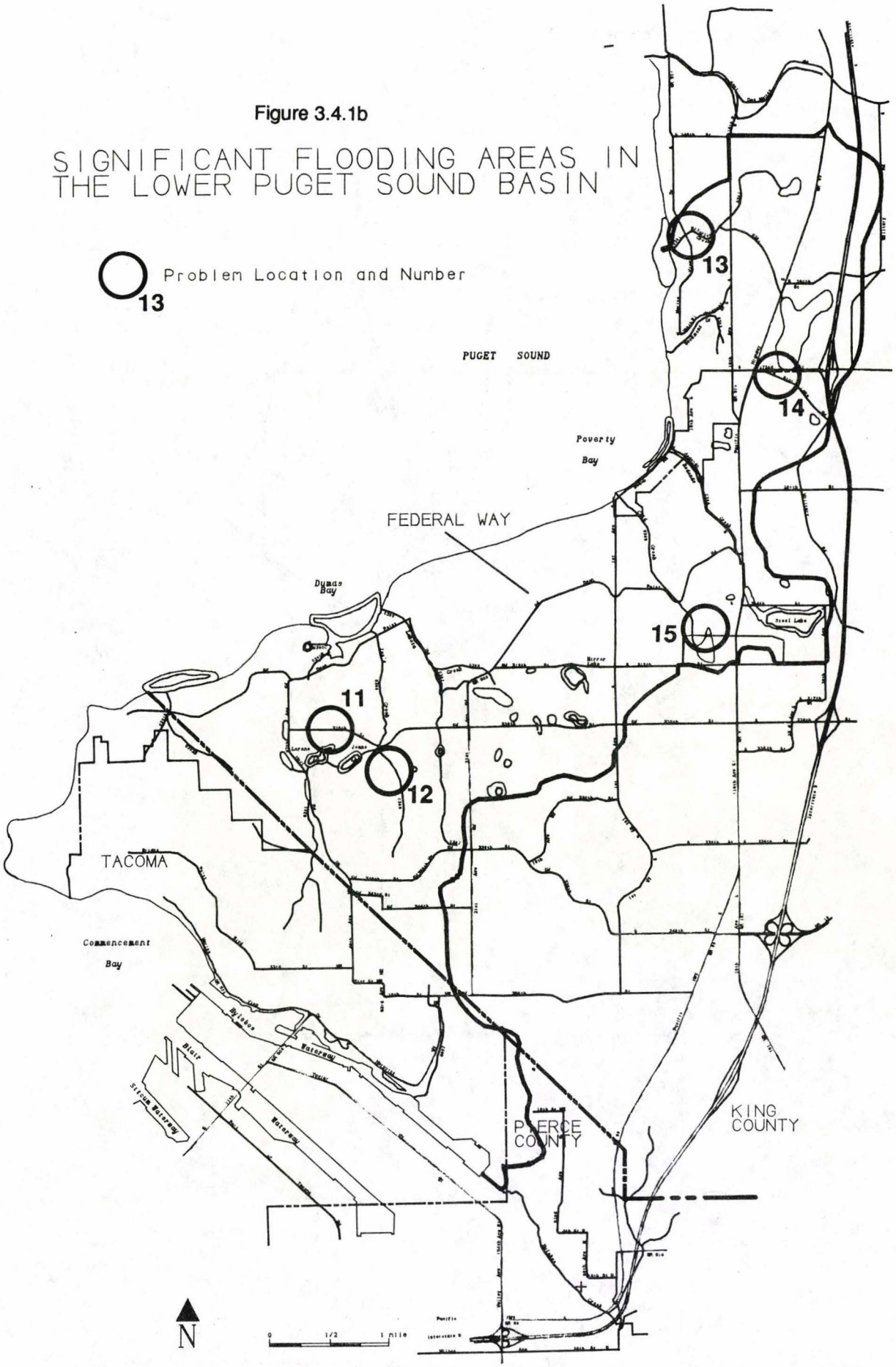


Figure 3.4.1b

SIGNIFICANT FLOODING AREAS IN THE LOWER PUGET SOUND BASIN



Preliminary results of a flood analysis of RM 0.00 to 2.33 indicates that the flat, broad topography of the valley area has a greater influence on flood profiles than the existing bridges and culverts along the creek. The analysis, being completed by James M. Montgomery (JMM) and Associates for the Pierce County Stormwater Management Plan, does not include the most recent HSPF flow estimates and only examines existing flow conditions. After analyzing culvert capacities, assuming the culverts are free of debris and sediment, JMM has determined that all bridges and culverts have adequate capacity for a 25-year flow event of 385 cfs. By comparison, the HSPF-estimated 25-year discharge for this area is 446 cfs under 1987 land use.

2) Tributary 0006 at 5th Avenue

Four homes near this culvert crossing in Milton were flooded during January 9, 1990. This area is the northeastern valley extension of the mainstem Hylebos Creek. The flat topography and the local hydraulic influence of the road culverts causes sediment deposition in the channel and culverts, reducing flow capacity. After the January storm, as much as 1.8 feet of silty sand was deposited in the 72-inch corrugated metal pipe and 0.4 feet in an adjacent 36-inch concrete pipe.

3) Tributary 0013 at S 373rd Street

This reach of Hylebos Creek undergoes regional flooding in the the broad floodplain valley that begins at the confluence with tributary 0014 (RM 1.55) and continues downstream one-half mile. The upper reach of tributary 0013 above the confluence has a relatively flat grade but tributary 0014 above the SR 99 crossing has a steeper gradient and carries large amounts of sediments from upstream sources into the valley below. Deposition of sediments in the channel has dramatically reduced the capacity of the stream and bridge, causing more frequent overbank flooding of adjacent pastures and one streamside home. Approximately 1,300 cubic yards of material were dredged from the bridge area in August 1986 but the influx of sediments continues. Prior to 1986, dredging was done every two years by King County Roads Maintenance Section.

During the January storm, streamside properties were severely damaged by large amounts of sediments deposited both upstream and downstream of S 373rd Street. The streamside home that was flooded on January 9th is located about 200 feet upstream of the bridge and approximately 10 feet from the stream's right bank. S 373rd Street, east of the bridge, also overtopped during the January storm. During a smaller storm in December 1989, neither the roadway nor the streamside home flooded. However, access to the home was blocked by flood waters that inundated the driveway and yard.

King County Roads Maintenance Section and three streamside property owners have requested Washington Department of Fisheries Hydraulic Project Applications to dredge the sediment from channel, upstream and downstream of the bridge, in the summer of 1990. This is considered an interim measure. The Draft Hylebos Creek and Lower Puget Sound Basin Plan will recommend long-term solutions for this and other problems.

4) Tributary 0013B at SR 99 near Swindell Road

This previously unnumbered tributary drains the northwestern portion of the Lower Hylebos sub-basin and joins with West Branch Hylebos Creek (0013) near RM 0.46. During the January 9th storm, sediments plugged both a 24-inch driveway culvert and a 24-inch cross culvert under SR 99. As water overtopped the highway, road shoulders were eroded. Large amounts of sediment carried downstream by the high flows were deposited into a wetland near the confluence of tributary 0013A and West Hylebos Creek (tributary 0013).

5) Tributary 0016A at S 363rd Place

A street and one home within a subdivision along 20th Place S and S 363rd Place were flooded on January 9, 1990. Tributary 0016A originally flowed to tributary 0013 in the West Hylebos sub-basin but was diverted during the construction of I-5 in the mid 1960s. After passing under I-5 through a 48-inch culvert (RM 0.68), tributary 0016A enters a 42-inch culvert at the north end of the subdivision at 20th Place S. During the January 9th storm, this culvert was continually clogged with debris despite local residents' efforts to clear it, and caused overtopping of 20th Place S. In addition, a very small R/D facility parallels the stream and 20th Place S. The retaining wall of the pond overtopped into the stream and also backed water onto 20th Place S.

6) Tributary 0013 at S 359th Street

This two-lane roadway was overtopped and partially washed out in the January 9th event. Overtopping occurred because the culvert became clogged with debris. Flow over the pavement eroded and undermined the downstream embankment, leaving less than one lane of roadway. The road has been closed by the King County Roads Division pending repair. King County has coordinated with the Washington Department of Fisheries to obtain the Hydraulic Project Application (HPA). According to the HPA conditions, culvert replacement and road repairs may begin after June 15th of this year.

7) Tributary 0014 at S 356th Street

Two 36-inch culverts at this crossing carry the outflow from the West Hylebos Wetland. Flood flows in December 1989 and January 1990 overtopped the road, washing out both shoulders.

8) Tributary 0014C at S 336th Street

Two houses were flooded when this roadway (RM 0.34) and SR 99 (RM 0.15) were overtopped during the January 9th storm. The top-ranked Basin Reconnaissance capital improvement project is located between these two locations, at King County inventoried Wetland 9. The project goals are to reduce chronic flooding and improve water quality (further information on this and other scheduled Capital Improvement Projects is listed below in the section, "Current Projects and Studies").

9) Tributary 0014B at 1st Avenue S

From S 348th Street, the stream parallels 1st Avenue S prior to entering an 18-inch culvert under SW 353rd Street, then crosses 1st Avenue S via a 21-inch culvert that outlets to the West Hylebos Wetland. This tributary is a new channel and has been created by recent surface outflows from Panther Lake, which historically infiltrated nearly all flows. During the January storm, outflow from Panther Lake overwhelmed both culverts and severely eroded the channel between S 348th and SW 353rd Streets. The sidewalk along 1st Avenue S was undermined and the channel was dramatically widened from an average pre-flood width of five feet to a width of at least 20 feet. The 1st Avenue S and SW 353rd Street intersection was flooded, and road shoulders on both streets were washed out. A sanitary sewer line and manhole at the intersection were also flooded by stormwater.

10) Tributary 0014B at SW 336th Street

SW 336th Street, just west of 1st Avenue S, was flooded during the January 9th storm. The outlet structure at Panther Lake became clogged with debris, causing overtopping of the berm road at the southern end of the lake. Downstream of the berm road, the tributary is carried under SW 336th Street by two culverts (36- and 30-inch). The 36-inch culvert also become clogged with debris, causing flooding of a portion of SW 336th Street that parallels the stream. SW 336th Street at the culvert alignment was not overtopped. The estimated flow capacity of these culverts, when clear of sediment and debris, is approximately 200 cubic feet per second. The actual flood discharge, which caused significant downstream flooding and erosion (item 9, immediately above), would have been less than 200 cfs because of the debris restricted flow in the 36-inch culvert.

11) Tributary 0388 (Joes Creek) at Lorene Lake and Jeane Lake.

These lakes, commonly referred to as Twin Lakes, are fed by tributary headwaters that lie in Pierce County and Tacoma. Past and current construction of subdivisions in the headwaters area has delivered significant quantities of sediment into both lakes, possibly reducing the flood storage capacity. The most recent upstream activity, in October 1989, included clearing of approximately 120 acres of forested land. In previous years, flooding around the lake perimeters has occurred. During the January 9th storm, however, at least 4 houses that were flood-free in the past were flooded for the first time. Flooding around the lakes' perimeters may have been exacerbated by earlier storms that raised lake levels prior to the January storm.

12) Tributary 0389 in Olympic View Park

This tributary (RM 0.20 to 0.60) has undergone chronic erosion and has flooded at least four times in the last five years. Drainage from approximately 700 home sites and the adjacent streets flow into this ravine. Existing gabion weir dams with overflow structures were built in 1986 as a County project to reduce velocities and stabilize the channel. High flows in January caused erosion downstream of the weirs and flooding of SW 325th Street. Debris clogged the inlet structure to the culvert system that passes between residences and under SW 325th Street and caused flows to overtop a small berm at the inlet.

13) Tributary 0381 in Salt Water State Park

In January 1990, the Park underwent severe flooding, with large depositions of sand and gravel in the stream channel, on park grounds, and in the delta into Puget Sound. Specific information on damages and the extent of the January flooding is presently unavailable. The Washington State Parks and Commission, and the City of Seattle are currently investigating the flooding patterns of the stream. Recent modeling of stream flows has been completed by the City for the design of a retention/detention pond for the Midway Landfill. The pipe outlet of the retention/detention pond enters tributary 0382 near 16th Avenue S, just upstream from the Park boundary.

14) Tributary 0381 at S 272nd Street and Star Lake Road

This area is currently the subject of King County SWM Drainage Investigation flood study (further details are provided in the section, "Current Project and Studies", below). Yearly complaints have been filed related to street flooding and malfunctioning retention/detention ponds.

15) Easter Lake near S 312th Street

Flooding around the perimeter of the lake has been a chronic problem. Specifically, the Evergreen Retirement Manor at 14th Avenue S has experienced flooding three times in the last 5 years. During the January 1990 storm, the first floor of the Manor was flooded but evacuations were not necessary. S 312th Street, on the southside of the lake, was also flooded during the January storm.

Other areas of roadway flooding during the January storm include:

- S 320th Street between SR 99 and 23rd Avenue S
- Tributary 0014 at S 348th Street near 11th Avenue S
- Tributary 0006 at SR 161 near S 370th Street
- Tributary 0016 at SR 161 near S 368th Street
- Tributary 0014C at S 330th Street and 20th Avenue S
- Headwater areas of tributaries 0014A and 0014C near S 317th Street between 20th and 23rd Avenues S
- Tributary 0384 at 4th Place S near Redondo Beach
- Adelaide Beach along 20 Place S (no tributary number)
- Lake Ponce De Leon near SW 324th Street and 26th Avenue SW
- SW 337th Street and 21st Avenue SW (malfunctioning commercial infiltration pond)
- Tributary 0016A southwest of the I-5 and S 348th Street interchange (behind Costco)

Current Projects and Studies

Efforts toward resolving flooding problems in the basins include capital improvement projects and drainage studies completed by the SWM Project Management and Design (PM&D) and Drainage Investigation (DI) sections. Some DI studies are initiated as a result of problems identified during inspections by SWM Facilities Maintenance personnel. The King County Roads Division has several projects in progress that have drainage design components. The Hylebos Creek and Lower Puget Sound Basin Plan, of which this conditions report is a prelimi-

nary analysis, will provide substantial new information and analysis to resolve long-range flooding problems. Because of the recent incorporation of Federal Way, continuation of work on these projects and studies will be determined through interlocal governmental agreements between King County and the City.

1) King County SWM Capital Improvement Projects

The King County Council has adopted a six-year capital improvement program (CIP) which is updated annually. Currently, the CIP list includes two projects in the Hylebos Creek basin (Kitt Corner Regional Pond and S 336th Street "South" Pond) and one project in the Lower Puget Sound basin (Lakota Detention Pond). Both Hylebos projects were identified in the 1979 Pacific Highway South Drainage Study completed by Kramer, Chin and Mayo for the King County Hydraulic Division. King County will design these projects by the end of 1990; Federal Way has subsequent responsibility for construction. King County, by enforcing a permit violation, will also oversee a culvert replacement on tributary 0014A at about RM 1.20 that will provide de facto detention just upstream of the S 336th Street project site. The violation was for the removal of a culvert that was functioning as the outlet control of a wetland.

Final design of the Lakota project will be completed in the first half of 1990 and provided to Federal Way. If constructed, the Lakota project would reduce erosion in the downstream reaches of tributary 0386 and prevent flooding of the ballfields, which currently occurs annually. The Lakota and Hylebos projects are utilizing the results of the HSPF model and will be designed to accommodate predicted flow under build-out land use. Since the incorporation of Federal Way, three additional County road-widening projects are now the responsibility of the City:

2) King County SWM Drainage Investigation (DI) Studies

Drainage Investigation receives an average of 700 drainage complaints per year throughout King County. About ten percent of these complaints result in enforcement action due to violations of the County Code. The remaining complaints are directed to appropriate agencies that have jurisdiction or the complaint is determined to be a private problem in which the citizen can only resort to civil action. Drainage Investigation has received at least 650 complaints related to the January storm event alone. For the week of January 8, 1990, three hundred and eighteen complaints were filed, in comparison to only 60 complaints filed during the week of December 4th in 1989 when a moderate winter storm occurred.

In addition to handling complaints, DI performs small-scale drainage studies to analyze flood problems and develop retrofit designs for existing retention/detention ponds. Studies in progress in 1989 included:

a) Star Lake Road and S 272nd Street

b) Alderbrook Division 1, Pond 1 - 1400 SW 323rd Street

c) Lakota Ridge - 22nd Avenue SW and SW 310 Place

d) Lakota Highland - SW 306th Place and 22nd Avenue SW

e) Marlbrook Division 1 - S 293rd Place and Redondo Way S

Due to staff assignments to field investigations of complaints related to the January storm, the Star Lake study was temporarily on hold. The study is now in progress and is expected to be completed by the end of this year. The other four areas listed above are retrofit studies, now in Federal Way, and are currently on hold. No studies have yet been initiated that address new problems related to the December 1989 and January 1990 storms.

3) King County SWM Facilities Maintenance (FM) Section

This section is responsible for the inspection and maintenance of residential R/D facilities throughout the SWM service area. Typically, a residential facility is inspected at least once a year by one of four inspectors. Currently, there are at least 20 residential R/Ds in the Hylebos Creek basin and 62 in the Lower Puget Sound basin. Through the inspections, design and maintenance problems are identified that may initiate retrofit studies such as those listed above in item 2).

SWM FM also inspects commercial R/D facilities but the maintenance of the facility is the responsibility of the property owner. Due to the limited staff of inspectors, commercial facilities are visited about every 1-1/2 years.

Regional R/D facilities such as the five West Campus retention ponds are inspected and maintained by the King County Roads Maintenance Section. However, these activities are funded by the SWM Division. Inspection of regional R/Ds usually occurs yearly during the dry summer months.

4) King County Roads Division Projects

Several road widening projects, which have surface water drainage components, have been proposed by the King County Roads Division to increase pedestrian and traffic safety. The project locations and current status are listed below.

a) Redondo Seawall and Beach Road S (in environmental review)

b) SW 356th Street between 21nd Avenue SW and 1st Avenue S (final design)

c) 16th Avenue S between SR 99 and S 348th Street (preliminary design)

d) S 356th Street between 1st Avenue S and SR 99 (preliminary design)

e) S 272nd Street between SR 99 and 500 feet west of 16th Avenue S (preliminary design)

Since the incorporation of Federal Way, three additional County road-widening project are now the responsibility of the City:

f) S 356th Street between SR 99 and SR 161

g) S 312th Street between SR 99 and 28th Avenue S

h) Southwest 312th Street between 1st Avenue S and SR 509

Anticipated Future Flooding Problems

Significant flow increases are predicted to occur from increased amounts of impervious surfaces within the Hylebos Creek and Lower Puget Sound basins. As discussed earlier in this report, the Hylebos Creek basin will have greater increases in peak flows than the Lower Puget drainages. The larger flow increase in the Hylebos Creek basin is a reflection of the relatively undeveloped 1987 conditions and the higher intensity land uses. Increased flows will exacerbate current flooding problems as well as cause flooding in previously flood-free areas. A concomitant of increased peak flows is increased frequency, causing flooding to occur more often. Increased flows and frequencies will result in greater amounts of property damage, more frequent maintenance, and a higher risk to public safety.

In order to evaluate the effect of increased flows on those areas identified previously as significant current flooding problems, culvert and bridge capacities were determined. Culvert capacities for problem numbers 3 and 5 - 10 were compared to HSPF-estimated 1987 and future 25-year flows. Culverts must be designed to pass the flow with a 25-year recurrence interval, according to the 1990 King County Surface Water Design Manual. For problem number 3, S 373rd Street, the King County Design Manual requires 100-year flow bridge capacity. Table 3.4.1 shows the estimated capacities and the predicted 1987 and future flows for these sites. One of the seven sites was adequate for existing flows, but none of the sites can accommodate future, unmitigated flows. The estimates of capacities assume that culverts and bridges are free of debris and sediment. If a bulking factor of fifty percent were applied in the analysis to account for reduction caused by debris (ASCE, 1969), none of the seven sites could pass the estimated 1987 flow.

Replacement of undersized culverts is currently proposed for three of the eight sites. An upgrade of the culvert under S 359th Street from an 18-inch concrete pipe to a 55 x 73 inch arch will accommodate the existing and future flows. Problem number 8 at S 336th Street is also slated for an upgrade as a component of the SWM capital improvement project. Assuming this occurs, the culvert will be designed to pass future flows and the design will include an overflow structure to protect the road embankment. Similarly, the King County Roads project on S 356th Street (problem number 7) would also be designed in this manner.

The remaining problem areas where capacities were not estimated are complex drainage issues that are currently under study (problem numbers 1, 11 and 14) or would require detailed investigations (problem numbers 2, 12, 13, and 15) to fully understand the site hydraulics. One location (problem number 4) lies within Pierce County and was not within the HSPF model study area.

Results of the HSPF hydrologic analysis show that future flows will increase over 150 percent in three Hylebos Creek subcatchments (WH7, WH13, and H2) and two Lower Puget Sound subcatchments (J6 and J8). Flooding downstream of Panther Lake (subcatchments WH7 and WH13) now occurs during large events and is predicted to occur annually under future flow conditions. Historically, Panther Lake infiltrated all flows and contributed no surface flow to tributary 0014B.

Table 3.4.1

FLOW CAPACITY INVESTIGATION FOR THE 25-YEAR EVENT

Problem No.	Problem Location	Tributary No.	Subcatchment No.	Estimated Capacity (in cfs)	Existing 1987 Flow (in cfs)	Future Flow (in cfs)	Adequate for Existing Flow	Adequate for Future Flow
3	S 373rd St.	0013	WH2	284	217.0	427.0	YES	NO
5	S 363rd Pl.	0016A	H9	55	73.8	120.0	NO	NO
6	S 359th St.	0013	WH3	30	74.2	130.0	NO	NO
7	S 356th St.	0014B	WH UW	100	129.0	306.0	NO	NO
8	S 336th St.	0014C	WH10	41	57.0	79.9	NO	NO
9	1st Ave. S	0014B	WH7	11	18.0	153.0	NO	NO
10	SW 336th St.	0014B	WH7	200	18.0	153.0	NO	NO

NOTES:

1) All existing and future flows listed are 25-year events except problem number 5, which is the 100-year.

2) All capacities were estimated assuming the culverts and bridge were clear of debris and sediment.

3) Estimated capacity for problem number 5 represents downstream culvert crossing at SR 161.

During the January 1990 storm, outflow from the lake occurred because land-use conditions in the tributary area have changed and because of reduced infiltration in the lake bottom. This more closely reflects future flow modeling, which predicts a 100-year, unmitigated lake outflow of nearly 200 cfs. This predicted increased future outflow from Panther Lake will exacerbate existing flooding in downstream reaches (see problem numbers 3, 7, 9 and 10). Recent land-use changes in the headwaters of Joes Creek caused similar flooding to the Twin Lakes area (subcatchments J6 and J8) during the January 1990 storm (problem number 11).

The most dramatic change in flooding conditions will occur in those areas that under current conditions are flood-free but will experience over a 2-fold increase in future peak flows. Two areas of concern are the East Branch Hylebos Creek (tributary 0016) downstream of North Lake in subcatchments H10 and H11, and a tributary (0015) to the East Branch within subcatchment H2. In the North

Lake area, the two-fold increase reflects relatively small quantities of flow and thus damage potential is limited. For example, the 100-year discharge of subcatchment H10 will increase from 17.4 cfs under 1987 conditions to 31.9 cfs. Farther downstream along tributary 0016, however, subcatchment H8 has a lower percentage increase but a much larger discharge for the same event (70.5 cfs and 117.0 cfs, respectively), mainly because of the conversion of forested areas to urban land uses. Residential development currently under construction along tributary 0016 south of SR 18, and existing residential areas just upstream of the SR 161 culvert crossing, could experience severe flooding if these future flows are not mitigated. Future overtopping of SR 161 at the tributary 0015 culvert crossing is also expected to occur because of greatly increased runoff from subcatchment H2.

KEY FINDINGS

- Fifteen locations within the Hylebos Creek and Lower Puget Sound basins currently experience significant flooding problems. At least six of these sites have culverts or bridges that when clear of debris and sediment, are undersized for the HSPF-estimated 1987 flows.

- The Panther Lake and Twin Lakes areas currently experience flooding that approaches future conditions flows because of significant land-use changes that have occurred since 1987. Subsequent increases in future flows from the Panther Lake area will increase the extent of flooding along the entire stream length of West Branch Hylebos Creek.

- Although existing flooding problems will worsen throughout the basins with future increases in impervious surfaces, the most significant change in flooding conditions will be the occurrence of chronic, severe flooding at locations that currently are not flood-prone. The two locations most likely to experience future flooding are in the East Branch Hylebos Creek sub-basin, along tributary 0016 downstream of the Weyerhauser Pond (subcatchments H8) and along tributary 0015, east of Milton (subcatchment H2).

SECTION 3.5 GROUNDWATER

INTRODUCTION

Groundwater plays a variety of roles in the hydrologic function of the basins. By definition, groundwater is water that is found in zones of saturated geologic material beneath the surface. In the non-urbanized parts of the basins, far more of the water falling as precipitation moves as groundwater rather than as surface water. That water returns to the surface as springs and seeps, providing baseflow for perennial streams; it also provides drinking water to this rapidly growing area.

Because of the importance of groundwater, a regional groundwater study was initiated by a consortium of government agencies and water purveyors in the south King County area in 1986. Its first report, stressing existing data and future analytical needs, was issued in 1989 and provides the basis for the following discussion (South King County Ground Water Advisory Committee, 1989). That report in turn has depended on a variety of sources, including numerous existing water-well drilling records, recent exploration wells, historical water-use and water-quality data, recent U. S. Geological Survey monitoring, and geologic mapping done for this basin plan.

CONDITIONS

Main Aquifers

Although groundwater exists by definition in all saturated geologic materials, it is accessible for water use or discharge to surface-water bodies only where it can move freely through those subsurface deposits. These freely transmitting deposits are characterized by relatively large pores and are known as aquifers. In the Hylebos Creek and Lower Puget Sound area, they are commonly deposits of sand and gravel. In contrast, deposits that restrict the movement of groundwater are called aquitards (if their are moderately restrictive) or aquicludes (if they are strongly restrictive). Their composition is dominated by silt and clay. The layering of geologic deposits in these basins has left a vertical sequence that includes successively deeper aquifers and intervening aquitards and aquicludes.

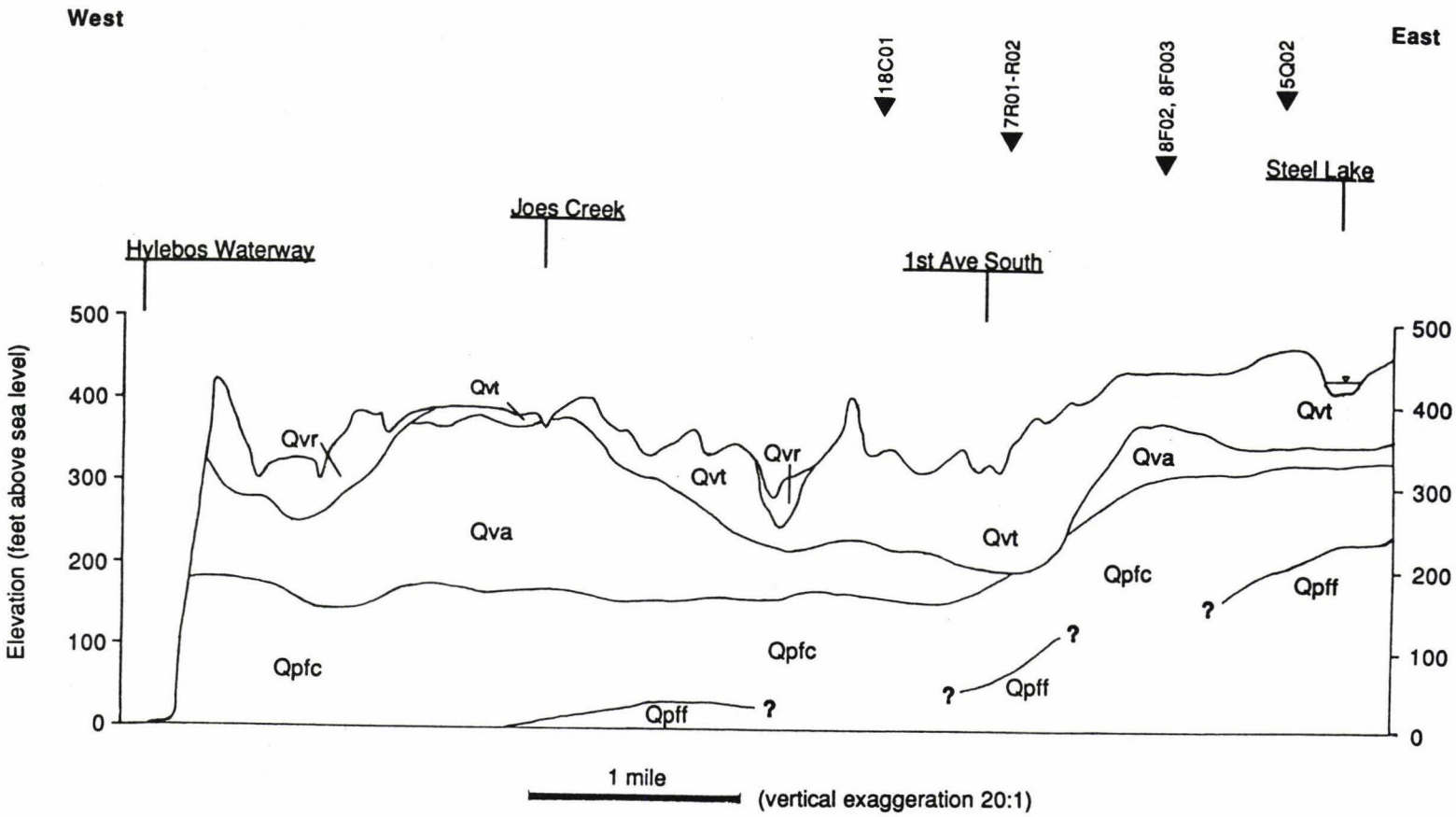
Although some of the deep aquifers may be significant for water supply, the shallower aquifers are particularly important to this basin plan. They are directly connected to lakes and streams; and to date, they have also been the aquifers most intensively used for water supply.

Two distinctly mapped geologic deposits, which may be partly connected hydrologically beneath the surface, form the main shallow aquifer zone in this area. The Vashon advance outwash, found primarily in the western part of the plan area, and older sand and gravel, located in the northern and eastern part of the plan area, compose this zone (see Figure 3.5.1). Both deposits are capped with relatively impervious till over most of the basin area, and so they are partly isolated from both surface-water contamination and direct recharge.

The Vashon advance outwash is concentrated in an area that extends south and east from Dumas Bay and Dash Point through the lower East Branch Hylebos Creek

Figure 3.5.1

GENERALIZED STRATIGRAPHY
HYLEBOS BASIN



DESCRIPTION OF MAP UNITS (FIG 3.2.1)

HOLOCENE DEPOSITS

POSTGLACIAL DEPOSITS (HOLOCENE) - Divided into:

Modified Land (m)

Beach Deposits (Qb)

Wetland Deposits (Qw)--Localities are compiled from the King County Wetland Inventory (1983).

Alluvium (Qal)

Landslide Deposits (Qls)--Only four are sufficiently large to show at map scale; smaller such features are common along many of the wave-steepened beach cliffs.

Mass-Wastage Deposits (Qmw)--Colluvium, soil, or landslide debris with indistinct morphology, mapped where sufficiently continuous and thick to obscure underlying material.

Older Alluvium (Qoal)--Similar in texture and morphology to unit Qal. May represent a late stage of deposition during the time of Vashon ice recession.

PLEISTOCENE DEPOSITS

DEPOSITS OF THE VASHON STADE OF THE FRASER GLACIATION (PLEISTOCENE) - Divided into:

Recessional Outwash Deposits, Lacustrine (Qvrl)--Laminated to massive silty clay to clayey silt, deposited in standing water during a late stage in the ice recession.

Recessional Outwash Deposits, Undifferentiated (Qvr)--Stratified sand and gravel, moderately to well sorted, with less common silty sand and silt.

Ice-Contact Deposits (Qvi)--Similar in texture to unit Qvr but containing a much higher percentage of silt mixed in with the granular sediment.

Till (Qvt)

Advance Outwash Deposits (Qva)

PRE-FRASER DEPOSITS (PLEISTOCENE)- Divided into:

Pre-Fraser Deposits, Fine-Grained (Qpff)--Laminated to massive silt, clayey silt, and silty clay, with or without interbedded sand and uncommon gravel.

Pre-Fraser Deposits, Coarse-Grained (Qpfc)--Interbedded sand and gravel with at most minor layers and lenses of silty sand and silt; moderately to heavily oxidatidized. Weathering rinds are common but not ubiquitous and range from 0.1-0.3 mm on fine-grained volcanic clasts.

Till, Undifferentiated (Qtu)--Compact, stony diamict, distinguished from its Vashon-age equivalent by oxidation of clasts and matrix, rare weathering rinds on clasts up to 0.5 mm thick, and stratigraphic and topographic position. Includes fluvial, lacustrine, and mudflow deposits too thin to discriminate at map scale.

and into the Milton area. It is penetrated by numerous water-supply wells along its entire length and is commonly known as the "Milton-Redondo Channel" in the hydrogeologic literature of the area (Robinson and Noble, 1987). Its major surface exposures are limited to coastal hillsides at the channel's northern end, which locally extend down to sea level; "windows" through the overlying till along the upper reaches of tributaries 0388 and 0389; and along the valley walls of the East Branch Hylebos Creek (see Figure 3.2.1). Elsewhere in this zone, it is continues but entirely subsurface.

The older sand and gravel deposits are exposed both beneath the Vashon advance outwash along the Hylebos Waterway and directly beneath Vashon till in the Des Moines, Midway, and Redondo areas. Surface exposures are found only along Des Moines Creek (just north of the plan area) and on hillsides and in stream valleys above Puget Sound. Excavations now occupied by the Midway Landfill also penetrated into this deposit.

Groundwater Flow Directions and Recharge

As in many other systems, the natural groundwater flow crudely mimics the pattern of surface-water flow. Water-table elevations, marking the top of the groundwater, show the area to be cut by two major flow divides (Figure 3.5.2). A north-south divide separates westward groundwater flow into the Hylebos Creek and Lower Puget Sound basins from that moving into the Green River valley; it lies east of I-5 and follows closely the eastern boundary of the Hylebos Creek-Lower Puget Sound drainage basin. The groundwater divide between southward flow into Puget Sound by way of Hylebos Creek and northward flow directly into Puget Sound largely follows the northern basin boundary of the Hylebos Creek basin, with the most pronounced demarcations just south of Mirror Lake and near the County line about 2 miles south southeast of Twin Lakes.

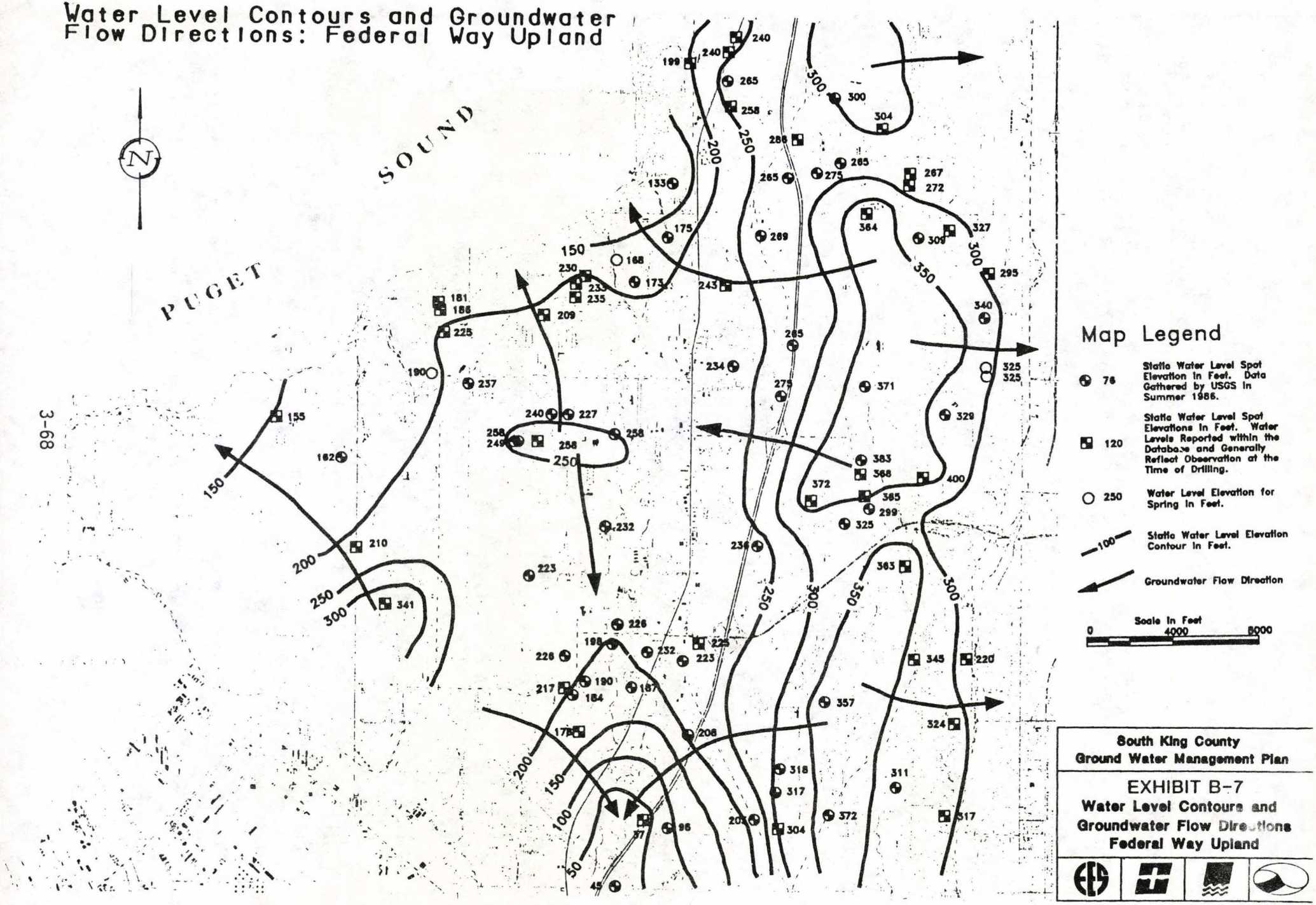
The present data are too sparse to definitively specify zones of recharge over the basin as a whole. Steep gradients in the water-table elevation suggest recharge near the groundwater divide south-southeast of Twin Lakes and along the eastern basin boundary in the area from North Lake to Fivemile Lake. "Windows" into the Vashon advance outwash, through the overlying till, along tributaries 0388 and 0389 lie at elevations far above the regional water table, and so these areas may be significant recharge zones as well. Conversely, strong discharge is suggested in the vicinity of Lower Hylebos Creek, where groundwater flow from the entire basin apparently converges in much the same pattern as the surface-water discharge.

Recharge of aquifers through the overlying Vashon till is enigmatic over the region as a whole. Measured permeabilities through till are typically about 4 orders of magnitude (10,000 times) smaller that through outwash (Olmstead, 1969) and allow recharge of only about 1 inch per month. Yet the broad areal extent of the till, and the possibility that fractures and sandier zones may allow substantially greater recharge rates in more localized zones, suggest that this path of groundwater migration may be as, or more, important than the areas of direct surface exposure of aquifers.

Other recharge zones are associated with the thinner, uppermost aquifer that overlies the Vashon till, mainly the Vashon recessional outwash. Although broad areas of this outwash are exposed on the southern uplands of the Lower Puget Sound basin, that area is largely covered with roads and houses. As a result, recharge is probably lower than would otherwise be anticipated. The southern

Figure 3.5.2

Water Level Contours and Groundwater Flow Directions: Federal Way Upland



extension of this deposit, however, forms a fairly discrete channel of thicker deposits through the Panther Lake area and into the West Branch Hylebos Creek. Although of uncertain importance for the recharge of deeper aquifers used for water supply, this deposit has functioned in the past to substantially reduce and locally eliminate the surface-water discharge of the surrounding areas. But because it is a surface aquifer, it is extremely susceptible to surface impacts. Most recently, the inwashing of fine sediment, probably released from surrounding construction activity, has severely reduced the infiltration capacity of this deposit and thus increased the amount of surface-water runoff (see Section 3.3, Hydrology).

EFFECTS OF WATER-SUPPLY PUMPING

Quantitative analysis of groundwater changes, particularly the impacts of pumping for drinking-water use, is limited by the absence of a groundwater model for this area. Only semi-quantitative methods, averaged over the area as a whole, are available to provide any such information. In addition, some historical information on water yields, water-table levels, and base flows in streams provide some additional evidence for past and future changes.

Most basic, and most common, of those semi-quantitative methods is the water balance. This method seeks to compare the amount of annual precipitation falling on the basin with the amount of surface-water runoff leaving the basin as stormflow, correcting for the amount of water presumed to annually evaporate. The residual of these surface and evaporative losses is assumed to be "groundwater recharge", which in turn is discharged via baseflow to streams, lakes, subsurface flow out to Puget Sound, and pumping for water supply. These elements of the hydrologic cycle are linked; an increase in stormflow due to increased impervious area decreases the residual water available for groundwater recharge, and an increase in pumping decreases the amount of water available for baseflow to streams.

There is no consensus on the percentage of groundwater recharge that can be removed by water-supply pumping before "unacceptable" impacts to surface-water bodies occur. This uncertainty reflects our fundamental ignorance on the quantitative aspects of groundwater movement in this (and, indeed, most) areas. In particular, monitoring data on withdrawal impacts is very spotty, a groundwater model to demonstrate surface-water connections is not available, and no analysis of surface-water conditions has yet established the framework for evaluating the consequences of any such impacts.

Relative to other regions, this basin area has rather good information on both water balance and pumping impacts. Recharge is estimated to vary between 15 to 17 inches per year (measured as a water volume of that thickness over the entire basin area; an undetermined error factor to this estimate should also be included). Of that recharge, about 15 percent was removed by water-supply pumping in 1977, but about 50 percent is now being extracted. The impacts of that increased extraction have been best documented at the pumping wells themselves, with water-table declines of up to 50 feet of decline in an isolated aquifer near Mirror Lake 10-12 feet in the main Vashon advance outwash aquifer. In addition, baseflow into Coldbrook Springs near Redondo (on Cold Creek), probably fed by this aquifer, now has greatly reduced discharge, once reported as 3.3 cfs but now less than 1 cfs; and Hylebos Creek, reported in 1969 to have a baseflow of 8.5 cfs, showed levels of only 3 to 5 cfs during the summer months

of gaging in this basin in water years 1987 and 1988. Equivalent or increased future pumping from the aquifers in this area are likely to have similar or increasing impacts on the surface-water bodies in these basins.

KEY FINDINGS

- As a result of many years of investigation, the quality of information on aquifers and groundwater movement in the plan is quite high by regional standards. Recognition of the need for yet additional information is also strong in both the public and private sectors.

- Shallow aquifers provide significant attenuation of storm peaks but are susceptible to either paving or clogging, either of which dramatically reduces their ability to absorb and later discharge water.

- Zones of groundwater recharge to deeper aquifers are only modestly well-correlated with the surface exposure of those deposits.

- The risk of deep groundwater contamination is limited by the degree to which such aquifers are exposed at the surface.

- Historic pumping rates in the basins have produced significant, identifiable impacts to some surface-water flows. Other impacts may be equally significant but are not yet recognized. The intensity of all such impacts is likely to increase if present pumping rates persist or accelerate.

SECTION 3.6 EROSION AND DEPOSITION OF STREAM-CHANNEL SEDIMENT

INTRODUCTION

The topography and distribution of geologic deposits imposed on the Hylebos Creek and Lower Puget Sound basins by glacial activity have exerted a profound effect on the pattern and processes of runoff. The central upland plateau collects water over much of the basin in low-gradient stream channels. Those channels of the Hylebos Creek basin flow south, following one of two distinct paths. The West Branch follows the course of a major recessional outwash channel, formed by outflow from the retreating Vashon-age ice sheet. In contrast, the East Branch drops precipitously off the edge of the upland plateau into a narrow canyon. The drainages of the Lower Puget Sound basin are similar to the East Branch Hylebos Creek, in that their present flow paths also drop abruptly off the edge of the plateau.

DATA GATHERING METHODS AND ANALYSES

Field Data

Information in this section was derived from a variety of sources. All stream channels were walked in 1986 and 1987 during the Basin Reconnaissance Program (King County, 1987) and again in 1988-1989 for this report, in order to collect data on zones and severity of erosion and sedimentation. Although channels throughout both basins were investigated, only limited field work and no additional analysis was performed on Lower Hylebos Creek. Throughout the rest of the basins, the average width and depth of the "bankfull" channel, as expressed by the location and height of unvegetated bars and marked changes in the channel-bank slopes, were measured. Several channel locations within the basin have been measured more precisely for the last 2 to 4 years in order to track short-term changes in width and depth. Several streams were also surveyed for their longitudinal channel profile, which allows for a rudimentary calculation of current and future sediment transport down these watercourses. The effect of projected flow increases can thus be predicted semi-quantitatively, guided and enhanced by more qualitative information generated by these other efforts.

Analysis of Channel Size

The response of stream channels to changes in land use has long been recognized (e.g., Wolman, 1967; Leopold, 1973). Quantifying the rate and magnitude of those responses, however, is more difficult. Undisturbed drainage basins commonly yield consistent relationships between discharge or drainage area and the channel width and depth (cf. Dunne and Leopold, 1978). The increase in flows that accompanies urbanization in a single basin is not identical to the increase in flows between a smaller and a larger undisturbed basin, but techniques developed by study of the latter case are still useful in understanding post-development conditions.

Studies of the "hydraulic geometry " of a channel (i.e., the channel width, depth, and flow velocity; Wolman and Miller, 1953) show consistent relationships between the flow at some specific discharge and the corresponding size of the channel. In comparing the increasing size of channels lower in the drainage basin, the "bankfull" flow, defined as the flow that just fills the active chan-

nel and typically assumed to be the 1.5-year flood discharge, is commonly used as the reference discharge. Plots of channel width and depth versus that 1.5-year flow at the point of measurement commonly show a consistent relationship, not because the 1.5-year flow necessarily determines the size of the channel but because that flow is a convenient reference discharge for all of the flows that, in combination, determine channel size. This relationship can be used to predict how future changes in the stream flow may affect the resulting size of the physical channel.

Channel Incision and Erosion

Channels require several conditions in order to incise into their beds, including substantial erosivity of the water flow and absence of adequate bed armoring by relatively immobile sediment or debris. In order to make comparisons between channels or predictions about future channel conditions, these factors must be quantified as best as possible. Although factors such as bed armoring by coarse debris are difficult to define precisely, the ability of the water to transport sediment is better understood.

This transporting ability, or erosivity, of the water flow is best represented by its basal shear stress, which is the tractive force applied by the water to its bed area and which consequently moves sediment particles downstream. The shear stress is calculated as the product of the water depth and the water-surface slope, multiplied together with a constant that is the unit weight of water (i.e. its weight per some specific volume, such as one cubic foot or one cubic meter). In this report the shear stress is reported in metric units of Newtons per square meter (N/m^2), using the measured depth of the bankfull channel and calculating the slope from 1:24,000 topographic maps. Most of the lower reaches of the channels were also field surveyed to provide comparative slope data; the results of the two methods of slope determination differ only modestly in most localities and do not affect any of the conclusions of the subsequent discussions.

CONDITIONS

Overview

Two overriding conditions of the physical channels in the basin are manifest: most of the natural channels have been heavily impacted by high flows, and they also show evidence of abundant introduction of fine sediment. The first condition is particularly well displayed by the flume-like nature of many channel reaches, where the hydraulic and biologic diversity provided by pools, bars, and large debris has largely been stripped away. As a result, channel erosion, neighboring hillside erosion, and downstream deposition of channel- and culvert-clogging sediment are much higher than normal. The second condition is partly related to the first; channel erosion releases some fine sediment into the downstream system. But upland urban development, particularly construction during wet weather, generates far more of this material. These fines not only clog stream-bed sediment, affecting fish habitat, but also carry pollutants off the uplands into and through the stream system. As such, they also represent one of the major threats to water quality in the basin as well.

Stream-Channel Characteristics

The degree of downcutting and lateral erosion found along each of the major stream valleys correlates well with their location and underlying geologic deposit. Most of the channels cut into sandy deposits, primarily of the Vashon advance outwash, on their decent from the upland plateau down to Puget Sound. This deposit is recognized here and elsewhere throughout the Lowland for its ease of erosion, by virtue of its relatively fine grain size and minimal cohesiveness. These channels lie in narrow valleys and canyons created by erosion from the streams themselves, formed over the last 14,000 years. These same erosive processes can be observed on a smaller but far more rapid scale along the banks and beds of these same channels where upstream development has recently increased flows. Bank slumps, undercutting, knickpoints (vertical steps in the stream profile, typically 1 to 6 feet high, that migrate upstream over time), and sporadic hillslope failures along the valley sides all reflect this erosive activity. The processes are the same today as they have been for the last thousands of years, but the rate at which they are occurring has increased dramatically in recent times with urbanization.

The West and Lower Branches of Hylebos Creek are unique of the streams here, in flowing in a drainage course pre-established by glacial runoff of much greater magnitude than found in the streams of today. The valley so created, is up to one-half mile wide in its lower reaches and is filled with a mixture of stream-deposited and lake-deposited sediment; the modern drainage has managed to cut only short and relatively shallow valleys in localized areas. As a result, erodible older sediments are nowhere exposed along the West Branch or its tributaries, and the profile of this channel shows no abrupt changes and few reaches of significant steepness.

As a result of these characteristics, the channel is intrinsically less susceptible to erosion and its flow less competent to transport sediment. Diversion of its northern headwaters during construction of I-5, highly infiltrative areas in the northwest part of the sub-basin, and modest buffering of peak flows by the West Hylebos Wetland have further reduced impacts of basin urbanization to date. The infrequency of significant erosion problems and presence of locally high-quality aquatic habitat despite high peak flows reflect these physical characteristics.

The channels of the North and Central Lower Puget Sound sub-basins (McSorley, Woodmont, Cold, and Redondo Creeks) flow only in part over steep, sandy deposits. In this part of the basin plan area, these deposits are thin, sandwiched between the Vashon till above and fine-grained sediment below. As a result, zones of intensive stream-channel downcutting are more limited than in the neighboring drainages farther west. Hillslope failures associated with these easily saturated, groundwater-perching deposits, however, are rather common.

Changes in Hydraulic Geometry

Cross-Section Changes - Using the method of comparing measured channel dimensions with an "index" or reference discharge permits prediction of future channel conditions. The HSPF model outputs provide 2-year flows under 1987 conditions, a convenient reference discharge; bankfull channel measurements were made at 24 separate stations in the two basins during 1988 and early 1989. A

relatively good relationship is plotted in Figure 3.6.1, with the equation of the best-fit line given as:

$$\text{width} \times \text{depth} = 0.61\ Q(2\text{-yr})^{0.71},$$

with width and depth measured in feet and Q in cubic feet per second.

These results allow for a rapid estimate of the overall effects of future flow conditions on existing channels. In general, future flow increases will yield increased channel sizes, with more sediment produced from those channels as a result. For example, flow increases of 1.5- to 2.5-fold, typical over most of the subcatchments in the East and West Branches of Hylebos Creek under future conditions without mitigation, yield a predicted channel expansion of 33 to 90 percent over existing conditions.

Where previous flows are anticipated to increase even more dramatically, the changes in the channel are even more pronounced. For example, flows from Panther Lake into the West Hylebos Wetland (tributary 0014B in subcatchment WH7; see Figure 4.2.1) are predicted to increase almost 9-fold under future conditions without mitigation. This would result in a predicted 4.6-fold increase in channel size. Interestingly, some of this channel expansion appears to have already occurred, probably reflecting substantial flow increases in this tributary since model calibration in 1987 (see Section 4.2, West Branch Hylebos Creek Sub-basin). Figure 3.6.2 plots the data from all measured channel sections together with the data from the channel connecting Panther Lake to the West Hylebos Wetland, measured in the vicinity of 1st Avenue S in 1989. The misfit between 1987-predicted flows, when Panther Lake was functioning as an efficient infiltration basin, and 1989, when the channel measurement was made and the basin had already been severely affected, is obvious. These results suggest that the channel is already experiencing flows about twice what is predicted under 1987 conditions. They also imply that more than half of the total future channel expansion has yet to occur.

Depth and Shear Stress Changes - An analysis equivalent to that above for cross-sectional area can be made for changes in channel depth alone. The relationship is not as consistent as for cross-sectional area, because local variability in channel conditions may lead to equally local increases or decreases in the depth at the expense of the width. The relationship is plotted in Figure 3.6.3, with the best-fit line given by:

$$\text{depth} = 3.1\ Q(2\text{-yr})^{0.27},$$

with all units again in feet and cubic feet per second.

The depth of the bankfull channel alone is not terribly sensitive to flow increases. For example, a 2-fold increase in the 2-year discharge yields only a predicted 20-percent increase in the bankfull channel depth.

This change can be used to calculate shear stress changes and to predict changes in stream erosivity. Based on field measurements and equivalent analyses in the Soos and Bear Creek basins (reported in Booth, 1989b, 1990b, in press b), observable erosive conditions in these lowland streams become common at a shear stress (based on the bankfull channel depth) of about 85 N/m^2. The threshold is quite distinct; in measuring and observing erosive conditions along over 50 miles of stream channels in these 2 other basins, only about 5 percent of the total length was mis-categorized by this sole criterion (Booth, in press b).

Figure 3.6.1

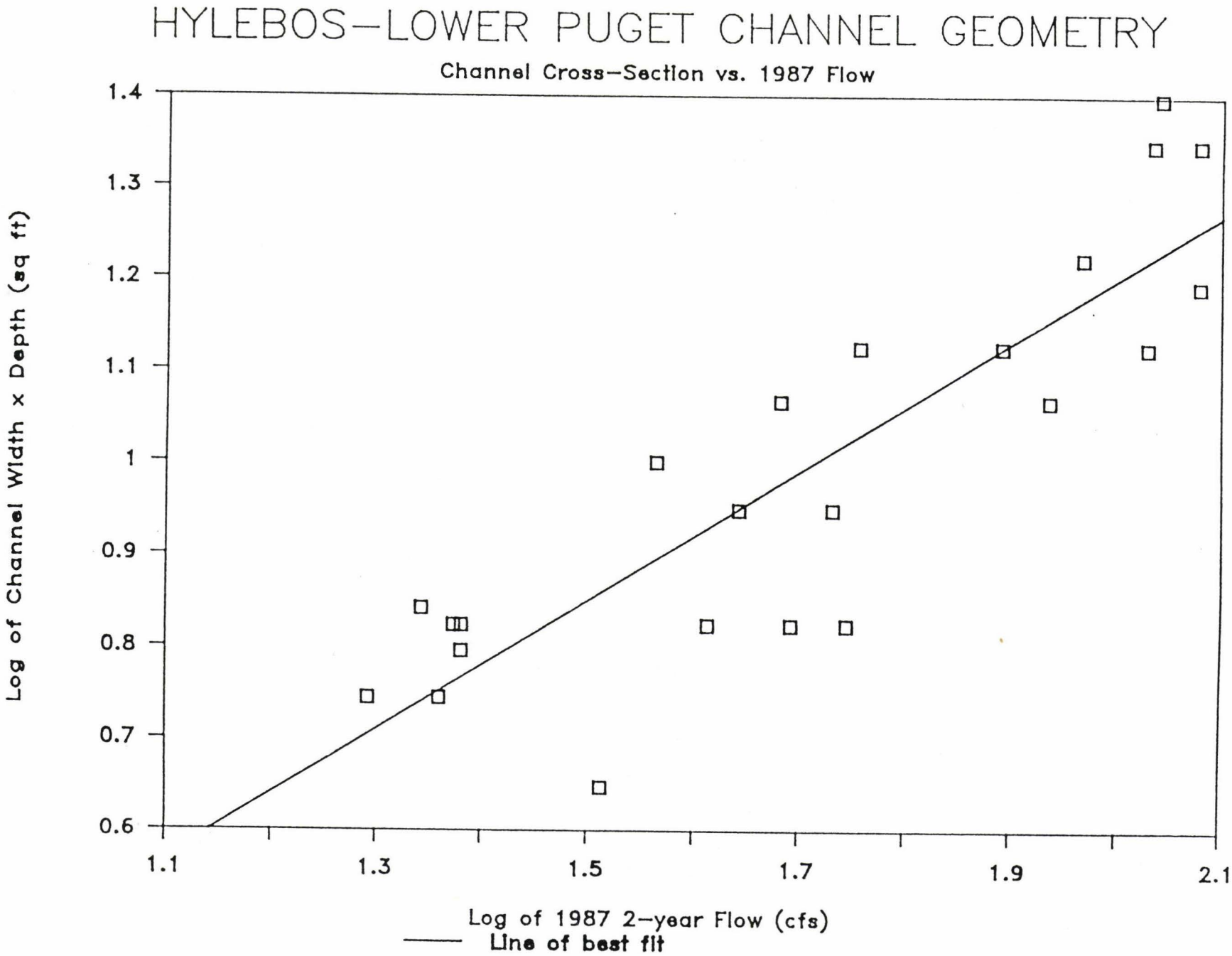

HYLEBOS—LOWER PUGET CHANNEL GEOMETRY
Channel Cross—Section vs. 1987 Flow
Log of Channel Width x Depth (sq ft)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
1.1
1.3
1.5
1.7
1.9
2.1
Log of 1987 2—year Flow (cfs)
Line of best fit

Figure 3.6.2

HYLEBOS–LOWER PUGET CHANNEL GEOMETRY

Channel Cross–Section, Incl. 0014B

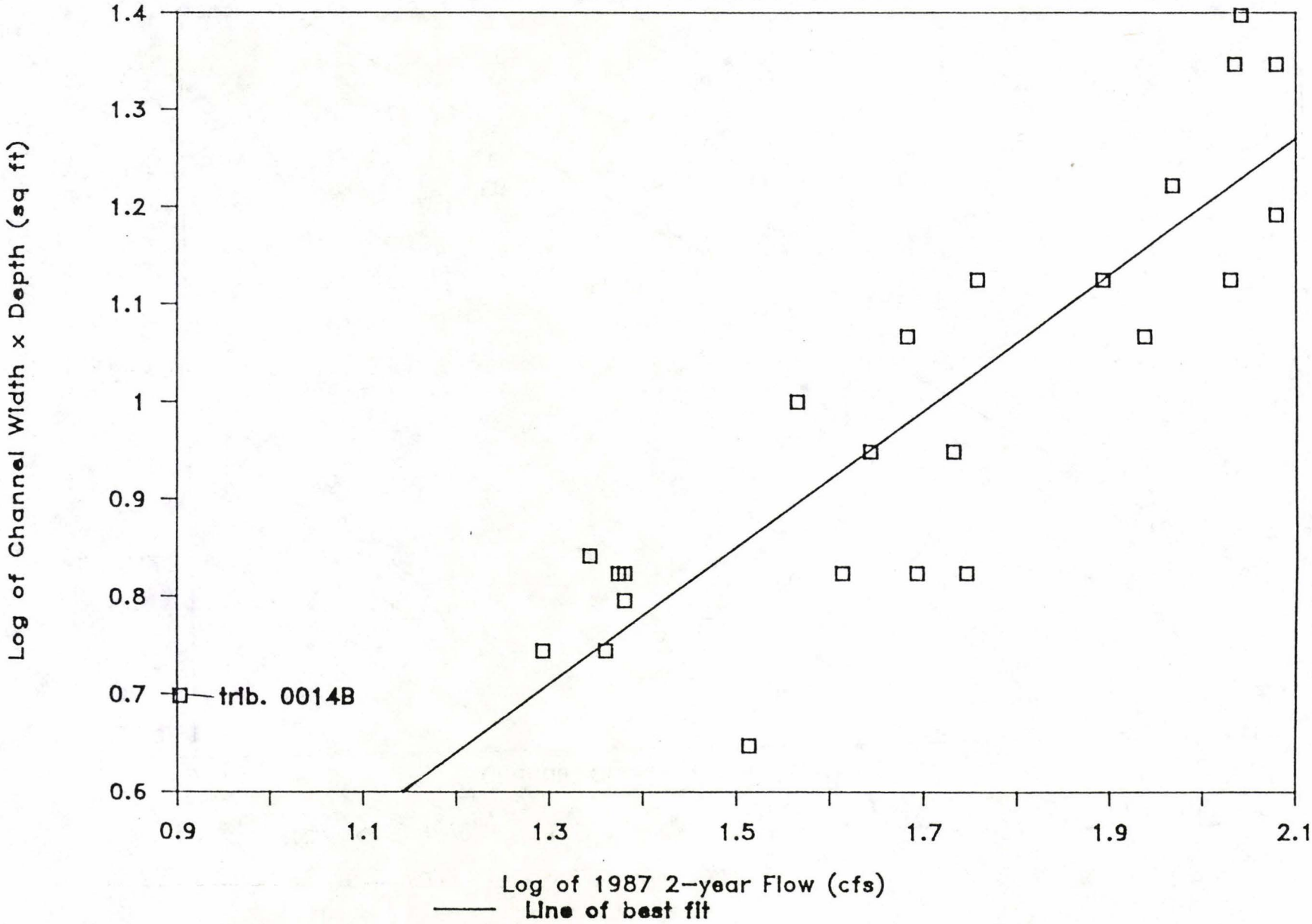
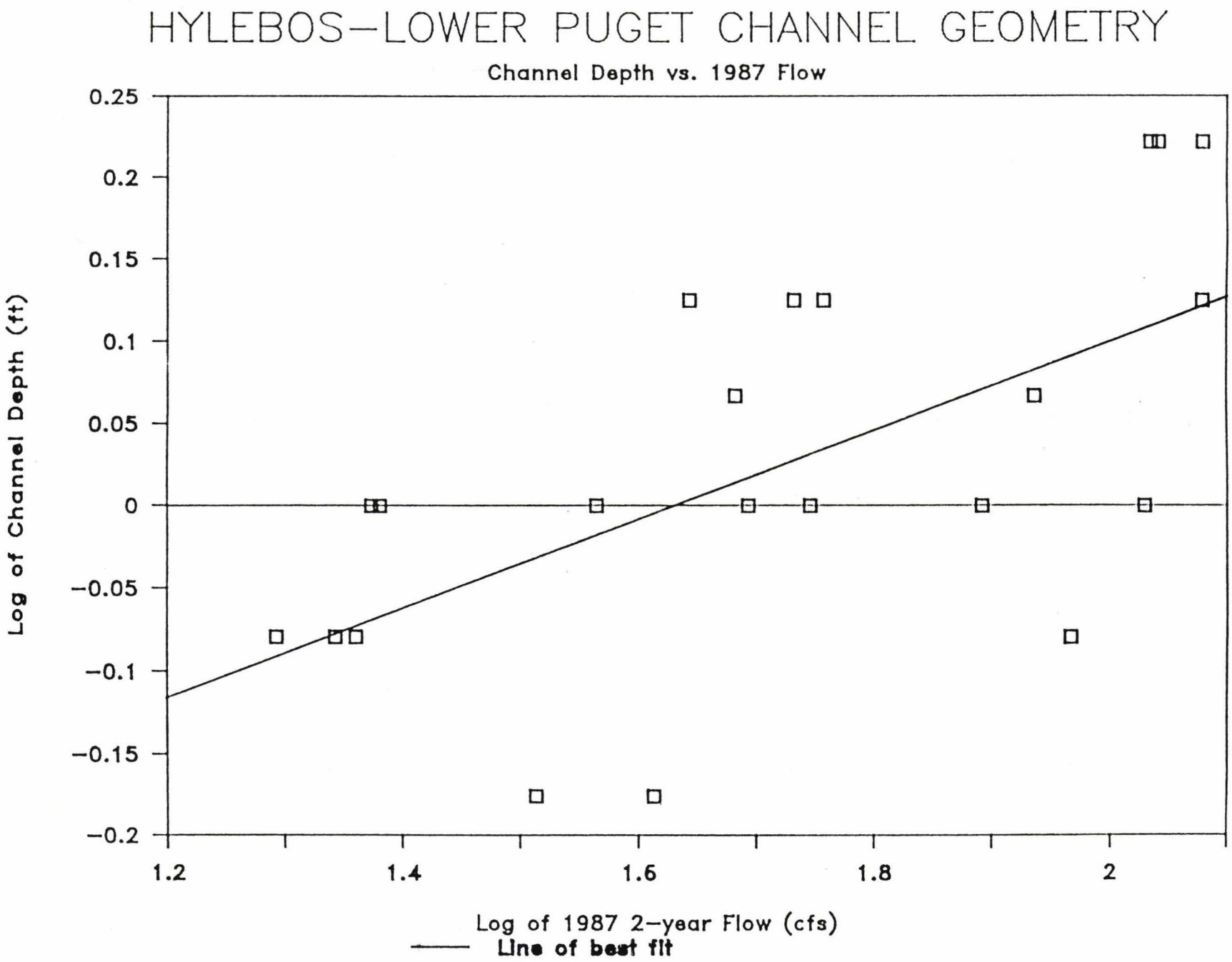


Figure 3.6.3


HYLEBOS—LOWER PUGET CHANNEL GEOMETRY
Channel Depth vs. 1987 Flow
Log of Channel Depth (ft)
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
1.2
1.4
1.6
1.8
2
Log of 1987 2−year Flow (cfs)
Line of best fit

This threshold level has been confirmed in this basin as well, although the sources of slope data are not as uniformly good as in the Soos and Bear Creek examples. Figures 3.6.4 and 3.6.5 plot the stream profiles of the Hylebos and Lower Puget Sound drainages in their lower and middle reaches, together with lines showing the threshold of channel erosivity for various values of depth and slope. For example, channel reaches more steep than the "depth=1 ft" line will experience a shear stress at bankfull flow of greater than 85 N/m^2 if their bankfull channel depth is greater than or equal to 1 foot. Similarly, as the channel slope decreases, greater depths can be tolerated without that "erosivity threshold" being crossed.

Presently, only a few of the plotted channel reaches fall under the 85 N/m^2 threshold. These include the West Branch Hylebos Creek up to the northern edge of the glacial-age lake bottom (tributaries 0013 and 0014; see Figure 4.2.1), the undiverted part of tributary 0013 on the flat till uplands and the equivalent segment of tributary 0014 through the West Hylebos Wetland, part of the lower-most reaches of Saltwater Creek (0381), parts of Lakota Creek just below its main confluence (0386), and parts of Joes Creek about 0.5 miles downstream of SW 320th Street (0388). All measured parts of the East Branch Hylebos Creek (0006, 0015, and 0016; between the County line and SR 161) lie above this threshold.

Conditions in the Hylebos Creek and Lower Puget Sound channels can be compared with these graphs to validate the assumption of a threshold value. Observation made prior to the storm of January 9, 1990 confirm this predicted distribution of largely "non-erosive" reaches (see Chapter 4 for specific discussions). In those reaches, where impacted by that January storm, subsequent lower flows are anticipated to rebuild and restore a relatively undamaged stream channel.

Future flow increases may eliminate some of this restorative ability. The erosivity of all flows will increase, by increasing their depth. This analysis considers only changes in the peak magnitude, although the duration of those flows will also change as a result of further development. As such, it may underestimate the effects of urbanization on these channels but by an indeterminate amount.

Using the relationship displayed in Figure 3.6.3, bankfull channel depths should increase proportionally to 2-year flow increases raised to the 0.27 power. This is not a terribly strong relationship, but it is adequate to increase the predicted bankfull shear stress without mitigation of the West Branch Hylebos Creek from a "non-erosive" to "erosive" condition over an additional 0.6 miles along tributary 0014 in the vicinity of its confluence, both upstream and downstream, with tributary 0013. Upper 0013 is also predicted to roughly equal that threshold under future flow conditions. None of the "non-erosive" zones in the Lower Puget Sound drainages change fundamentally, mainly because the basins are already substantially built-out and anticipate only moderate future flow increases.

Stream-Channel Incision - Incision differs from simple channel expansion by its magnitude and by its relationship to the flows that cause it. Whereas increases in the bankfull depth or width reflect a proportional increase in the flows that form the channel, incision reflects a disequilibrium entrenchment of the channel bed. A "bankfull channel" may still exist through an incised reach, but it lies at the bottom of a recently entrenched ravine or canyon of far greater significance to the system as a whole.

Figure 3.6.4

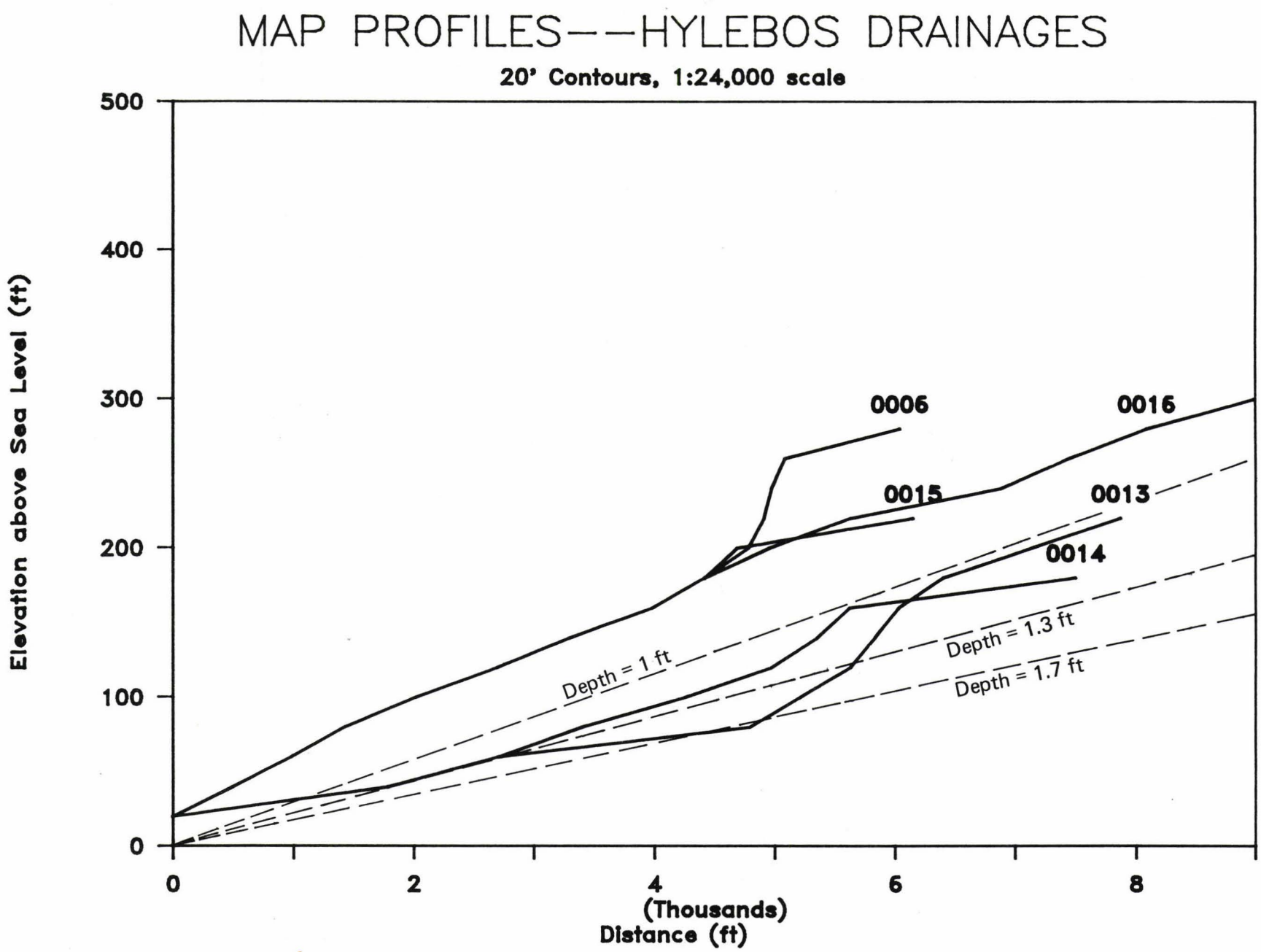
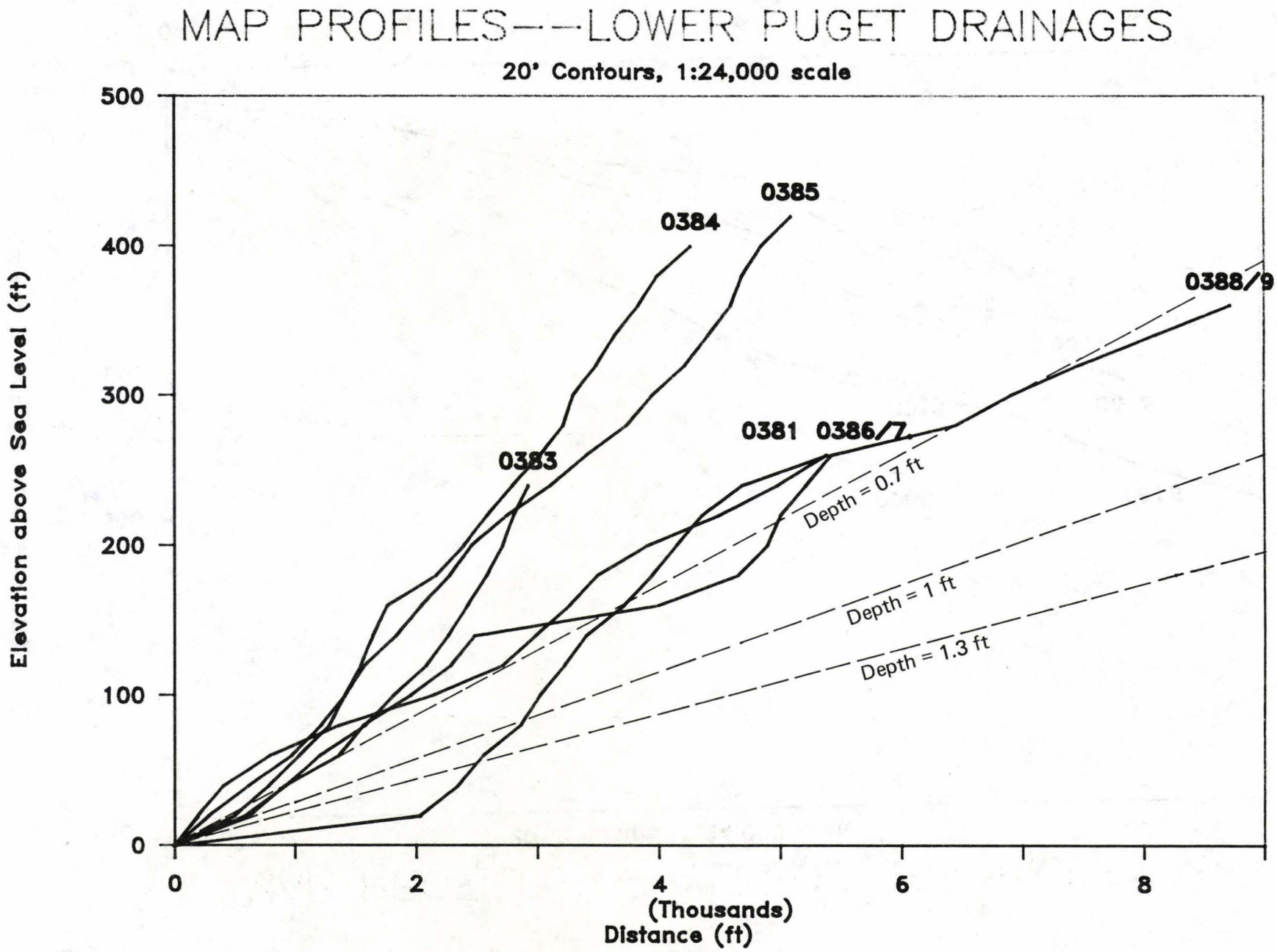

MAP PROFILES--HYLEBOS DRAINAGES
20' Contours, 1:24,000 scale
Elevation above Sea Level (ft)
500
400
300
200
100
0
0
2
4
6
8
(Thousands)
Distance (ft)
0006
0016
0015
0013
0014
Depth = 1 ft
Depth = 1.3 ft
Depth = 1.7 ft

Figure 3.6.5


MAP PROFILES--LOWER PUGET DRAINAGES
20' Contours, 1:24,000 scale
Elevation above Sea Level (ft)
500
400
300
200
100
0
0
2
4
6
8
(Thousands)
Distance (ft)
0385
0384
0388/9
0381
0386/7
0383
Depth = 0.7 ft
Depth = 1 ft
Depth = 1.3 ft

Although adequate erosivity of the flow is one of the necessary conditions for channel incision, other factors are also necessary. The channel must lack large organic debris or sediment that would otherwise dissipate some of the flow energy. The water must flow over a substrate that is itself easily eroded and not cemented (thus excluding, for example, unweathered till). The channel must also lie well above its "base level", namely the elevation below which it cannot fall (Puget Sound, for example, or a fixed culvert inlet). If base level lies nearby, an incising stream will rapidly reduce its overall slope as it downcuts, reducing its erosivity and so limiting its own further activity. If, on the other hand, base level is so far downstream that a local bed lowering does not noticeable change the overall channel slope, further erosion will continue unabated.

The combination of little immobile debris, easily eroded bed material, and distant base level, is achieved along several channel reaches in these basins. Most pronounced of these are found along the tributaries of East Branch Hylebos Creek (0006, 0015, and 0016 below SR 161), where high discharges flowing over deposits of the Vashon advance outwash have yielded recent examples of substantial channel incision and knickpoint migration. Damage from the January 9, 1990 storm in these tributaries is among the most dramatic countywide. Similar substrate conditions are located along the drainages of the South Lower Puget Sound sub-basin, although the proximity of Puget Sound reduces the possibility of significant downcutting. Yet the valley walls are also very susceptible to erosion from increased flows, yielding observed problems of sideslope landsliding and bank failures that reflect these physical conditions. Elsewhere, most of the channel lengths of the Lower Puget Sound drainages flow over relatively unerodible sediment, and so their associated problems are comparatively less despite their greater slopes.

Deposition - Both channel expansion and channel incision yield sediment, which in turn must come to rest farther downstream in the system. Just as increasing erosivity and transporting ability are marked by increased flow depth or slope, so a reduction in transporting ability is caused by reductions in these parameters. The most significant reductions are typically in the slope, and they generally occur where either the overall gradient of the landscape, and thus the stream channel flowing over it, flattens. Over many millennia, erosion and deposition tend to "smooth" the stream profile to allow efficient delivery of the entire sediment load to the mouth of the river; but the channels here in the basin plan area are relatively young and are still strongly affected by the glacial topography. They are also affected by local constrictions and backwaters from bridges and culverts, which tend to focus and so amplify any regional patterns of deposition.

The most profound flattening in the area occurs near the base of the Hylebos Creek basin, as the East and West Branches descend off the till-covered upland plateau onto the late-glacial lake bed near the County line. Coarse sediment is deposited first, followed by progressively finer material as the gradient drops progressively downstream. The deposition of sediment in this area is inescapable; the amount of sediment so deposited, however, will depend critically on the magnitude of erosion by upstream flows. Because of the magnitude of upstream erosion, deposition here is presently noteworthy not only across these two basins but also countywide.

KEY FINDINGS

- The West Branch Hylebos Creek is intrinsically more resistant than the East Branch to urbanization effects by virtue of channel gradient, past diversions, and some upstream hydraulic buffering. Individual tributaries however have experienced dramatic incision from development-increased runoff.

- Erosion susceptibility of tributaries in the North and Central Lower Puget Sound sub-basins is lower than in the South sub-basin, where channel incision has been locally substantial.

- Deposits of the Vashon advance outwash are particularly susceptible to stream-channel erosion, as demonstrated along Lakota Creek, Joes Creek, and East Branch Hylebos Creek.

- Increases in future flows will cause significant expansion of most channels, which in turn will result in substantial transport and downstream deposition of sediment.

- Deposition of sediment is particularly favored, and the resulting problems particularly significant, in the vicinity of the confluences of West Branch, the north fork of the West Branch, and East Branch of Hylebos Creek.

- Fine sediment commonly cements gravel beds throughout the basins, derived in significant measure from construction activity on the till uplands.

- The channel of tributary 0014 in the vicinity of its confluence with 0013, and much of 0013, will likely experience significant increases in the intensity of erosion under future flows without mitigation.

- Incision of the East Branch Hylebos tributaries downstream of SR 161 is presently among the most active county-wide and will likely accelerate further under predicted future flow increases.

SECTION 3.7 WATER QUALITY

INTRODUCTION

Past monitoring provides an incomplete picture of water quality in the Hylebos Creek and Lower Puget Sound basins. There exists very little scientific or engineering data describing the nature of nonpoint pollution and its effects on the streams, lakes, and the Puget Sound shoreline within the Federal Way Community (Minton, 1985).

This section includes a description of the water quality studies in the planning area, criteria for determining significant conditions; a description of current conditions during both baseflow and storm event periods; and implications for future water quality conditions.

WATER QUALITY CONCEPTS

Physical Conditions That Affect Water Quality

The northern portions of the Hylebos Creek basin are highly urbanized and are currently (1987) dominated by one of three types of land uses: commercial, high density single family, and multifamily. These types of land uses are relatively high in impervious areas and have been shown to concentrate and transport significant pollutant loads to surface waters. In addition, two major highway systems (State Route [SR] 99 and Interstate 5 [I-5]) dissect the basin. These large volume traffic corridors are significant sources of nonpoint pollutants in this basin. Five lakes (North, Weyerhauser, Killarney, Brook, and Panther) also characterize the upper reaches of the basin. These lakes can act either as "sinks" (i.e., trapping incoming pollutants such as nutrients) or as "sources" of pollutants such as nutrients. The middle and lower reaches of the Hylebos Creek basin are bordered by relatively large wetlands and forested areas as well as some agricultural lands. Poor agricultural practices such as those allowing livestock unlimited access to creeks, excessive fertilizer/pesticide applications, failing sewage systems, and overgrazing of pastures can contribute significantly high levels of pollutants to surface waters and receiving bodies.

The Lower Puget Sound basin is dominated by high-density single-family residences on the plateau areas that drain to steep ravines and easily eroded lower channel reaches. As a result, high volumes of eroded sediment are common. Contaminants (such as, phosphorus, some metals, and to some degree fecal coliform organisms), originating from residential land areas, tend to adhere to these sediments and can contribute significant pollutant loadings to receiving waters such as Puget Sound. Pollutant loadings can be defined as streamflow multiplied by a particular pollutant concentration. Pollutant loadings can become significant when receiving waters such as lakes (e.g., Steel Lake, Mirror Lake, Lorene Lake, and Jeane Lake) cannot flush contaminants. However, when the receiving water is Puget Sound, there is usually a large dilution factor in mixing zone areas (i.e., where freshwater systems meet marine waters) and pollutant loading is not a large concern except where water supplies and recreational shellfish harvesting are locally important beneficial uses.

Criteria for Determining Significant Conditions

Chapter 173-201 of the Washington Administrative Code (WAC) contains water quality standards for surface waters of the State of Washington. The purpose of Chapter 173-201 is to establish water quality standards for surface waters of the State consistent with public health and public enjoyment and the propagation and protection of fish, shellfish, and wildlife.

Waters within both the Hylebos Creek and Lower Puget Sound basins are classified as Class A (Excellent). State water quality standards require that water quality with Class A waters meet or exceed the requirements for all or substantially all beneficial uses. Characteristic uses include, but are not limited to the following:

- Water supply (domestic, industrial, agricultural)
- Stock watering
- Fish and shellfish (migration, rearing, spawning, and harvesting)
- Wildlife habitat
- Recreation (swimming, sport fishing, boating, and aesthetic enjoyment), and
- Commerce and navigation.

Washington State has established water quality criteria for fecal coliform densities, dissolved oxygen, temperature, pH, and turbidity. Other variables such as key nutrients (e.g., nitrogen and phosphorus) do not have state water quality criteria established due to the large variability among water bodies and their drainage basins which may have large differences in soil type and land use (e.g., highly erosive versus non-erosive or rural versus urban).

In some instances, other agencies have set recommended guidelines (e.g., EPA criterion for total phosphorus) to prevent the development of biological nuisances and to control accelerated or cultural eutrophication, or State Board of Health Drinking Water Regulations maximum contaminant levels for inorganic chemical characteristics. Table 3.7.1 lists the current State and/or federal water quality criteria/recommendations. For two variables (nitrate + nitrite - nitrogen, and total suspended solids) no state criterion exists. For the purpose of this report, a basin plan "threshold value" was set to allow comparison of sub-basins and identifying problem areas. These threshold values (although highly subjective) were arrived at by reviewing other study results, monitoring experience, and King County SWM water quality staff professional judgement.

Table 3.7.1

SUMMARY OF STATE AND FEDERAL WATER QUALITY CRITERIA
[(mg/L) unless otherwise noted.]

VARIABLE	Washington State Water Quality Criteria Class A (Excellent)[a]	Environmental Protection Agency (EPA) Recommended Guidelines[b]		State Board of Health Drinking Water Regulations[c]	Basin Plan Threshold Values[d]
Fecal Coliform	shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10 percent of samples exceeding 200 organisms/100 mL	--		1 organism/100 mL as the average of all samples tested each month (membrane filter technique)	--
Temperature	shall not exceed 18.0° C[e]	--		--	--
pH	shall be within the range 6.5-8.5[f]	--		--	--
Dissolved Oxygen	shall exceed 8.0 mg/L	--		--	--
Total Phosphorus	currently none established	0.10[g]		--	--
Nitrate + Nitrite - Nitrogen	currently none established	10.0[h]		10.0[h]	1.25[i]
Total Suspended Solids	currently none established	Settleable and suspended solids should not reduce the depth of the compensation point for photosythetic activity by more than 10 percent from the seasonally established norm for aquatic life.		--	50[j]
		Freshwater Aquatic Life[k]			
		Acute Toxicity	Chronic Toxicity		
Copper		0.0039	0.003	1.0	--
Lead		0.010	0.0004	0.05	--
Zinc		0.030	0.027	5.0	--

a) Chapter 173-201 WAC Water Quality Standards for Surface Waters of the State of Washington
b) U.S. EPA 1986 Gold Book Quality Criteria for Water.
c) State Board of Health-Drinking Water Regulations, Department of Health, Revised September 1989.

Table 3.7.1 (cont.)

d) Basin Plan Threshold Value (see text page 3-84).
e) Due to human activities, temperature increases shall not, at any time, exceed $t = 28/(T + 7)$. "t" represents the maximum permissable temperature increase measured at a dilution boundary; and "T" represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge.
f) With a man-caused variation within a range of less than 0.5 units.
g) A desired goal for the prevention of plant nuisances in streams or other flowing waters not discharging directly to lakes or impoundments. To prevent the development of biological nuisances and to control accelerated or cultural eutrophication, total phosphates as phosphorus (P) should not exceed 0.05 mg/L in any stream at the point where it enters any lake or reservoir, nor 0.025 mg/L within the lake or reservoir.
h) For domestic Water Supply (health). Serious and occasionally fatal poisonings in infants have occurred following ingestion of untreated well waters shown to contain nitrate at concentrations greater than 10 mg/L nitrate nitrogen (N).
i) Basin Plan Threshold Value (see Text p. 3-84).
j) Basin Plan Threshold Value (see Text p. 3-84). In a study downstream from the discharge of a rock quarry where inert suspended solids were increased to 80 mg/L, the density of macroinvertebrates decreased by 60 percent while in areas of sediment accumulation benthic invertebrate populations also decreased by 60 percent regardless of the suspended solid concentrations (Gammon, 1970-EPA Goldbook).
k) Freshwater quality criteria for some chemicals are a function of hardness. For this table, a criteria concentration based on a hardness value of 20 mg/L calcium carbonate is provided.

-- This symbol means "not applicable for this report."

DATA GATHERING AND ANALYSIS METHODS

Background Surveys

Since the early 1980s, water quality studies have focused on the main stem of Hylebos Creek due to water quality concerns associated with industrial activities adjacent to Commencement Bay. The following section briefly describes both these studies and those conducted for the Lower Puget Sound basin.

1981-1984 Water Quality in the Lower Puyallup River Valley and Adjacent Uplands, Pierce County, Washington [U. S. Geological Survey (USGS)]

The USGS assessed ground and surface water quality in Hylebos Creek as part of a study of the Puyallup River, White River, and most small streams in the lower Puyallup River valley. Groundwater samples were collected in 1984 and analyzed for metals, organic compounds, nutrients, and indicator bacteria. Water column and bottom-sediment samples, collected in 1983 through 1984, were analyzed for metals and organic compounds. Water samples were also analyzed for nutrients, indicator bacteria, dissolved oxygen (DO), and biochemical oxygen demand (BOD). Suspended-sediment samples were analyzed for metals.

Fecal coliform and fecal-streptococcal densities increased downstream in Hylebos Creek. These results may have indicated the impact of agricultural activities on downstream reaches during the early- to mid-1980s. The USGS study also revealed that concentrations of nitrogen compounds (nitrate, organic nitrogen, and ammonia) and ratios of nitrogen to phosphorus were generally higher in the small streams than in the Puyallup River. Additionally, as expected, total phosphorus concentrations were generally higher during stormflows and generally increased from upstream to downstream sites within Hylebos Creek. Bed sediments from the small streams generally contained more arsenic, lead, and zinc than bed sediments from the Puyallup and White Rivers. The study concluded that the Puyallup and White Rivers are suitable in quality or, with minimum treatment, could be made suitable for fish hatchery use. An exception was Fife Ditch where fish life may not be suitably sustained.

1981-Ongoing Commencement Bay Nearshore/Tideflat Superfund Surveys (Various agencies/consultants)

Commencement Bay was targeted for Superfund action in 1981, when the U.S. Environmental Protection Agency (EPA) announced a national "interim priority list" of 115 top priority hazardous waste sites. At that time, Commencement Bay was the highest priority site in the State of Washington and one of the ten highest national priority sites. Industrial surveys conducted by the Tacoma-Pierce County Health Department and the Port of Tacoma identified 281 industrial activities and 480 point and nonpoint sources including drains, seeps, and open channels in Hylebos Waterway and other tributaries in Commencement Bay.

In 1985, the Commencement Bay Nearshore/Tideflats Remedial Investigation (CBRI) was completed. The Commencement Bay Nearshore/Tideflats Feasibility Study (CBFS) was completed in 1988. Finalization of the Record of Decision (ROD), which formally designates preferred remedial alternatives, was published in mid-1989. Four main categories of problems were identified: contaminated facil-

ities, wastewater discharges, storm drains, and contaminated sediments. An Integrated Action Plan (IAP) will address these four problems. Regulatory and enforcement action to deal with these problems will utilize a number of state and federal authorities. Local governments along with the Puyallup Indian Tribe will also be involved in regulatory and management programs associated with Commencement Bay.

1983-1984 Metal Concentrations in Water, Sediment, and Fish Tissue Samples from Hylebos Creek Drainage (Washington State Department of Ecology (DOE)--Commencement Bay/Nearshore/Tideflats Remedial Investigation

Water, sediment, and fish tissue samples collected from Hylebos Creek between 1983 and 1984 were analyzed for arsenic and other metals, with the primary aim of identifying impacts due to two industrial landfills within the drainage.

The report concluded that metal concentrations were low in Hylebos Creek during low flow with the exception of arsenic and cadmium which were high and originating from two industrial landfills (United States Gypsum and B & L). Arsenic concentrations in the Surprise Lake drainage from one identified source, B & L Landfill, were found to be potentially toxic. In addition, metal concentrations in Hylebos Creek during wet weather conditions were not substantially different than during low flow, except arsenic. Elevated concentrations in upper Hylebos Creek suggested a source in the upper basin. Substantial increases in arsenic concentrations in sediment were also observed below both landfills. Additionally, the report concluded that gill tissue from Hylebos Creek cutthroat trout showed arsenic concentrations one to two orders of magnitude above gill and whole fish samples from other western Washington streams. Furthermore, arsenic concentrations at the mouth of Hylebos Creek were typically an order of magnitude higher than in other local rivers. The report suggested Hylebos Creek and Penwalt process effluent were major sources except during storm events when runoff from log sort yards with Asarco slag ballast may predominate.

1985 Nonpoint Source Pollution in the Federal Way Community (Executive Summary and Recommendations)
Nonpoint Pollution in the Federal Way Community (Volume 2 Technical Analysis) (Resource Planning Associates)

In a 1985 report to the Federal Way Water and Sewer District, the Executive Summary and Recommendations Report assessed the types and sources of nonpoint pollution in the Federal Way area. In addition, the report documents specific sources of nonpoint pollution and provides a technical analysis of these findings.

1986-Ongoing Water Quality Monitoring of McSorley Creek (Green River Community College (GRCC) for the City of Kent)

Since January, 1986, chemistry students from the GRCC have obtained routine monthly surface water samples in McSorley Creek at 251st Street and 16th Avenue South (see Location #11) Figure 3.7.1b. Variables being sampled include nutrients, solids, bacteria, and metals. The purpose of this project is to develop a baseline database for the City of Kent's Water Quality Management Program.

1987 Seattle-King County Health Department Repairs and Septic Tank Overflows

The Seattle-King County Health Department has documented repairs and septic tank overflows in various areas of King County. Figures 3.7.2a and b show septic system repairs and overflows in the Federal Way area during 1987.

1988-Ongoing South King County Ground Water Management Plan (South King County Ground Water Advisory Committee, Economic and Engineering Services, Inc., Hart-Crowser, Inc., Pacific Groundwater Group, and Robinson & Noble, Inc.)

This plan describes groundwater quality trends in southwest King County beginning in 1970. Water quality indicator parameters were chosen based on land use characteristics. Water quality trends for indicator parameters were analyzed for data within the Federal Way subarea, one of four subareas evaluated also including Des Moines, Green River Valley, and Covington. A total of 24 wells, 17 shallow (i.e., wells completed at a depth of less than or equal to 250 feet) and 7 deep (i.e., a depth greater than 250 feet) were used in the analysis. No significant trends were observed for any of the indicator parameters for either the shallow or deep wells.

Recent Surveys

1987-1988 Hylebos Creek and Lower Puget Sound Drainage Basin Water Quality Report (Metro)

The primary purpose of this report was to provide water quality data for the Hylebos Creek and Lower Puget Sound Basin Plan. Streams in the Hylebos Creek and Lower Puget Sound basins were sampled monthly from May 1987 through April 1988. Seven stations were monitored, all at flow gaging sites near the mouths of Joes (QJ1), McSorley (QM1), Cold (QC1), and Lakota (QL1) Creeks, respectively, and East Hylebos (QEH1), West Hylebos (QWH3), and North Fork of West Hylebos (QWH8) Creeks respectively (see Figures 3.7.1a and b). Baseflow grab (hand-dipped) samples were obtained near the mouths of these creeks during non-storm conditions.

Staff gage height and twelve water quality variables were measured. The water quality variables included: temperature, pH, conductivity, turbidity, total suspended solids, dissolved oxygen, ammonia, nitrate + nitrite, soluble reactive phosphorus, total phosphorus, and bacteria. Bacteria levels are an indication of the water quality relative to physical contact by humans and were estimated by two parameters, fecal coliforms and Enterococcus. Neither group of bacteria cause illness itself, rather, they are both indicators of the presence of organisms which do or have the potential to cause illness. The Washington State criteria set by Ecology are for fecal coliforms. Epidemiological studies have defined correlations between concentrations in water and increased probabilities of illness in swimmers for Enterococcus, but not for fecal coliforms.

Eight trace metals--cadmium, chromium, copper, iron, mercury, nickel, lead, and zinc--were measured quarterly. Steel Lake was sampled twice during late winter or early spring by Metro staff and twice per month from May through October by a trained volunteer as part of the Metro Small Lakes Program. The following

Figure 3.7.1a

Hylebos Creek Basin Planning Area

WATER QUALITY SAMPLING LOCATIONS

- ■ Metro Baseflow Monitoring Site (1987 - 1988)
- ● SWM Storm Event Monitoring Site (1989 - 1990)
- ◆ Suspended Solids Only
- WH9 Subcatchment Boundary, Number
- Wetland

King County
Surface Water Management Division

0 1/2 1 mile

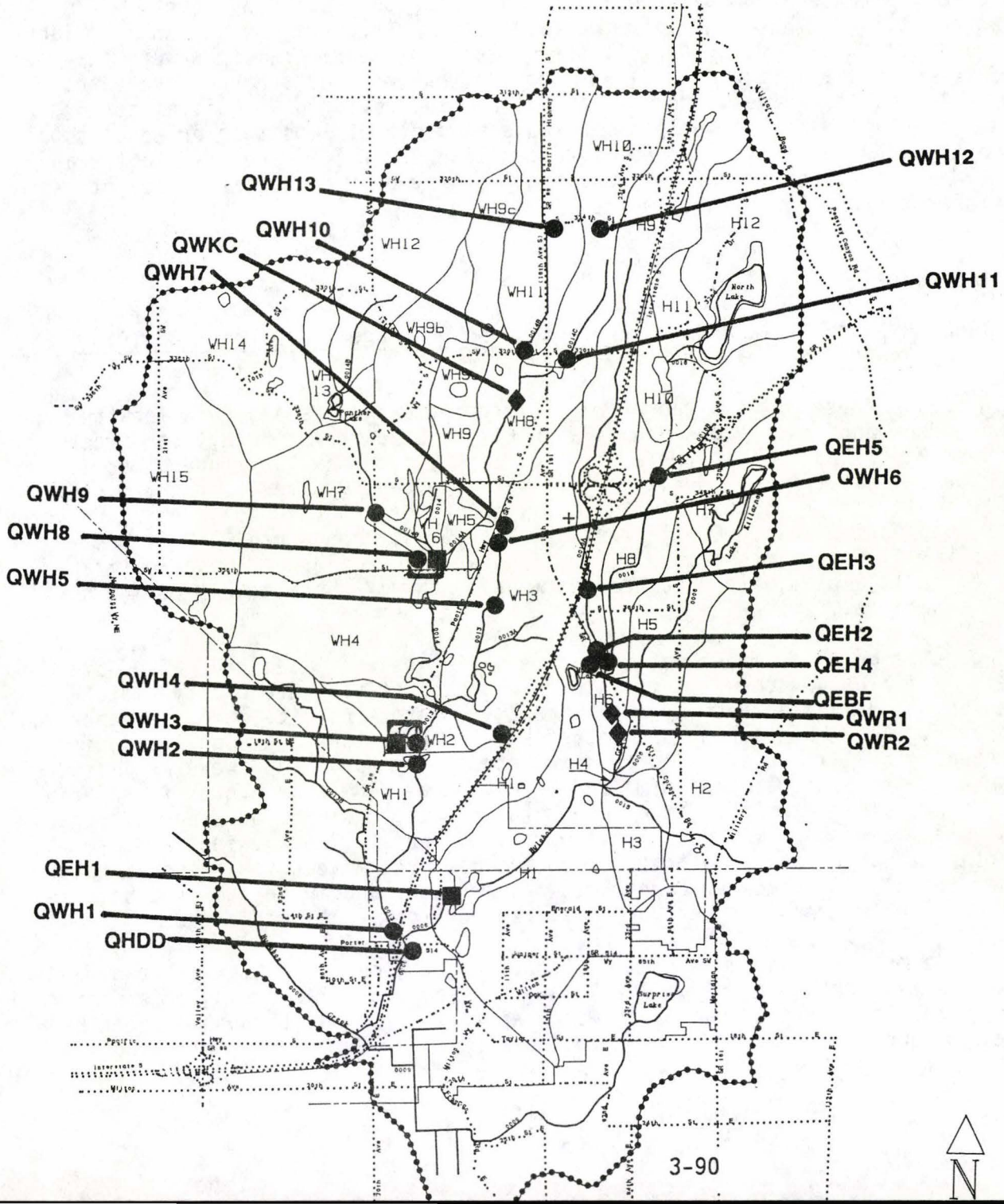
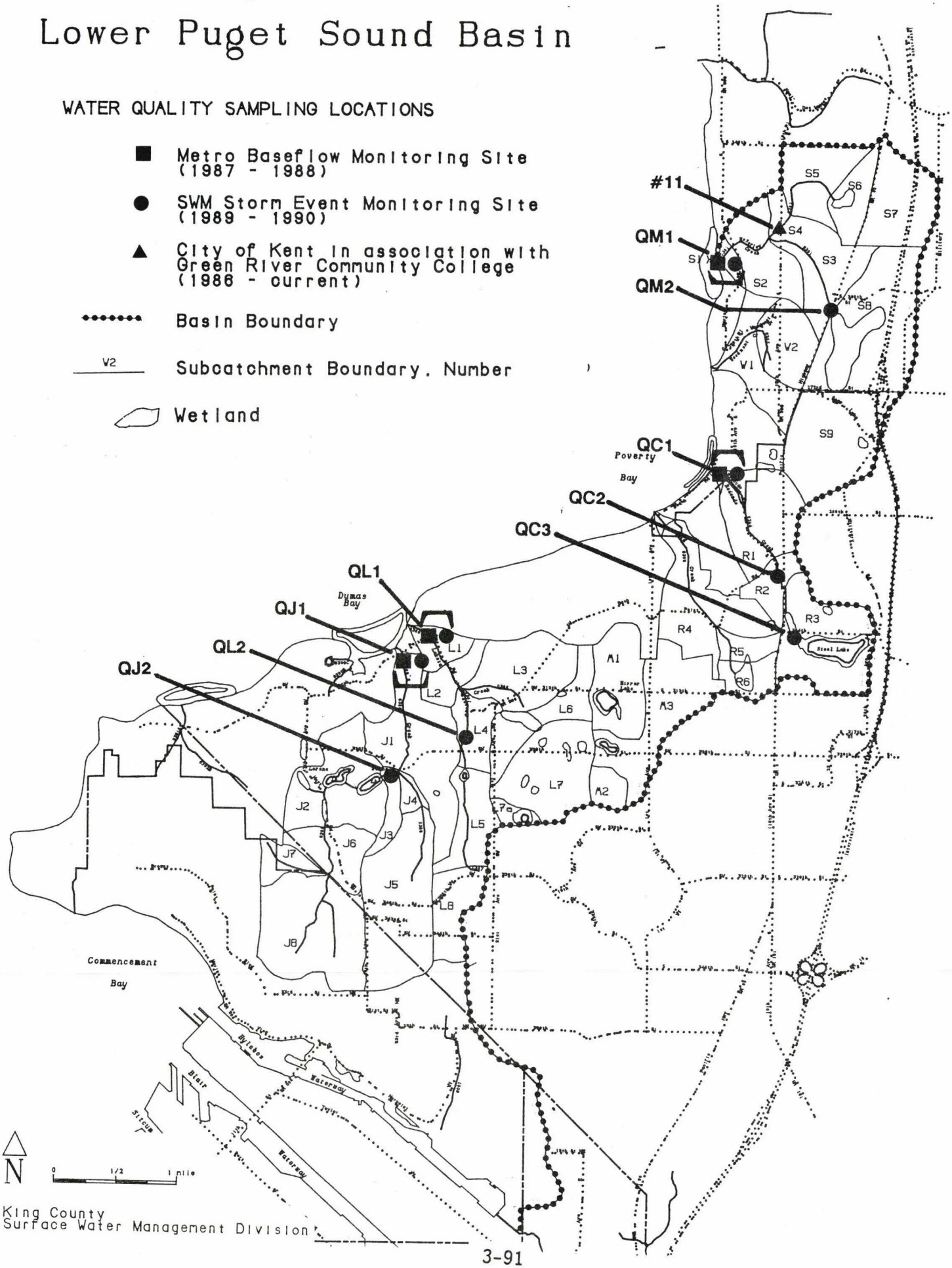


Figure 3.7.1b

Lower Puget Sound Basin

WATER QUALITY SAMPLING LOCATIONS

- ■ Metro Baseflow Monitoring Site (1987 - 1988)
- ● SWM Storm Event Monitoring Site (1989 - 1990)
- ▲ City of Kent in association with Green River Community College (1986 - current)
- Basin Boundary
- V2 Subcatchment Boundary, Number
- Wetland



King County
Surface Water Management Division

Figure 3.7.2a

Hylebos Creek Basin Planning Area

●REPAIRS AND SEPTIC TANK OVERFLOWS IN FEDERAL WAY IN 1987*

*From Seattle - King County Health Dept. 1987

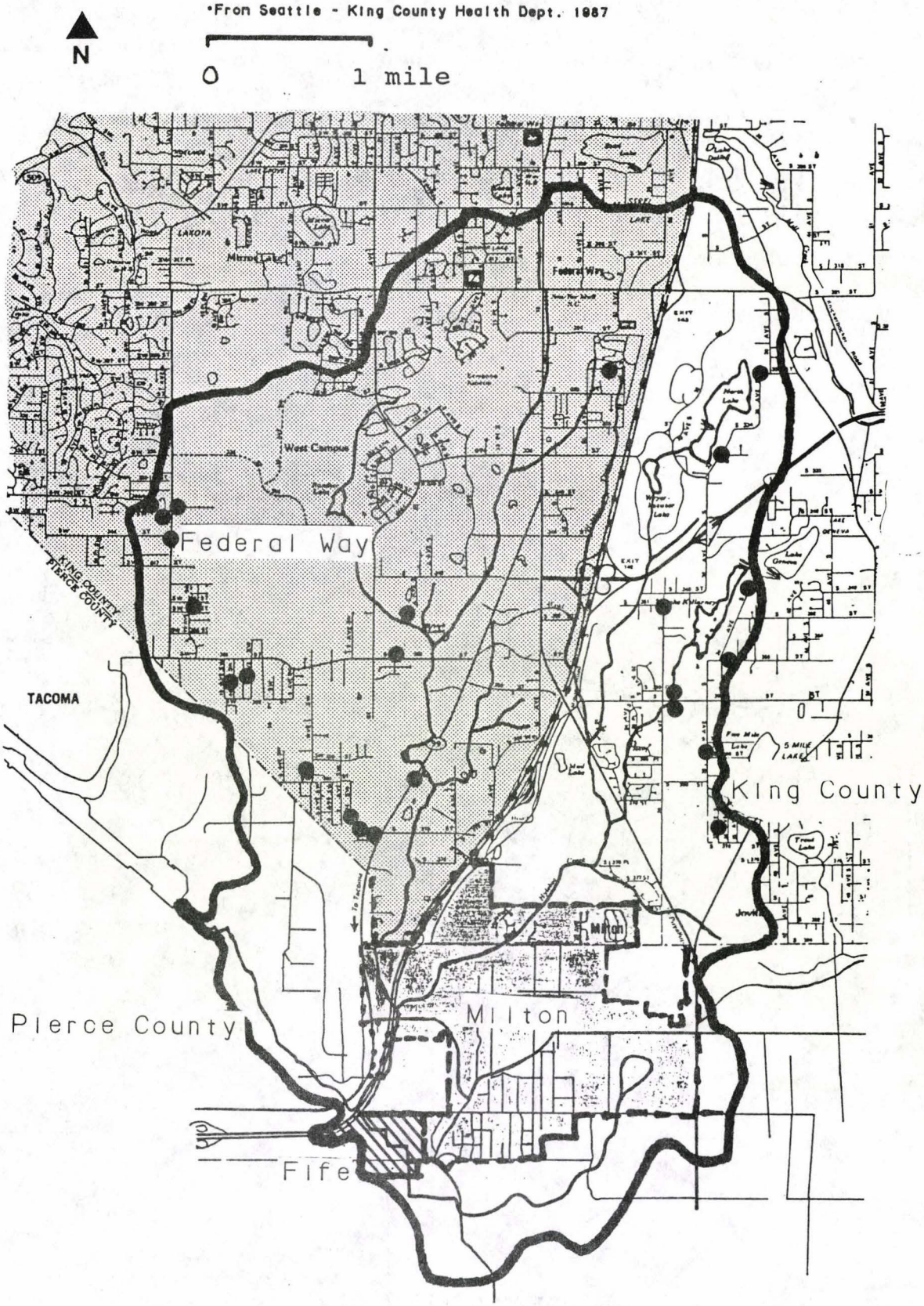
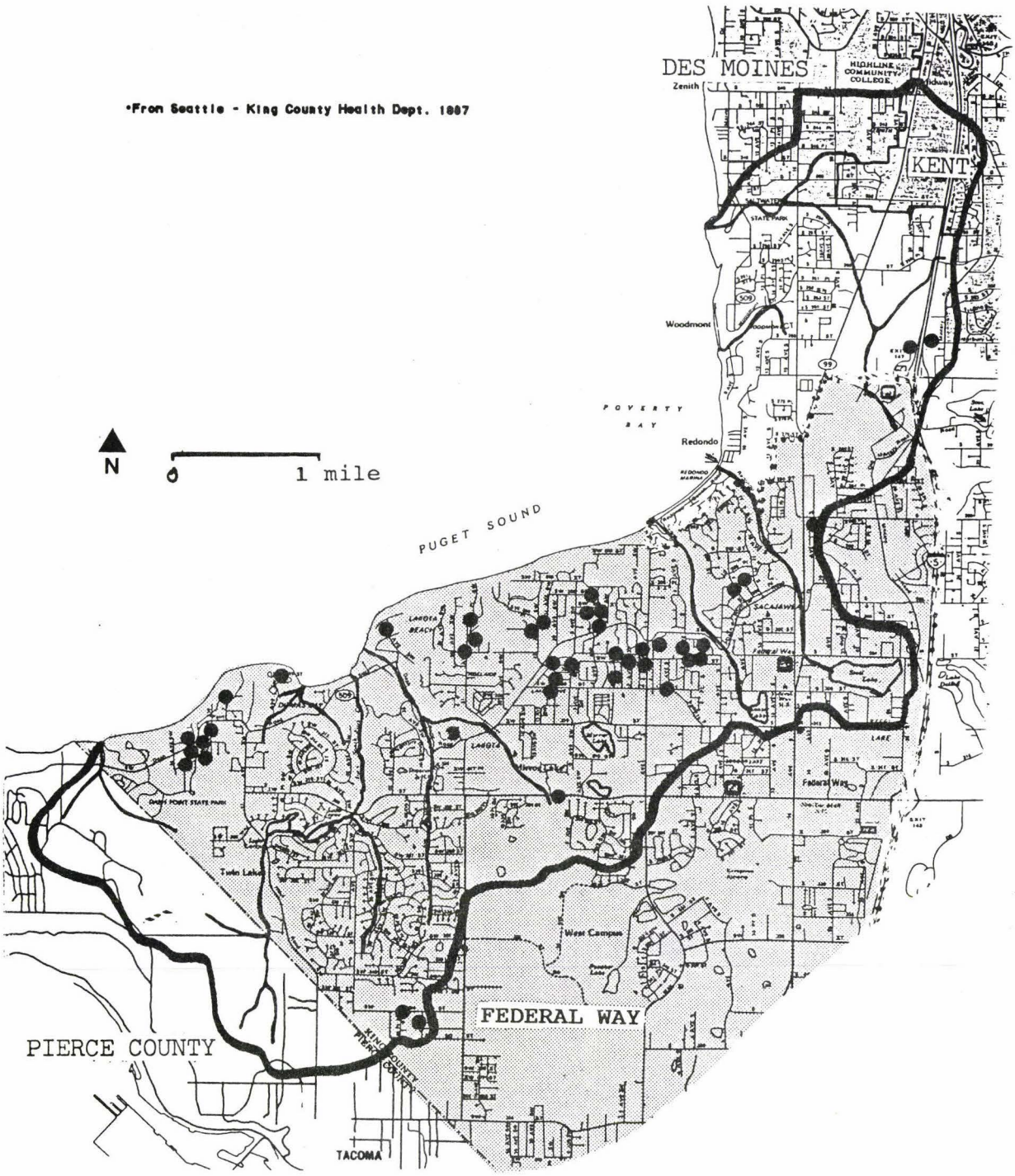


Figure 3.7.2b

Lower Puget Sound Basin

●REPAIRS AND SEPTIC TANK OVERFLOWS IN FEDERAL WAY IN 1987*

*From Seattle - King County Health Dept. 1987



variables were analyzed by Metro staff: total phosphorus, chlorophyll a, transparency, conductivity, pH, temperature, and dissolved oxygen at depths of 1, 3, and 6 meters. The volunteer sampled at a depth of 1 meter, measuring temperature and transparency in situ, and obtained a sample to be analyzed at the Metro laboratory for total phosphorus and chlorophyll a.

1989-1990 Hylebos Creek and Lower Puget Sound Supplemental Storm Event Monitoring Program [King County Surface Water Management (KCSWM)]

To better characterize nonpoint pollutants during storm conditions in both basins, KCSWM implemented a limited program to sample storm runoff events. Seven variables were chosen for study: fecal coliform, nitrate + nitrite - nitrogen, total phosphorus, total suspended solids, copper, lead, and zinc. The purpose of the program was to supplement storm runoff water quality data that the Metro baseflow study did not collect and to characterize water quality in upper reaches of tributaries not previously sampled by Metro.

Sample locations were based on field reconnaissance visits and chosen according to the following criteria:

- existing water quality data (Metro and King County Basin Reconnaissance reports)
- proximity to known nonpoint pollution sources
- accessibility

Various storm runoff samples were obtained at up to 32 sampling locations (Figure 3.7.1a and b) during October 26, 1990 (precipitation = 0.50 in. recorded at Sea-Tac Airport), December 2, 1989 (precipitation = 1.18 in. recorded at Mr. Ted Enticknap's residence - 36817 - 12th Avenue S, Federal Way), and January 7, 1990 (precipitation = 1.25 in., recorded at Mr. Ted Enticknap's residence). Grab samples were usually obtained early in or near the peak of each storm event. Three teams composed of KCSWM staff and a Citizen Advisory Committee member, Federal Way Water and Sewer District personnel, and Tacoma-Pierce County Health Department personnel were involved in the supplemental storm event monitoring program. A number of nonpoint pollutant sources were identified and isolated, however, a more in depth monitoring program will be needed to reliably identify nonpoint sources of pollution in both basins.

1990-Ongoing Additional Storm Event Monitoring Program (Federal Way Water and Sewer District (FWWSD))

FWWSD personnel will obtain samples during two additional storm runoff events during the spring of 1990. Sampling at 18 stations is expected.

CONDITIONS

Current Conditions

Baseflow

The monthly values (obtained during Metro's 1987-1988 baseflow study) for the variables: dissolved oxygen, temperature and pH were usually within the state water quality criteria values listed in Table 3.7.1. For all stations the fecal coliform geometric mean was less than 100 organisms/100 mL. Samples exceeded 200 organisms/100 mL once on Hylebos Creek, twice each on Cold Creek and Lakota Creek, three times on McSorley Creek, and four times on the north fork of West Branch Hylebos Creek during the sampling period. The maximum value for fecal coliform during the baseflow study was 350 organisms/100 mL on Cold Creek. EPA has established criteria for Enterococcus bacteria based on human health effects. For swimming, the maximum allowable level is 89 organisms/100 mL. All samples obtained in November and most in October 1987, exceeded these criteria (Table 3.7.2). These criteria were exceeded three times on the north fork of West Branch Hylebos Creek and twice at the other stations. The median values ranged from 32 to 58 organisms/100 mL. The highest value was 1120 organisms/ 100 mL, was obtained from Cold Creek.

Table 3.7.2

BASEFLOW WATER QUALITY SUMMARY RESULTS
(Exceedances of State Standards and Federal Recommended Criteria)

		Variable				
Station		Dissolved Oxygen	Temperature	pH	Fecal Coliform	Enterococcus
East Hylebos	(QEH1)	0	0	0	1	2
West Hylebos	(QWH3)	0	0	0	0	2
	(QWH8)	1	0	0	4	3
Joes	(QJ1)	0	0	0	0	2
McSorley	(QM1)	0	0	1	3	2
Cold	(QC1)	0	0	0	2	2
Lakota	(QL1)	0	0	0	2	2

Metal concentrations obtained during the baseflow study were quite low and frequently below detection limits.

The monthly values for the seven stations monitored (during baseflow conditions) within the Hylebos Creek and Lower Puget Sound basins were compared to values for 44 routine stream and river sites monitored during the same period (May 1987 to April 1988) in the Metro Freshwater Assessment Program. Table 3.7.3 lists a summary comparison of these data.

Table 3.7.3

HYLEBOS CREEK AND LOWER PUGET SOUND
MINIMUM, MEDIAN, AND MAXIMUM VALUES FOR FIVE VARIABLES VERSUS
METRO'S 44 ROUTINE MONITORING STATIONS

Station	Dissolved Oxygen (mg/L)			Turbidity (ntu)		
	Min	Med	Max	Min	Med	Max
7 Hylebos/ Lower Puget Sound Stations	7.8	10.9	12.9	0.6	1.2	14.0
44 Stream Stations	3.4	10.5	13.7	0.3	2.1	75.0

Station	Total Suspended Solids (mg/L)			Nitrate+nitrite-nitrogen (mg/L)		
	Min	Med	Max	Min	Med	Max
7 Hylebos/ Lower Puget Sound Stations	0.6	3.2	153.0	0.09	0.32	3.02
44 Stream Stations	0.3	4.5	305.0	0.001	0.67	2.05

Station	Total Phosphorus (mg/L)		
	Min	Med	Max
7 Hylebos/ Lower Puget Sound Stations	0.018	0.053	0.14
44 Stream Stations	0.002	0.058	1.02

The seven Hylebos Creek and Lower Puget Sound basin stations were usually very close to the median value observed at Metro's 44 stream stations.

The baseflow water quality was generally good in the Hylebos Creek and Lower Puget Sound basins during 1987-1988. Water quality appeared sufficient to support beneficial uses in both basins. Stations sampled were cool, clear, and well oxygenated and had relatively low bacteria levels. Some stations did have relatively high nitrate + nitrite levels. This can be a concern during summer months when these high levels along with high temperatures and lower DO concentrations, may impact fish populations and increase the frequencies of algal blooms and aquatic macrophyte (i.e., aquatic vegetation) biomasses that may impact recreational uses.

Storm Event

Storm event monitoring data were analyzed from both basins. A basin comparison of water quality constituents is listed in Table 3.7.4. The Hylebos Creek basin had higher maximum concentrations in five out of six variables; however, the Lower Puget Sound basin had higher mean concentrations in four of the six constituents. Nevertheless, only fecal coliform bacteria densities in the Lower Puget Sound basin (see Figure 3.7.3a) and nitrate + nitrite - nitrogen concentrations in the Hylebos Creek basin (see Table 3.7.5) are substantially higher, when comparing one basin to the other. The first significant storm in the fall, commonly referred to as a "first flush" storm event, usually contains some of the highest pollutant concentrations of any given year. This is a result of a "build-up" of pollutants along roadways and adjacent to water courses during the dry periods of summer months. Figures 3.7.3a-c reflect this "build-up" and "first flush" effect with three selected contaminants (fecal coliforms, total suspended solids, and zinc).

Figures 3.7.4a-f highlight the significant surface water quality problems observed during the 1989-1990 SWM storm event monitoring program. The most significant problem identified in West Branch Hylebos Creek sub-basin is metals. Nutrients (e.g., nitrogen and phosphorus) are the most serious surface water quality problems in East Branch Hylebos Creek sub-basin (see Figure 3.7.4b). Contaminant loading to Commencement Bay from an accumulation of upstream sources in Hylebos Creek is the surface water quality problem of concern in Lower Hylebos Creek sub-basin. Figure 3.7.4c highlights the only two stations monitored in this sub-basin during the 1989-1990 SWM storm event program. In the North Lower Puget Sound sub-basin, total phosphorus is identified as the most significant water quality concern from the 1989-1990 SWM storm event monitoring program (Figure 3.7.4d). Copper and fecal coliform bacteria are also significant water quality concerns in this sub-basin. Total suspended solids are the major surface water quality problem in the Central Lower Puget Sound sub-basin (see Figure 3.7.4e). While the chief surface water quality issue in the South Lower Puget Sound sub-basin is fecal coliform bacteria (see Figure 3.7.4f). In addition, total suspended solids and total phosphorus are significant water quality concerns in this sub-basin.

Figure 3.7.3a

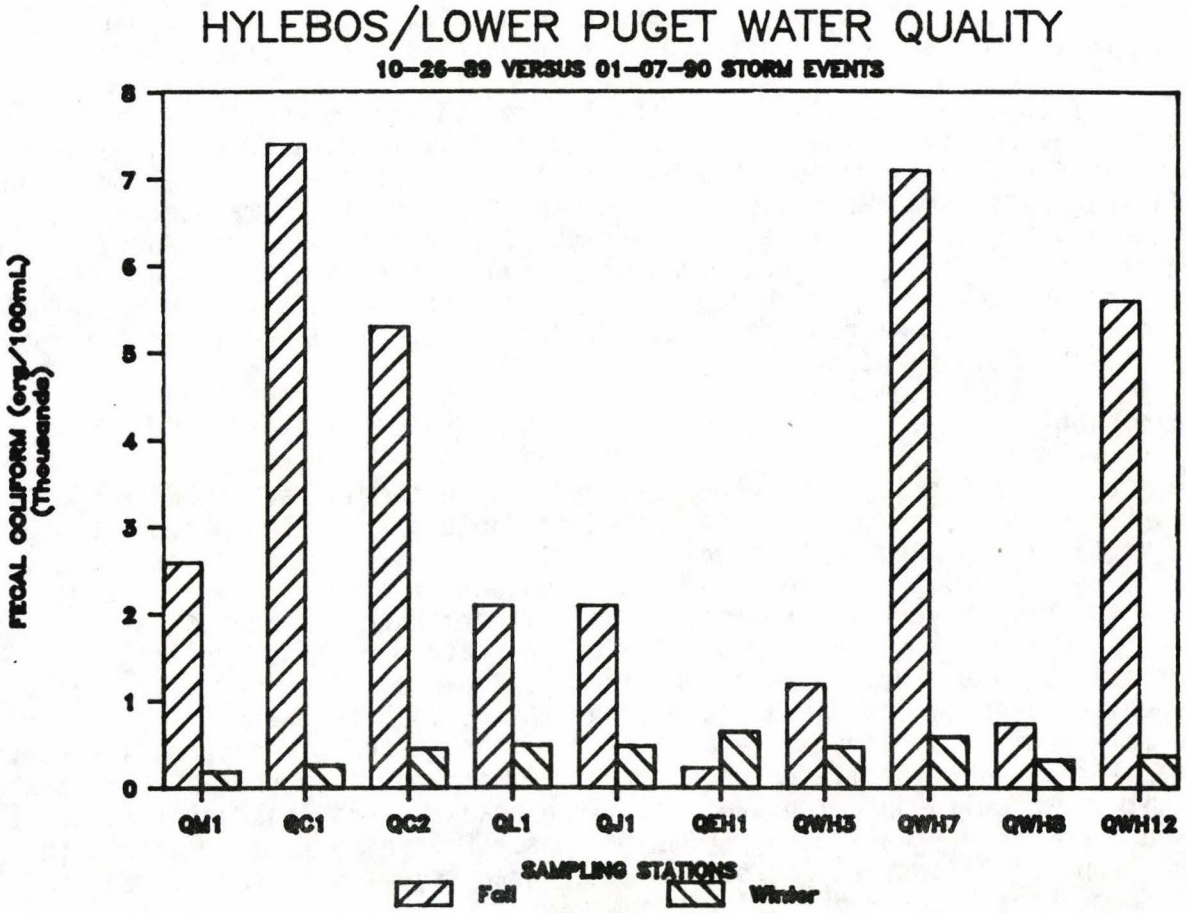


Figure 3.7.3b

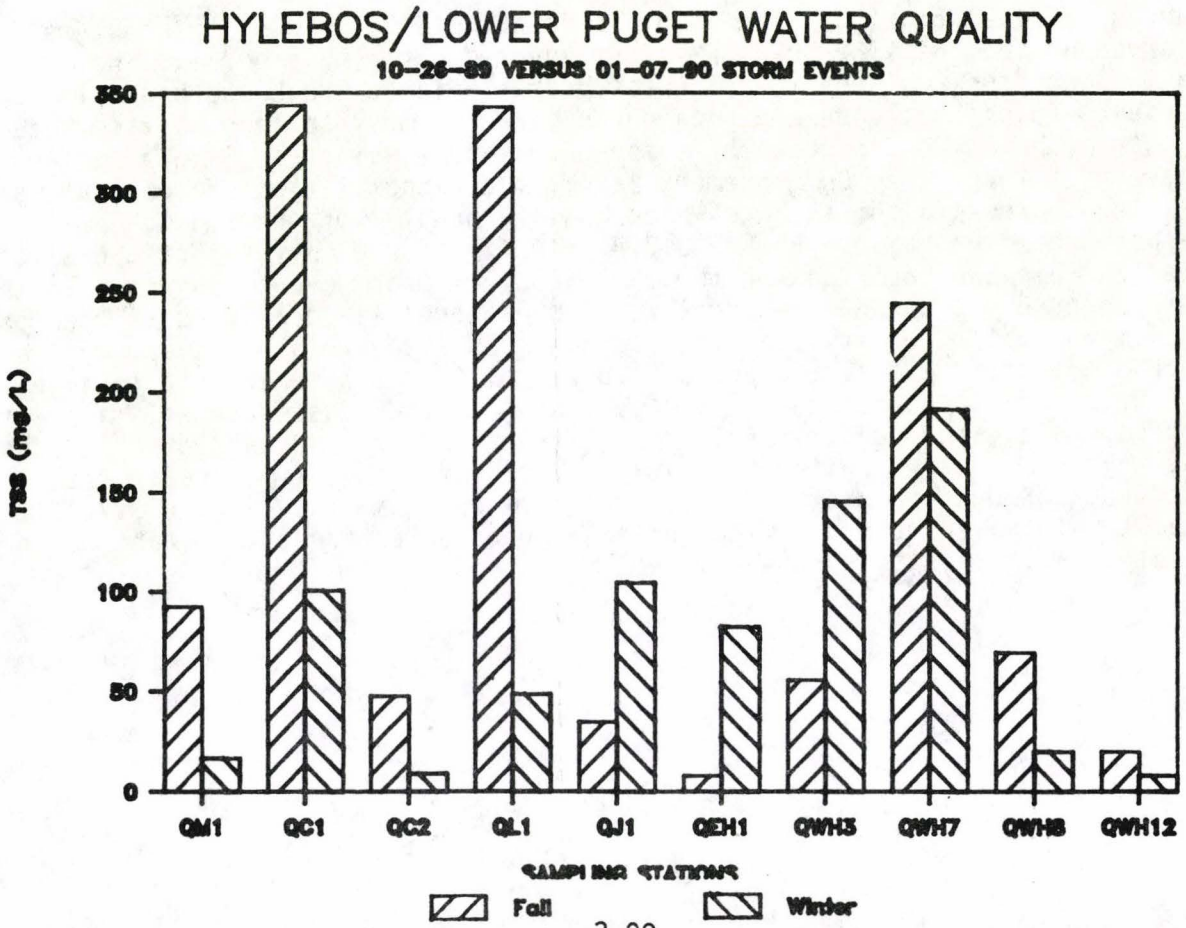


Figure 3.7.3c

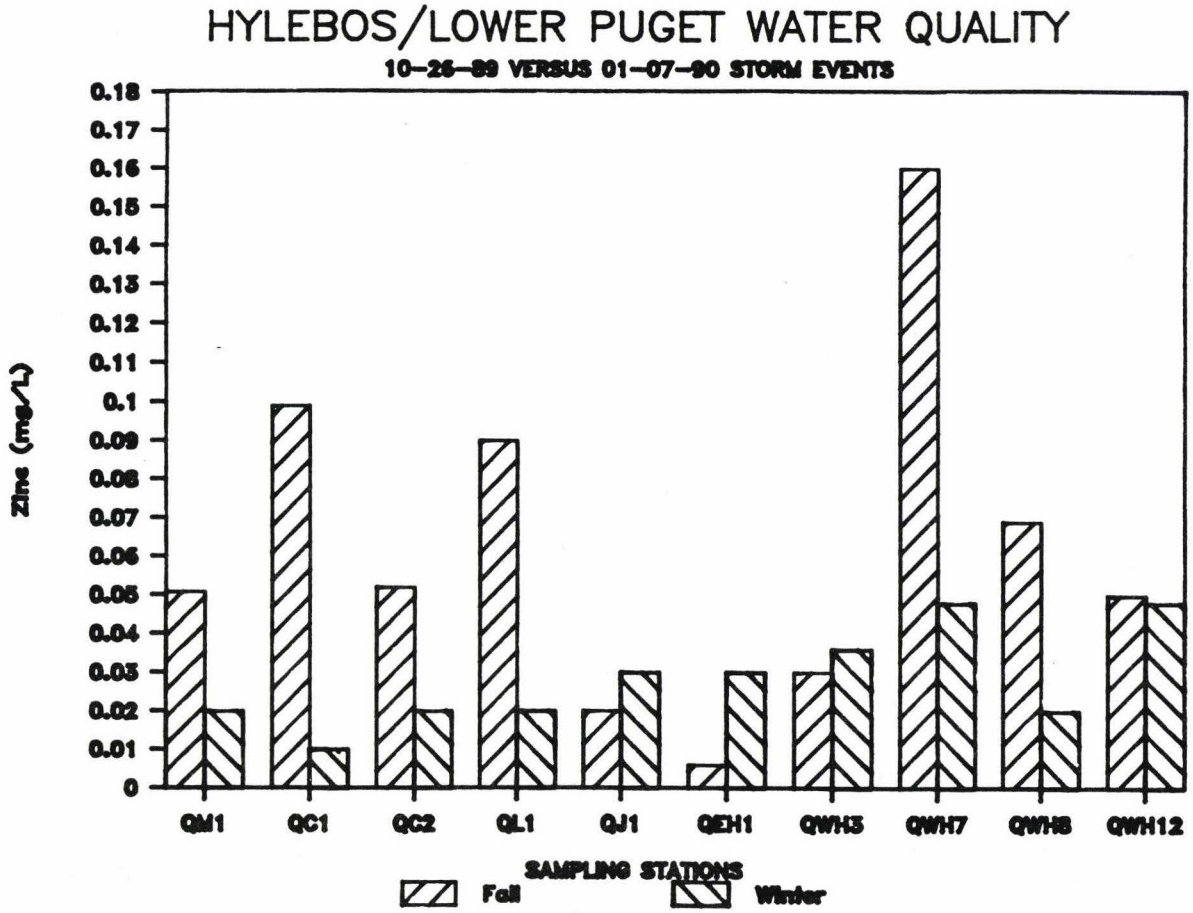

HYLEBOS/LOWER PUGET WATER QUALITY
10-26-89 VERSUS 01-07-90 STORM EVENTS
Zinc (mg/L)
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
QM1
QC1
QC2
QL1
QJ1
QEH1
QWH3
QWH7
QWH8
QWH12
SAMPLING STATIONS
Fall
Winter

Table 3.7.4

BASIN SUMMARY STORM WATER QUALITY RESULTS

VARIABLE		HYLEBOS CREEK BASIN	LOWER PUGET SOUND BASIN
Fecal Coliform	Average Geometric Mean*	594	801
	Range	30-39,300	100-7,400
Total Phos-phorus	Average Mean (mg/L)*	0.17	0.19
	Range	0.03-0.76	0.04-0.61
Nitrate + nitrite - nitrogen	Average Mean (mg/L)*	0.80	0.53
	Range	0.06-2.54	0.08-0.88
Total Suspended Solids	Average Mean (mg/L)*	57	66
	Range	4-297	6-344
Copper	Average Mean (mg/L)*	0.009	0.011
	Range	0.002-0.067	0.005-0.028
Zinc	Average Mean (mg/L)*	0.036	0.031
	Range	0.005-0.16	0.007-0.099

* This number was obtained by averaging the means listed in Table 3.7.8.

Figure 3.7.4a

West Branch Hylebos Creek Sub-basin

SIGNIFICANT SURFACE WATER QUALITY PROBLEMS

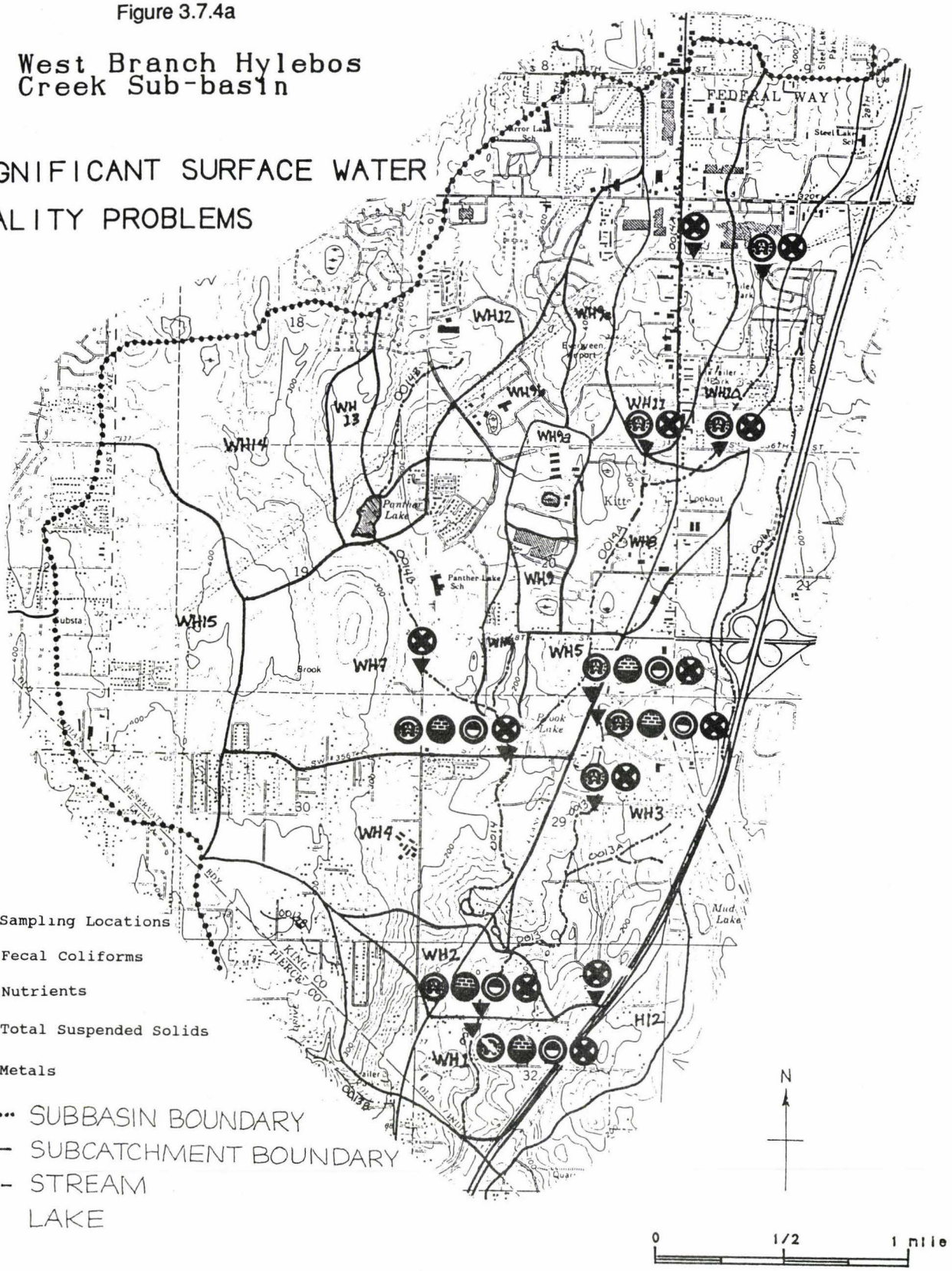


Figure 3.7.4b

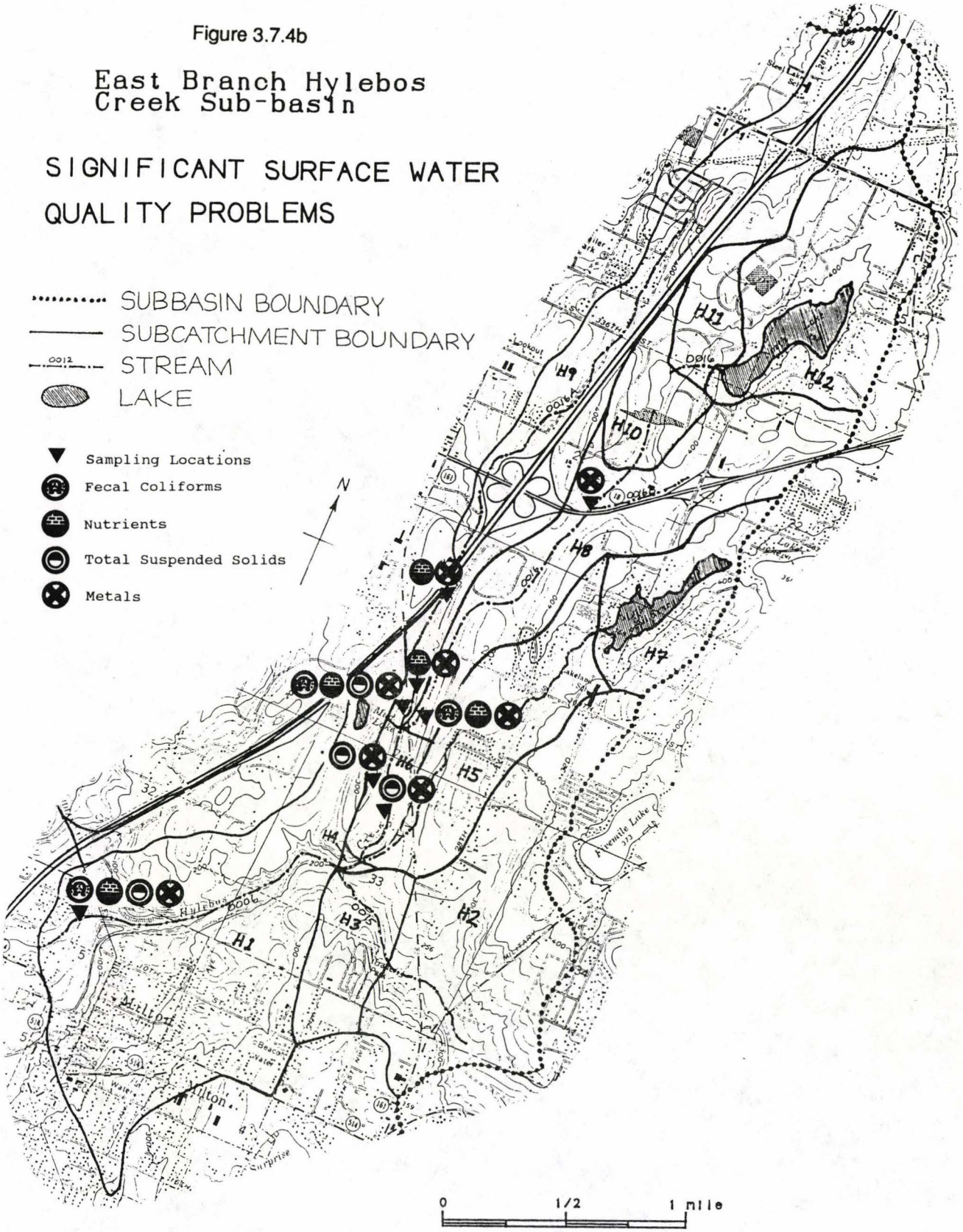

East Branch Hylebos Creek Sub-basin
SIGNIFICANT SURFACE WATER QUALITY PROBLEMS
SUBBASIN BOUNDARY
SUBCATCHMENT BOUNDARY
STREAM
LAKE
Sampling Locations
Fecal Coliforms
Nutrients
Total Suspended Solids
Metals
N
H1
H2
H3
H4
H5
H6
H7
H8
H9
H10
H11
H12
Milton
Fivemile Lake
0
1/2
1 mile

Figure 3.7.4c

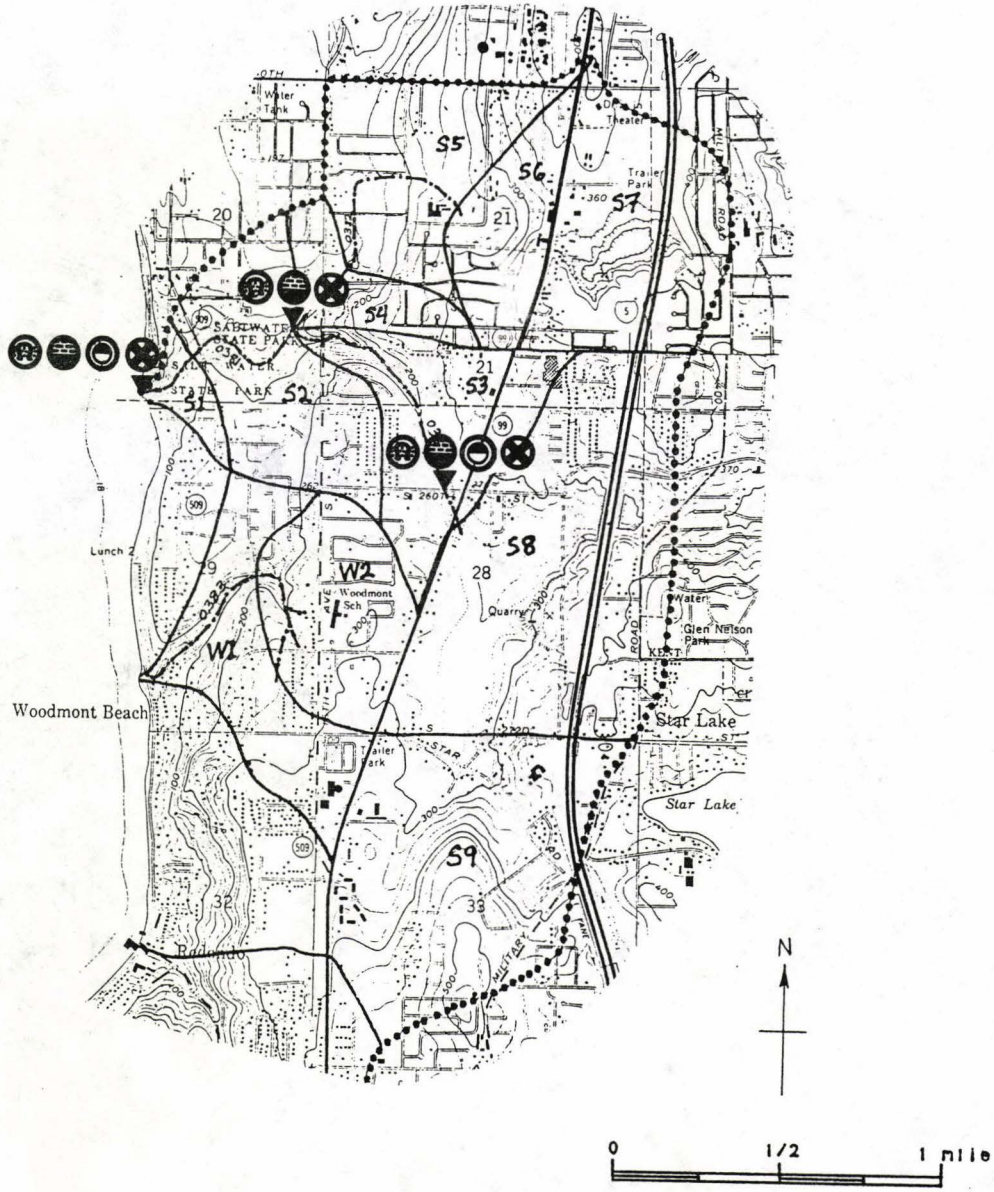
Lower Hylebos Creek Sub-basin

Figure 3.7.4d

North Lower Puget Sound Sub-basin

SIGNIFICANT SURFACE WATER QUALITY PROBLEMS

- Sampling Locations
- Fecal Coliforms
- Nutrients
- Total Suspended Solids
- Metals



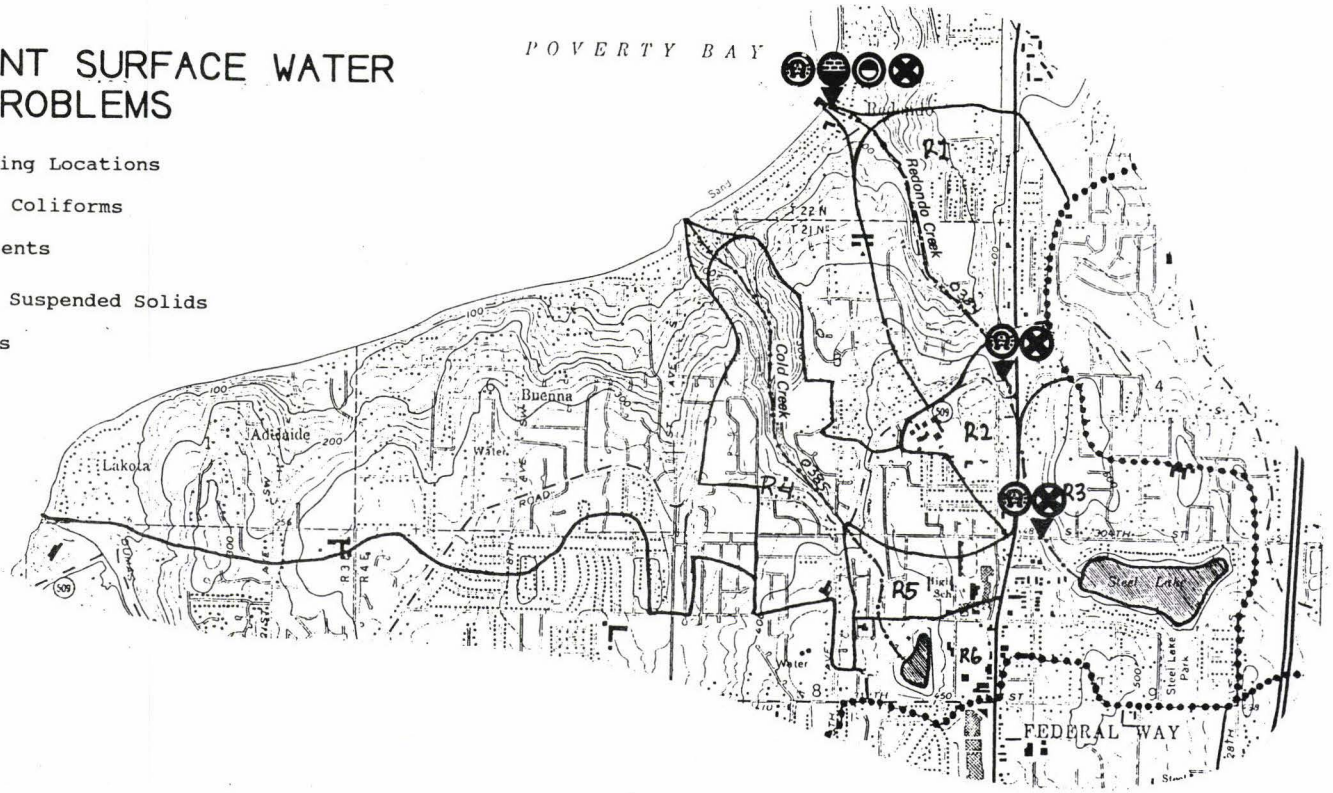
SUBBASIN BOUNDARY
SUBCATCHMENT BOUNDARY
STREAM
LAKE

Figure 3.7.4e

Central Lower Puget Sound Sub-basin

SIGNIFICANT SURFACE WATER QUALITY PROBLEMS

- Sampling Locations
- Fecal Coliforms
- Nutrients
- Total Suspended Solids
- Metals



SUBBASIN BOUNDARY
SUBCATCHMENT BOUNDARY
STREAM
LAKE

N

0 1/2 1 mile

Figure 3.7.4f

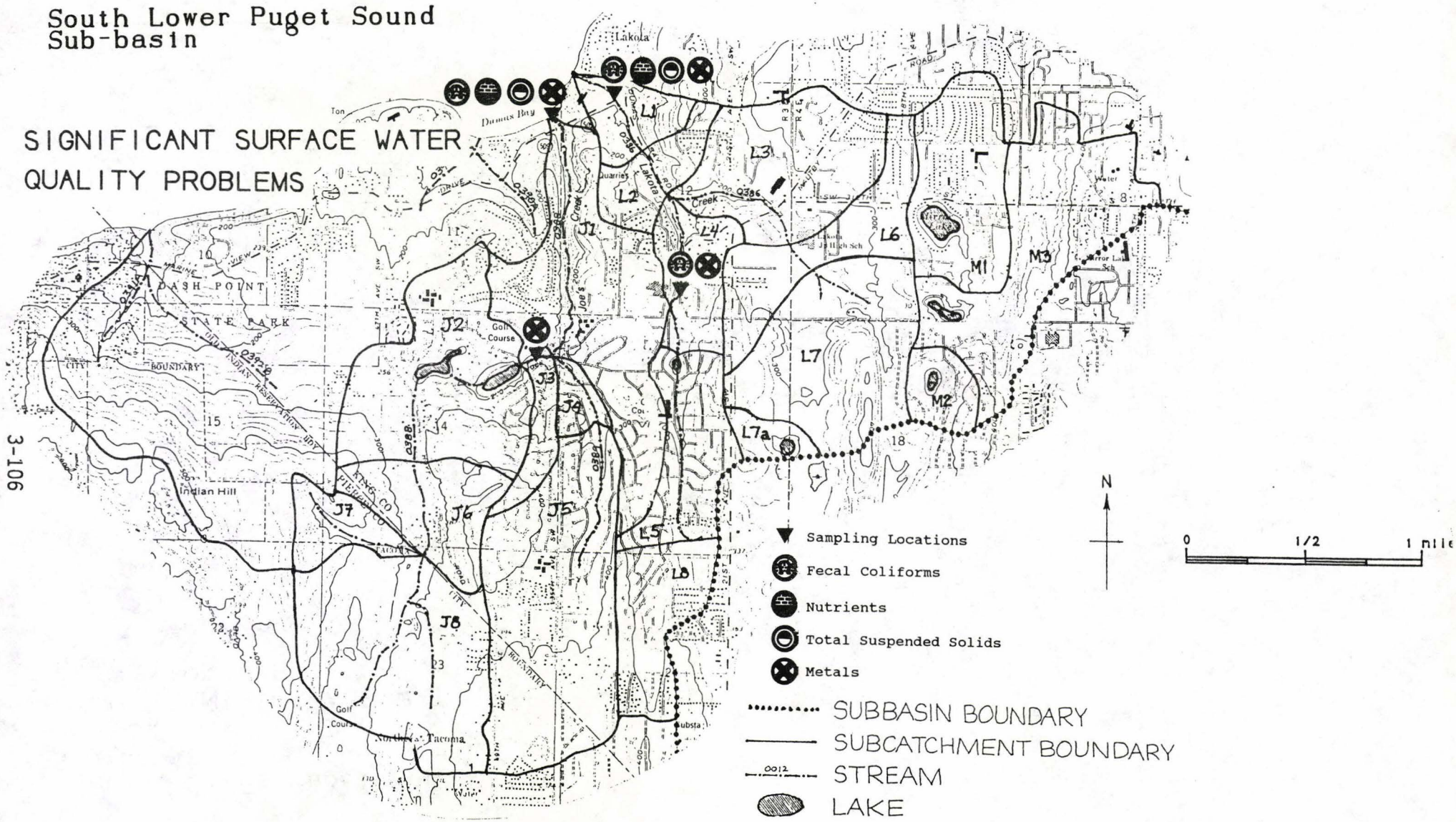

South Lower Puget Sound
Sub-basin
SIGNIFICANT SURFACE WATER
QUALITY PROBLEMS
Lakola
Dumas Bay
DASH POINT
STATE PARK
Indian Hill
Tacoma
Golf Course
L1
L2
L3
L4
L5
L6
L7
L7a
L8
J1
J2
J3
J4
J5
J6
J7
J8
M1
M2
M3
N
0
1/2
1 mile
Sampling Locations
Fecal Coliforms
Nutrients
Total Suspended Solids
Metals
SUBBASIN BOUNDARY
SUBCATCHMENT BOUNDARY
STREAM
LAKE

Table 3.7.5 lists mean concentrations and number of samples exceeding criteria for six out of seven variables. Mean concentrations are broken down by sub-basin for comparisons.

Table 3.7.6 lists a summary of the total number of samples exceeding water quality criteria both by basin and by variable. A total of 53 percent of the samples exceeded water quality criteria in the Hylebos Creek basin compared to 47 percent in the Lower Puget Sound basin. It is interesting to note that these percentages are similar, even though more than twice as many samples were obtained within the Hylebos Creek Basin.

"Pollution points" (2-12) were assigned to each sub-basin based on ranking of mean concentrations (i.e., the higher the mean concentration, the higher the pollution points assigned to a sub-basin). The Lower Puget Sound basin had 139 total "pollution points" versus 113 for the Hylebos Creek basin based on their rankings of mean concentrations (Table 3.7.7).

Table 3.7.5

STORM EVENT WATER QUALITY RESULTS SUMMARY

Fecal Coliform

Sub-basin	Geometric Mean (colonies/100 mL)	Number of Samples Exceeding Criteria (100 colonies/100mL)
South Lower Puget	869	8/8
Lower Hylebos	825	4/4
North Lower Puget	819	4/4
Central Lower Puget	716	6/7
West Hylebos	586	25/26
East Hylebos	372	10/13

Total Phosphorus

Sub-basin	Mean (mg/L)	Number of Samples Exceeding Recommended Guide-lines (0.10 mg/L)
North Lower Puget	0.22	3/4
East Hylebos	0.20	6/13
South Lower Puget	0.19	4/8
Lower Hylebos	0.17	4/4
Central Lower Puget	0.16	3/7
West Hylebos	0.15	14/26

Table 3.7.5 (continued)

Nitrate + Nitrite - Nitrogen

Sub-basin	Mean(mg/L)	Number of Samples Exceeding Basin Plan "Threshold Value" (1.25 mg/L)
East Hylebos	1.01	3/13
Lower Hylebos	0.98	2/4
South Lower Puget	0.60	0/8
North Lower Puget	0.54	0/4
Central Lower Puget	0.45	0/7
West Hylebos	0.40	0/26

Total Suspended Solids

Sub-basin	Mean(mg/L)	Number of Samples Exceeding Basin Plan "Threshold Value" (50 mg/L)
Central Lower Puget	75	2/7
South Lower Puget	73	2/8
East Hylebos	67	6/17
West Hylebos	58	9/28
North Lower Puget	49	2/4
Lower Hylebos	45	2/4

Copper

Sub-basin	Mean(mg/L)	Number of Samples Exceeding Chronic 4-day* Criteria	Number of Samples Exceeding Acute 1-hr** Criteria
West Hylebos	0.014	19/20	19/20
North Lower Puget	0.013	3/4	3/4
Central Lower Puget	0.012	5/5	5/5
South Lower Puget	0.009	6/6	5/5
East Hylebos	0.007	13/15	12/13
Lower Hylebos	0.006	3/4	3/4

Table 3.7.5 (continued)

Lead

Detection limits of 0.03 mg/L or parts per million (ppm) used in this supplemental monitoring program is above EPA toxicity criteria and typical freshwater concentrations. However, lead concentrations obtained from Metro of Seattle (Stormwater Runoff Data) typically exceeded USEPA acute and chronic criteria 100% of the time (Resource Planning Associates, 1985).

Zinc

Sub-Basin	Mean(mg/L)	Number of Samples Exceeding Chronic 4-day* Criteria	Number of Samples Exceeding Acute 1-hr** Criteria
West Hylebos	0.058	23/27	23/27
Central Lower Puget	0.037	4/7	4/7
South Lower Puget	0.030	3/8	3/8
East Hylebos	0.026	6/15	6/15
North Lower Puget	0.025	1/4	1/4
South Hylebos	0.025	1/4	1/4

* Chronic 4-day Criteria: EPA recommend guidelines for deriving Numerical National Water Quality Criteria for the protection of aquatic organisms and their uses indicate that, except possibly where a locally significant species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the 4-day average concentration is not exceeded more than once every 3 years on the average.

** Acute 1-hour Criteria: EPA recommend guidelines for deriving Numerical National Water Quality Criteria for the protection of aquatic organisms and their uses indicate that, except possibly where a locally significant species is very sensitive, freshwater aquatic organisms and their uses should not be affected unacceptably if the 1-hour average concentration is not exceeded more than once every 3 years on the average. Three years is the EPA's best scientific judgement of the average amount of time aquatic ecosystems should be provided between excursions.

Table 3.7.6

BASIN SUMMARY OF WATER QUALITY CRITERIA EXCEEDANCES

Total number of samples exceeding criteria

Basin	Total Number of Samples Exceeding Criteria		Percent
Hylebos	136/258	=	53%
Lower Puget Sound	52/110	=	47%

Percent of samples exceeding criteria by water quality variable

Variable	Hylebos	Lower Puget Sound
Fecal Coliform	91%	99%
Copper (chronic)	90%	94%
Zinc (acute)	65%	42%
Total Phosphorus	56%	53%
Total Suspended Solids	35%	32%
Copper (acute)	16%	8%
Nitrate + nitrite - nitrogen	12%	0%

Table 3.7.7

TOTAL POLLUTION POINTS

Sub-Basin		Basin	n
South Lower Puget	52		(8)
Central Lower Puget	44		(7)
North Lower Puget	43	Total	(4)
		139	
East Hylebos	42		(13)
West Hylebos	38		(26)
Lower Hylebos	33	Total	(4)
		113	

n = total number of samples used in analysis

Comparison of Baseflow and Storm Event Conditions

Water quality data collected in the Hylebos Creek and Lower Puget Sound Basins during baseflow conditions were compared to storm event data (Table 3.7.8). As expected, total suspended solids and fecal coliforms showed the greatest increases. In general, the Lower Puget Sound basins tended to have larger increases in concentrations during storm events than the Hylebos Basin.

Table 3.7.8

COMPARISON OF BASEFLOW TO STORM EVENT SAMPLES
IN HYLEBOS/LOWER PUGET SOUND BASINS

Fecal Coliform Bacteria (colonies/100mL)

Sampling Station	Baseflow (Geometric Mean)	Storm Event (Geometric Mean)	Storm Event Geometric Mean Times as High as Baseflow (Geometric Mean)
QEH1 (E. Hylebos)	42	386	9 X more
QWH3 (W. Hylebos)	92	751	8 X more
QWH8 (N. Hylebos)	44	487	11 X more
QJ1 (Joes Creek)	42	1,004	24 X more
QM1 (McSorley Creek)	80	703	9 X more
QC1 (Cold Creek)	65	1,387	21 X more
QL1 (Lakota Creek)	24	1,014	42 X more

Total Phosphorus (mg/L)

Sampling Station	Baseflow Median	Storm Event Range	(Storm Event Conc.) Mean Times as High as Baseflow Conditions
QEH1 (E. Hylebos)	0.037	0.06-0.20	2-6 X more
QWH3 (W. Hylebos)	0.062	0.15-0.24	2-4 X more
QWH8 (N. Hylebos)	0.07	0.13-0.17	2 X more
QJ1 (Joes Creek)	0.065	0.20-0.22	3-3.5 X more
QM1 (McSorley Creek)	0.053	0.16-0.47	3-9 X more
QC1 (Cold Creek)	0.052	0.14-0.61	2.5-12 X more
QL1 (Lakota Creek)	0.050	0.15-0.56	3-11 X more
(44) Stream Stations (Baseflow)	0.058		
(7) Hylebos Creek and Lower Puget Sound Stations (Storm Event)	0.185		

TABLE 3.7.8 (continued)

Total Suspended Solids (mg/L)			
Sampling Station	Baseflow Median	Storm Event Range	(Storm Event Conc.) Mean Times as High as Baseflow Conditions
QEH1 (E. Hylebos)	3.2	8-83	2.5-26 X more
QWH3 (W. Hylebos)	6.8	56-146	8-21 X more
QWH8 (N. Hylebos)	3.8	20-70	5-18 X more
QJ1 (Joes Creek)	3.0	35-105	11-35 X more
QM1 (McSorley Creek)	2.7	17-93	6-34 X more
QC1 (Cold Creek)	4.3	101-344	23-80 X more
QL1 (Lakota Creek)	3.2	49-343	15-107 X more
(44) Stream Stations (Baseflow)	4.5		
(7) Hylebos Creek and Lower Puget Sound Stations (Storm Event)	76.5		

Nitrate + Nitrite - Nitrogen (mg/L)			
Sampling Station	Baseflow Median	Storm Event Range	(Storm Event Conc.) Mean Times as High/ Low as Baseflow Conditions
QEH1 (E. Hylebos)	1.24	0.57-0.71	2 X less
QWH3 (W. Hylebos)	0.65	0.57-0.69	--
QWH8 (N. Hylebos)	0.23	0.42-0.60	2-3 X more
QJ1 (Joes Creek)	1.26	0.61-0.64	2 X less
QM1 (McSorley Creek)	0.31	0.37-0.82	1-2.5 X more
QC1 (Cold Creek)	0.33	0.64-0.71	2 X more
QL1 (Lakota Creek)	2.56	0.69-0.88	3-3.5 X less
(44) Stream Stations (Baseflow)	0.67		
(7) Hylebos Creek and Lower Puget Sound Stations (Storm Event)	0.185		

Future Conditions

Conversion of existing open space to commercial and residential impervious areas will negatively impact water quality in both the Hylebos Creek and Lower Puget Sound basins. One way to qualitatively evaluate the impact on beneficial uses in the basins is to examine effects from urban developments in other drainage basins and existing problems mentioned previously in this chapter.

Changes in water quality with increased urbanization have been studied in Kelsey Creek in Bellevue (Richey, 1982). In general, the concentrations of several selected variables (e.g., nutrients and suspended solids) were greater in the urban stream than the rural stream.

Metro collected storm event samples from Springbrook, McAleer, Kelsey, and Juanita Creeks during 1988. Table 3.7.9 lists mean concentrations in comparison to stations within the Hylebos Creek and Lower Puget Sound basins.

Table 3.7.9

STORM EVENT WATER QUALITY FROM REGIONAL VS. HYLEBOS CREEK AND LOWER PUGET SOUND SAMPLING

Stations	Fecal Coliform (geometric mean colonies/ 100mL)	Total Phosphorus (mg/L Mean)	Total Suspended Solids (mg/L Mean)	Nitrate + Nitrite - Nitrogen (mg/L Mean)
Metro: Springbrook, McAleer, Kelsey, and Juanita Creeks	345	0.29	109	0.76
King County SWM: Hylebos Creek and Lower Puget Sound (7 stations)	819	0.19	77	0.64

Although extremely limited, these data appear to indicate that with the exception of fecal coliform, measured concentrations (for these variables) were generally lower in the Hylebos Creek and Lower Puget Sound basins in comparison to Metro's data.

The Seattle Engineering Department collected storm runoff samples from Pipers and Longfellow Creeks during 1988-1990. Table 3.7.10 lists selected water quality results in comparison to Hylebos Creek and Lower Puget Sound basin concentrations.

Table 3.7.10

STORM EVENT WATER QUALITY IN PIPERS AND LONGFELLOW CREEK VS. STUDY AREA

Basin	Fecal Coliform Geometric Mean (Organisms/100mL)	Total Phosphorus mg/L(Mean)	Total Suspended Solids mg/L(Mean)	Copper mg/L(Mean)	Zinc mg/L(Mean)	n
Pipers Creek[a]	20,000[d]	0.14	40	0.0009	0.080	3
Longfellow Creek[b]	1,818[d]	0.22	177	0.019	0.096	21
Hylebos/Lower Puget[c] (7 stations during three storm events)	819[e]	0.19	77	0.012	0.038	14

a = from 3 sample sites during one storm event
b = from 5 sample sites during four storm events (composites)
c = from 7 sample sites during three storm events (grabs)
d = MPN (most probable number method)
e = MF (membrane filter method)
n = number of samples

Although extremely limited, these data appear to indicate that with the exception of fecal coliform bacteria and zinc, storm event water quality data collected recently in the Hylebos Creek and Lower Puget Sound basins may have generally higher concentrations than Pipers Creek. In comparison to Longfellow Creek, water quality concentrations in the Hylebos Creek and Lower Puget Sound basins appear to be much lower. This is much more evident when one considers that data from Longfellow Creek consisted of composited samples which tend to dilute the peak concentrations usually appearing in the early periods of a storm event up through the peak of the storm.

In addition, the City of Seattle collected stormwater runoff samples in storm drains during 1986 through 1988. Selected water quality results are presented in Table 3.7.11.

Table 3.7.11

STORM EVENT WATER QUALITY IN SEATTLE STORM DRAINS VS. STUDY AREA

STUDY	Geometric Mean Values: Total Suspended Solids mg/L	Copper mg/L	Zinc mg/L
City of Seattle Storm Drains	49	0.031	0.117
Hylebos/Lower Puget Sound Basin	34	0.008	0.027

Although extremely limited, these data appear to indicate copper and zinc concentrations measured in Seattle storm drains were about 4 times as high as the concentrations detected in the Hylebos Creek and Lower Puget Sound basins. It is important to point out that direct comparisons of water quality data from other basins/studies during different periods, are difficult to make due to the wide variety in conditions (e.g., land use, soils, build-out conditions, precipitation levels) that can exist.

The EPA's typical national values for stormwater pollutant concentrations as a function of land use are displayed in Table 3.7.12:

Table 3.7.12

STORMWATER POLLUTANT CONCENTRATIONS FROM URBAN USES

Urban Land Use	Pollutant Concentrations (mg/L): Total Suspended Solids (TSS)	Biochemical Oxygen Demand (BOD)
Residential	240	12
Commercial	140	20
Industrial	215	9
Other developed areas	17	1

Reference: (Sullivan, 1977)

These TSS data are similar to those observed during the Hylebos Creek and Lower Puget Sound basin storm event monitoring program where residential land use was the largest contributing sediment sources (see TSS Table 3.7.8).

The combined sewer overflow plan for the City of Everett, Washington lists average stormwater runoff concentrations relative to land use as follows:

Variable	Pollutant Concentrations (mg/L) Industrial	Commercial	Residential
BOD	5	11	7
TSS	45	30	50
Pb	0.22	0.38	0.21
Zn	0.35	0.32	0.21

These data also support findings in West Branch Hylebos Creek where industrial and commercial land use contributes higher metal concentrations (see Figure 3.7.3c).

It can be concluded that without mitigation, increases in these urbanized land uses within both the Hylebos Creek and Lower Puget Sound basins will lead to increased concentrations of these pollutants as well as others.

As discussed previously, there are indications of water quality problems presently in both basins that could be exacerbated in the future. A few instances during baseflow conditions documented low dissolved oxygen and pH readings. These water quality constituents, when low, can create stress levels for salmonids and may indicate future potential limitations for these fish populations. These limitations can include reduced growth (metabolic stress), possible migration blockages, and potential mortality, if contaminant concentration levels reach lower limits of an aquatic species suitable range.

Population increases and associated development in both basins will likely result in loss of open space. As a result, without mitigation, temporary increases in turbidity and sedimentation can be expected from construction activity and long-term streambank erosion from increased flows. Increases in fine sediment can limit the success of salmonid spawning and reduce available rearing habitat.

Increased levels of fecal coliforms could be associated with a more urbanized area as well. Pet (e.g., dog and cat) wastes can be a significant source of fecal coliforms in heavy use areas (e.g., trails, parks, etc.). As onsite septic systems age, failure rates tend to increase, especially without proper maintenance. The same can be said for sewer line systems. Onsite septic systems and sewer lines might be two probable major sources of fecal contamination in the basins. Increased impervious surface areas will lead to increased volumes of surface water runoff. Without mitigation, this will result in increased contaminant concentrations and pollutant loadings.

Heavy metals in highway runoff originate from highway materials and various aspects of vehicle operations (Wang et al., 1982). Sources and the metals they contribute include gasoline and exhaust emissions (lead, nickel), lubricating oils (lead, nickel, zinc), grease (zinc, lead), tire wear (cadmium, zinc), concrete paving wear (various metals depending on aggregate source), asphalt paving wear (nickel), bearing wear (copper, lead), brake lining wear (copper, chromium, nickel) and wear of moving engine parts (iron, manganese, chromium, copper) (after Kerri et al., 1976; Hopke et al., 1980; and Novotny and Chesters, 1981).

In a report entitled, "Effects of Seattle Area Highway Stormwater Runoff on Aquatic Biota," (Portele, et al., 1982), impacts of stormwater runoff from freeways on aquatic species was investigated. Algae and zooplankton were adversely affected by metal concentrations in the runoff, while suspended solids caused high mortalities of rainbow trout fry. Results from this study demonstrated that draining highway runoff directly to receiving waters via pipes or bare channels should be avoided. Grassy drainage channels were shown to effectively capture and retain metals. Mud or paved channels, however, demonstrated little or no ability to remove metals from runoff.

Metro conducted bioassay toxicity tests on stormwater during 1987-1989. Toxicity tests were performed on three different organisms (Ceriodaphnia dubia - water flea, Salmo gairdneri - rainbow trout, and Selenastrum capricornutum - freshwater green alga). Two concentrations, 10% and 60% sample, and a dilution water control (0%) were used in conjunction with toxicity tests for rainbow trout.

Five of 17 (29%) of the samples tested with rainbow trout either were acutely toxic or caused stress. Five of 13 (38%) of the samples tested with Ceriodaphnia either were acutely toxic or caused behavior indicative of stress. Results from four samples tested with the algal organism (Selenastrum) indicated that stormwater generally stimulates growth. Stormwater tested in this study was more toxic than treated sewage tested over the same period.

Differing responses were observed at stations that were retested during various storm events. This study suggested the variation in response could result from chance deposition or accumulation of toxic substances during an antecedent dry period or may result from pollutant loads that are not delivered at a constant rate throughout the storm period (Metro, 1990).

Metro is also currently conducting toxicity tests at selected transit base facilities. Data results from these studies were not available at the time of this writing. It is important to point out that toxicity testing using metals (total) is not a good index for assessing the bioavailability of various metals. This is due to the fact that there are currently no real good analytical methods for measuring bioavailable speciation. Total metals are generally bound up in nonbioavailable forms and as such it is difficult to determine the fate and effects of these contaminants (Buckley, 1990).

The Wisconsin Department of Natural Resources (DNR) (Bureau of Water Resources Management) conducted stormwater bioassay toxicity tests at seven sites between September 1989 and March 1990. Two organisms, juvenile fathead minnow (Pimephates promelas) and Daphnia magna were tested with undiluted stormwater. At two locations, both representative of medium density residential land use, percent mortality (at 24 hours) for Daphnia magna was 95 and 100 respectively (Wisconsin DNR, 1990). It is interesting to note that both stations exhibited 0% mortality for the juvenile flathead minnow during these same storm events. In general, metals (i.e., copper, lead, and zinc) typically exceeded acute toxicity criteria for warm water fish (Bannerman, 1990).

Without additional detention and treatment, runoff from impervious areas such as the six miles of state and interstate highways, other roads and streets, major shopping/commercial areas, and similar sources in the future planning area, will likely contribute increased levels of suspended sediments and heavy metals. It is interesting to note that six miles of interstate highway that dissects the

Hylebos Creek Basin are approximately equivalent to 90 impervious acres, which is about twice the size of the Sea Tac Mall and its parking lots.

The water quality in both the Hylebos Creek and Lower Puget Sound basins is generally good during baseflow conditions. As such, both basins are able to support most beneficial uses. During storm events, high sediment and fecal coliforms in the Lower Puget Sound basin and high metal and fecal coliforms in the Hylebos basin are impacting beneficial uses. Storm events for the most part are usually short-lived; however, the long-term impacts associated with these accumulated toxins in receiving water bodies may seriously alter habitat and their ecosystems.

The general impacts of nonpoint sources on beneficial uses that are likely to be of concern in the Hylebos Creek and Lower Puget Sound basins are indicated in Table 3.7.12.

KEY FINDINGS

- Several areas of undeveloped wetlands and riparian corridors still exist throughout the planning area. These areas are providing shade which keeps stream temperatures low and water oxygenated. Streamside vegetation is also providing biofiltration that is filtering out contaminants to water bodies downstream.

- Relatively high concentrations of heavy metals (e.g., copper, lead, and zinc) are transported during storm events from road runoff and automobiles to water-bodies, particularly in the Hylebos Creek basin. A relatively large number of samples were found to contain sufficient concentrations that are toxic to aquatic species. This is especially true when combined with total suspended solids from construction sites, roadway dust, and erosional processes associated with high runoff periods that can build up over time in bottom habitat areas. With each storm event, these accumulated toxins in bottom sediments can contribute to the contamination now present in Hylebos Waterway and Commencement Bay. This will continue to occur even on top of freshly capped contaminated sediment. Contaminated bottom fish and shellfish that may be routinely consumed from this area are a public health hazard.

- Uncontrolled large sediment loads and their associated contaminants may impact commerce and navigation activities, stock watering, industrial operations (e.g., cooling water), and fish and wildlife.

- Relatively high concentrations of fecal coliforms, particularly in the Lower Puget Sound basin, are likely to be originating from sewer line leaks, failing onsite septic systems, farm animal access to creeks, and pet wastes. These bacteria are a potential threat to human contact with surface waters and effect recreational shellfish harvesting while contributing to the decertification of commercial shellfish beds in Puget Sound. Wildlife probably contribute a very minor loading of microbial pollution to these water bodies based on the minimal remaining habitat.

- Relatively high concentrations of nutrients from fertilizers, failing sewage systems, decomposing organic matter from leaves and grass clippings, agricultural runoff, urban street refuse, and atmospheric deposition are probably contributing to algal blooms in lakes and lowered oxygen levels in both lakes and streams.

Table 3.7.13

GENERAL IMPACT OF NONPOINT SOURCES ON BENEFICIAL USES LIKELY TO BE OF CONCERN IN THE HYLEBOS CREEK AND LOWER PUGET SOUND BASINS

Body	Key Pollutants	Effect on Water	Affected Uses (a)
Lakes	Bacteria/viruses	Contamination	Contact recreation
	Phosphorus	Algae growth	Contact recreation, nuisance odors, visual pollution
	Sediment/ suspended solids	Visual turbidity, creates shallows	Aesthetic pollution by silts, weed growth in shallow areas
	Metals	Bioaccumulation	Fishing
Streams	Sediment/ suspended solids	Turbidity deposition in stream pools and wetlands	Loss of flood control capacity, fishing, loss of wetland cleaning ability, visual pollution
	Hydraulic erosion	Streambank loss, sediment deposit downstream	Damage of private and public property
	Bacteria/viruses	Contamination	Swimming(b)
Puget Sound	Bacteria/viruses	Contamination	Loss of recreational and commercial shell fishing
	Metals	Bioconcentration	Same as above
	Sediment/ suspended solids	Shellfish loss	Same as above
Ground water	Nitrates	Loss of use as a drinking water supply	
	Toxic organics	Cancer, related diseases	
	Bacteria/viruses	Contamination	

(a) For all three types of water bodies a loss in property values for properties abutting the water body have been found in several research studies.

(b) The only stream in which swimming may occur is the Hylebos and probably at a very low frequency given its smallness.

Source: Resource Planning Associates, Nonpoint Source Pollution in the Federal Way Community (Executive Summary and Recommendations), 1985, p. 2.

SECTION 3.8 HABITAT

INTRODUCTION

The Hylebos Creek system is composed of over 25 miles of streams, five named lakes, and over 30 identified wetlands totalling more than 250 acres. The basin also contains a number of other small unnamed ponds and uninventoried wetland areas.

Hylebos Creek originates at Lake Killarney and North Lake on the northeast border of the basin and flows south and west to the confluence of West Branch Hylebos Creek in Pierce County. The original headwaters of the West Branch were situated within a complex of wetlands in the vicinity of S 320th Street and within the West Hylebos Wetland, whose present approximate boundaries lie between S 348th Street, S 356th Street, 1st Avenue S, and SR 99. Altogether, there are 28.2 river miles in the Hylebos stream system: 18.5 miles on the mainstem and East Branch, and their tributaries, and 9.7 miles on the West Branch and its tributaries (see Figure 3.8.1).

Many of these headwater wetland areas were eliminated during construction of commercial areas in the vicinity of S 320th Street. Other prominent alterations of the stream system occurred when drainage from the headwaters of the north fork of the West Branch was routed into the East Branch in the mid-1960s during construction of I-5, and when runoff from Panther Lake was routed into the West Branch in the mid-1980s. South of the confluence with the West Branch, the mainstem turns northwest, flowing through a broad floodplain that extends to Hylebos Waterway which in turn empties into Commencement Bay.

The eight independent Lower Puget Sound drainages together comprise over 18 miles of stream channels, five named lakes, and 30 inventoried wetlands--including over 250 acres of shallow intertidal and subtidal areas in adjacent waters of Puget Sound.

Historical Information

Hylebos Creek may have at one time been among the most productive small stream systems in central Puget Sound. Accounts of early settlers and Puyallup tribal elders indicate that prior to settlement of the basin the system might have supported annual returns of several thousand adult coho (*Oncorhynchus kisutch*) and chum (*O. keta*) salmon, plus hundreds of chinook (*O. tshawytscha*) salmon, steelhead trout, (*O. mykiss*) and cutthroat trout (*O. clarkii*). Like most Puget Sound lowland streams (Gonor et al., 1988), lower Hylebos Creek consisted of a network of sloughs, beaver ponds, and driftwood dams grading into steeper segments of the stream system flowing through ravines forested with old growth conifers. Large organic debris played an important role in the ecology of the stream system by forming diverse sequences of riffles and pools used by salmon and trout as spawning and rearing areas. By comparison, fish habitat within present-day Hylebos Creek contains only remnant areas of productive fish and wildlife habitat. Fish populations are small due to the basinwide influences of urbanization on the remaining productive fish habitat within the system.

In the West Branch, historic spawning and rearing habitat extended from the area behind what is now Gethsemene Cemetery up to the West Hylebos Wetland. Additional rearing habitat existed in the lower reaches of the West Branch and mainstem (see Figures 3.8.2a and b). Because of its moderate gradient and

Figure 3.8.1

HYLEBOS CREEK AND LOWER PUGET SOUND BASINS REFERENCE MAP

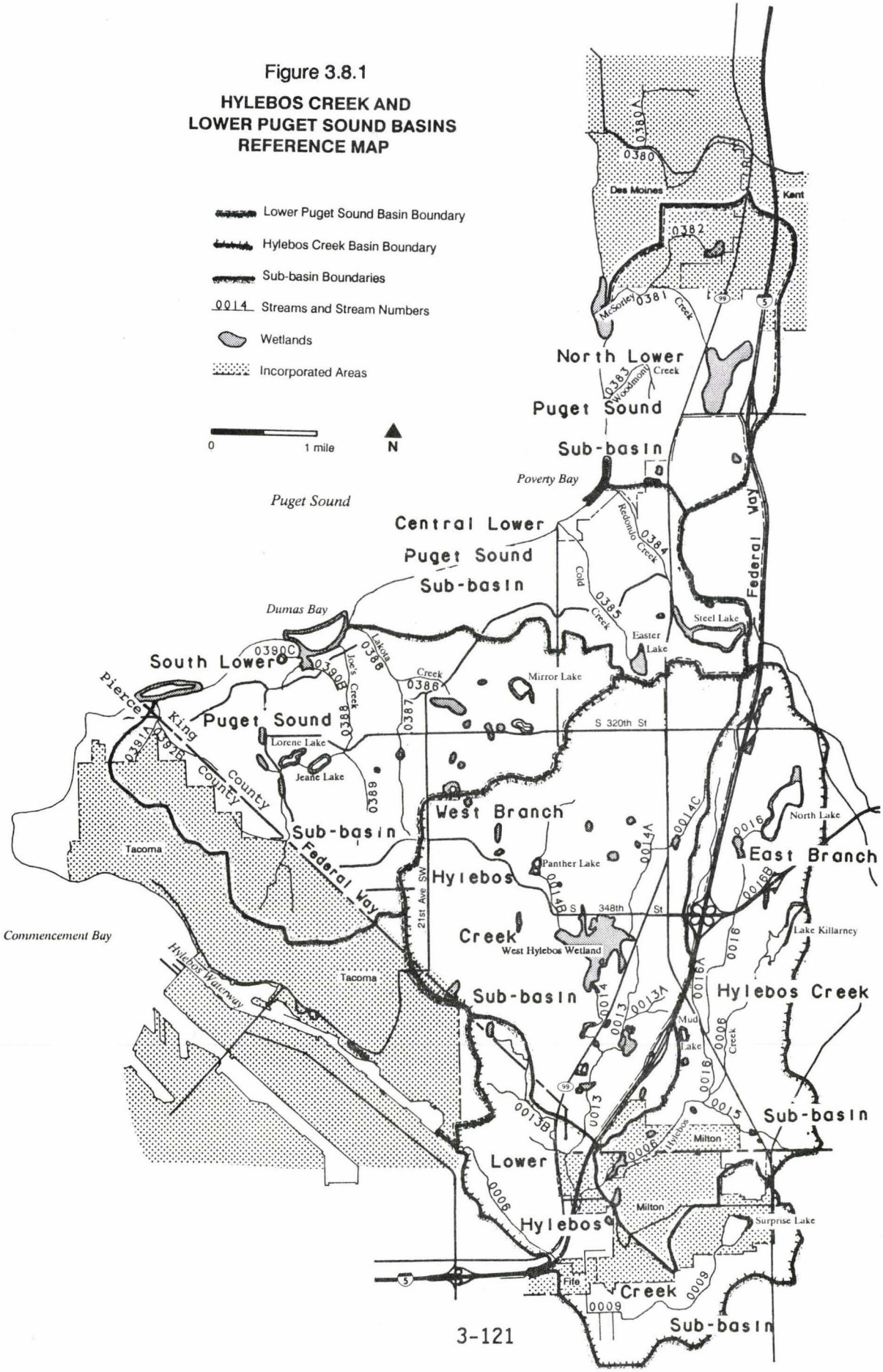


Figure 3.8.2a

West Branch Hylebos Creek Sub-basin

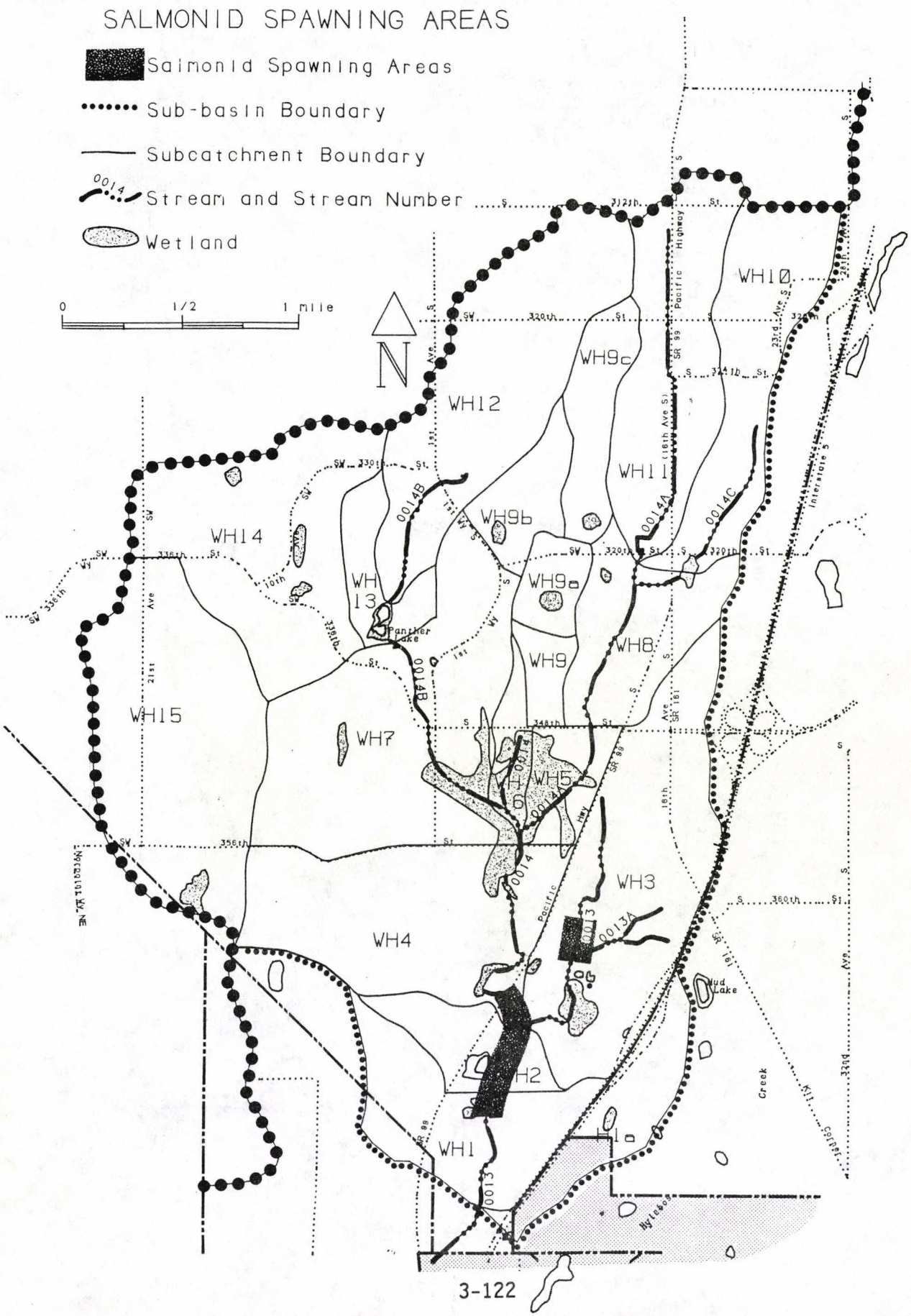
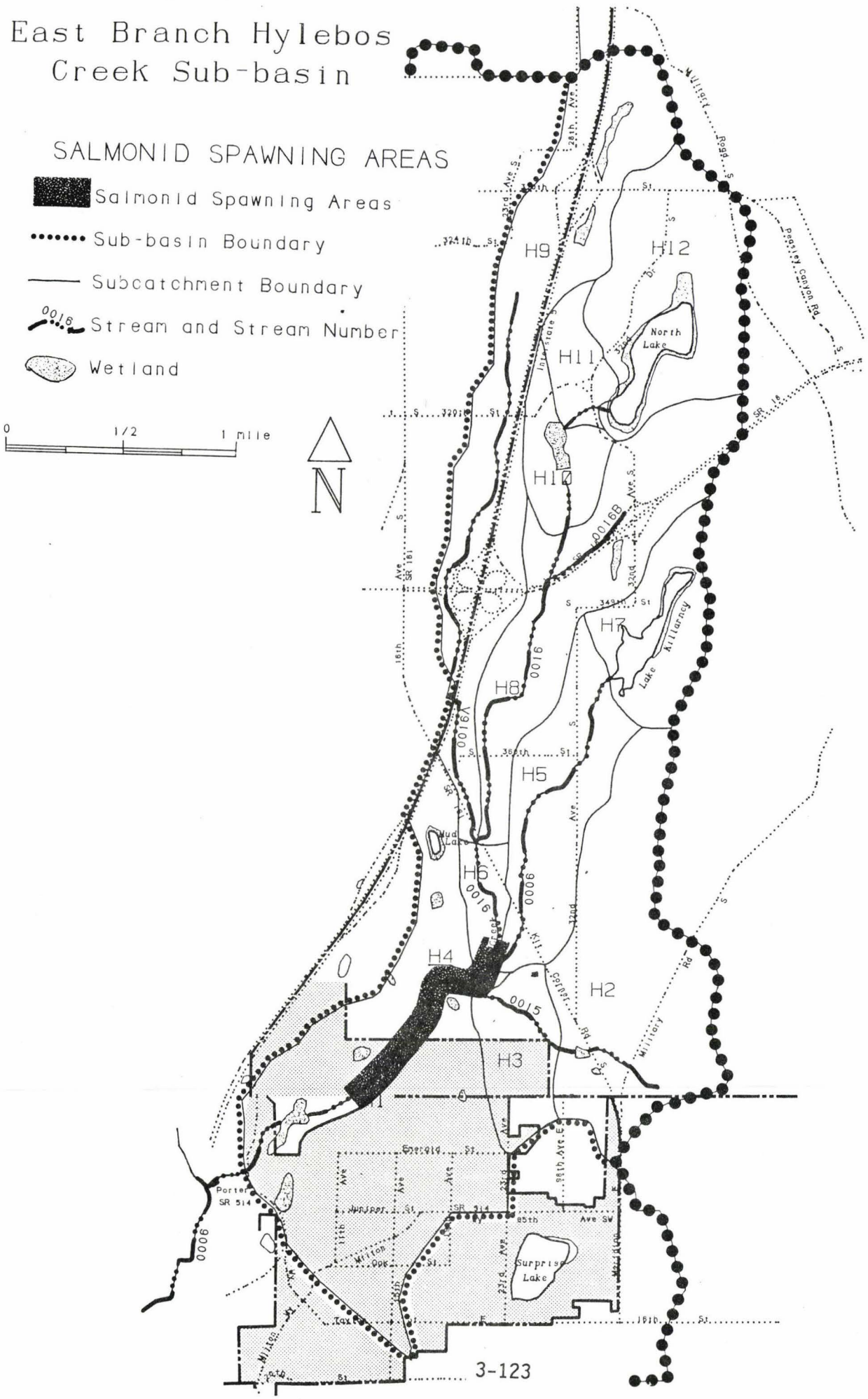


Figure 3.8.2b


East Branch Hylebos Creek Sub-basin
SALMONID SPAWNING AREAS
Salmonid Spawning Areas
Sub-basin Boundary
Subcatchment Boundary
Stream and Stream Number
Wetland
0
1/2
1 mile
N
H1
H2
H3
H4
H5
H6
H7
H8
H9
H10
H11
H12
North Lake
Lake Killarney
Surprise Lake
Mud Lake
Porter SR 514
0016
0016B
0015
0006
Military Rd
Peasley Canyon Rd
Milton Ave
Meridian Ave
Interstate 5
3-123

glacially-derived geology, the East Branch used to provide excellent spawning and rearing habitat for anadromous fish up to approximately RM 7.0 on tributary 0006, RM 0.5 on tributary 0015, and RM 0.4 on tributary 0016, with some resident fish and cutthroat habitat in upstream headwaters.

Each of the Lower Puget Sound tributaries is considerably shorter, steeper, and conveys less flow than Hylebos Creek and its main tributaries. As a consequence, even in pre-settlement times none of these streams supported large populations of salmonids, although collectively their contribution to local fish abundances may have been important.

Due to past habitat damage caused by filling of headwater wetlands; channel alterations; excessive peak flows and severe erosion; and disruptions to year-around streamflow, only McSorley, Lakota, and Joes Creeks at present support residual fish populations of any significance. All of these streams, however, are important for support of local wildlife and because of their potential for adverse impacts on Puget Sound water quality and sensitive estuarine and coastal bluff habitats.

HABITAT CONCEPTS

The ability of the Hylebos Creek and Lower Puget Sound stream systems to support resident and anadromous salmonid fish is directly related to the quality and quantity of instream and riparian habitat. Before discussing detailed habitat findings, some background information on fish and wildlife habitat is presented.

Stability of Riparian Ecosystems

Riparian ecosystems evolve naturally under conditions of dynamic change punctuated by occasional catastrophic events caused by floods, fires, and impacts from beaver activity. The occurrence of large floods--those that occur during 25-, 50-, or 100-year storms--is the major environmental factor that shapes riparian and instream habitats by causing bank cutting, debris torrents, landsliding, and sediment deposition (Hall, 1988). While periodic natural disturbance is normal in riparian ecosystems, human-caused impacts from logging, grazing, dredging, and the use of streams as conveyances for stormwater can chronically increase the magnitude and frequency of disturbance in the riparian environment, making it less suitable as habitat for fish and wildlife (Leopold, 1971; Meehan, et al., 1977).

Habitat Structure

The two primary fish habitat types are riffles and pools. Riffles are shallow, gravelly, fast-water areas that are the main food production areas of streams. Riffles provide habitat for aquatic insect species that make up most of the diet of salmon and trout, although insects of terrestrial origin falling into the stream also constitute an important source of food. Riffles also provide spawning areas for all salmonids and rearing habitat for early life stages of certain species, such as steelhead. Pools, which form in deeper, slower flowing areas or downstream from obstructions such as logs, rootwads, and boulders, are the main fish rearing and resting areas for most salmonids, including coho (Reeves, et al, 1989).

Riparian Vegetation and Large Organic Debris

Good fish habitat depends to a great degree on the many useful functions of riparian trees, shrubs, and ground cover (Sedell, et al., 1988). Root masses along stream banks help prevent erosion and maintain channel stability. As trees die and topple into the water or are dislodged due to windthrow, large organic debris (LOD) in the form of logs and stumps is added to streams. In addition to its role in pool and riffle formation, LOD provides cover, a source of nutrients, and sediment storage sites. Riparian vegetation also helps trap and filter sediments, debris, and pollutants from surface runoff. During high flows, riparian vegetation slows and disperses floodwaters, reducing water velocity and erosion that damage fish spawning and aquatic insect production areas. Riparian vegetation also buffers streams from temperature extremes that are stressful to fish. It also benefits many wildlife species by providing food, cover, migration corridors, and places for nesting and perching that are close to water, an essential habitat requirement for wildlife.

Different riparian tree and shrub species support typical groups of terrestrial insect species that are important sources of food for fish; 266 insect species have been recorded from willow, 90 from alder, and 16 from fir (Mundie, 1969, and Mundie, no date). Leaves, needles, cones, and other small woody debris entering streams from trees and shrubs are a principal source of food for many aquatic insects that are in turn eaten by young salmonids (Meehan et al., 1977). Some categories of aquatic insects are very sensitive to disturbance and tend to disappear when streamside vegetation is removed by logging, construction, or landscaping. Their disappearance can damage vital links in the food web of stream-dwelling organisms on which fish depend.

Streamflow Maintenance

All juvenile and adult salmonids need adequate flows of clean, cold (50-55 degrees Fahrenheit), well-oxygenated water for migration, spawning, and rearing. Survival of their food supply--mainly aquatic insects found in cold, fast-running water--also depends on adequate streamflows. Different salmonid species vary in their dependence on year-around streamflow, depending on how long they reside in the freshwater environment. Chum salmon, for example, spend a relatively short period of time in freshwater during incubation and development to the fry stage. Young chum fry swim downstream to feed in nearshore areas of Puget Sound almost immediately after hatching and absorbing their egg sac nutrients. Coho salmon, and steelhead and cutthroat trout, on the other hand, spend much longer periods in freshwater, and thus are much more susceptible to the damaging impacts of low flows and high temperatures. Chinook juveniles spend an intermediate amount of time in freshwater and are almost as dependent on estuarine food resources as are chum.

Urbanization alters streamflow patterns by increasing flows during storms and decreasing infiltration of rainflow into groundwater, the major source of summer streamflows (Leopold, 1971). Groundwater discharge in turn affects thermal habitat space. The size of fish and benthic invertebrate populations in a stream depends strongly on the amount of near-optimal thermal habitat available during the critical warm periods of summer. Moreover, some salmonid species select groundwater discharge areas for redd (egg nest) construction and rely on relatively stable temperatures for egg and larval development (Meisner et al., 1988). As flows decrease, juvenile fish tend to crowd into upstream groundwater discharge areas, downstream rearing areas, or get trapped and die in pools due

to lack of food and/or oxygen. Stream corridors also lose much of their value as wildlife habitat when streamflows disappear.

Wetlands

Wetlands are marshes, bogs, swamps, intertidal areas, and shallow waters of lakes and ponds. They are identified by saturated soils or by the presence of plants that require wet soils for their survival. Wetlands serve as critical fish and wildlife habitat by providing food, cover, water, refuge from predation, breeding and rearing areas, and migration paths for many animals. Wildlife diversity in wetlands is high. More than 230 species of wildlife in western Washington depend on wetlands and riparian areas for survival during one or more stage of their life cycle (Brown, 1985). As much as 90 percent of the biological energy (food for fish) produced in a stream corridor comes from adjacent wetlands and riparian vegetation. Wetlands store water in rainy periods and release it slowly during periods of dry weather. By acting as sponges during peak stormflows, wetlands protect streams from erosion and scouring. Wetlands also help filter silt and pollutants, thereby protecting water quality in streams and in Puget Sound.

Upland buffers next to streams and wetlands also provide significant resource benefit. Such buffers contain cover and nesting habitat for birds and mammals that depend on wetlands, such as bald eagles, osprey, various duck species, and beavers. Upland buffers also protect sensitive wetlands from noise, light, glare, pollutants, and predation of their inhabitants by house pets.

The King County Wetland Inventory (King County, 1983) documents 30 wetlands each in the Hylebos Creek and Lower Puget Sound basins, ranging in size from from the unique and outstanding 93 acre West Hylebos Wetland and the extensive intertidal sand flats of Dumas Bay, to remnant wetlands under one acre in size. Most of the Hylebos wetlands are smaller than five acres. The freshwater Lower Puget Sound basin wetlands average somewhat larger, just over five acres. Additional uninventoried wetlands can be found in both basins. An example of an uninventoried wetland area is the large forested wetland in Spring Valley along the north fork of the West Branch of Hylebos Creek.

Coastal Habitats

High bluffs occur along much of the Lower Puget Sound basin shoreline. These areas serve as important habitat for a number of wildlife species. They provide perching and nesting areas for birds, including bald eagles and several species of owls, swallows, and pigeon guillemots. They also provide habitat for small mammals, such as mice, shrews, and voles that are favored prey items of bluff-dwelling raptors. In addition, bluffs generally represent valuable "edge" habitat because they contain borders between terrestrial and marine habitats. Forested areas atop steep bluffs or ravines also provide nesting and roosting areas for colonies of great blue herons. A long-standing heron colony near Dumas Bay currently supports over three dozen nesting birds and their offspring, which forage in nearby estuarine habitats that contain a rich source of food.

As mentioned in Section 3.2, Geology, of this report, bluffs are prone to erosion and landslides due to a variety of natural and and human-caused forces. Erosion may occur when vegetation is disturbed or removed, when construction occurs too close to the edge, or when runoff is carelessly routed over the face of a bluff. Landsliding may occur due to wave action or groundwater, and is a fairly common

occurrence after heavy rainfall or in locations containing springs and poorly defined soil strata. Natural erosion of bluffs along beaches is important to sediment-dependent habitats on associated beaches and in shallow intertidal and subtidal areas. However, excessive erosion and landsliding related to development can be extremely damaging to coastal habitats.

Effects of Urbanization on Habitat

The effects of development on watersheds are pervasive and generally damaging to fish and wildlife habitats. As discussed in Section 3.3., Hydrology, the magnitude and frequency of floods may be doubled or more by future urbanization of the basins. With increased flows and especially where protective riparian vegetation is absent, stream channels tend to be widened and stream beds scoured by the erosive forces of high velocity water and transported sediments. Scouring flows also remove much of the habitat-stabilizing LOD within streams, reducing habitat diversity and sediment storage capacity. Urbanization also increases the total amount of sediment, dissolved solids, and pathogenic bacteria entering streams from terrestrial sources (Leopold, 1971). Even in fully developed watersheds, suspended sediment loads are chronically increased by runoff from roads, parking lots, and other impervious surfaces (Whipple, et al., 1981). These impacts lead to loss of spawning and rearing habitat for fish due to filling in of pools and siltation and compaction of spawning gravels. Frequent and prolonged high flows also result in replacement of spawning gravels by cobble too large to be used by fish for spawning. In extreme cases, all gravels may be scoured down to bare glacial till or bedrock.

Other effects of urbanization include riparian corridor and channel alterations such as removal of streamside vegetation and instream LOD, channel straightening and dredging, construction of roads and bridges, stream bank armoring, and the loss of off-channel areas that are a refuge for fish during extreme flood events. While these activities may be viewed as necessary for full use of property or to protect against flood flows, they also fragment riparian corridors and open them up to disturbances by humans, domestic animals, and influxes of pollutants. They also cause loss of habitat and food-chain support for both fish and wildlife. Some alterations such as bank armoring and channelization decrease the roughness of channels and accelerate flows, while others, such as bridges and culverts can cause local flow constrictions and flooding during storms.

Another prominent effect of urbanization is destruction of wetlands, resulting in losses of fish and wildlife habitats, flood storage, sediment trapping, biofiltration, and groundwater exchange areas. These changes amplify the effects of urbanization listed above. Some of the most severe losses of wetland habitats in the Hylebos Creek and Lower Puget Sound basins have occurred in forested and scrub-shrub swamps. These areas are frequently overlooked because their wetland characteristics are more difficult to identify, inventory, and map.

DATA GATHERING METHODS

Information in this section was gathered from several sources. All stream channels were walked in 1986 and 1987 during the Basin Reconnaissance Program (King County, 1987) in order to collect data on habitat conditions. All fish-bearing stream segments in the Hylebos Creek basin were walked again in 1989 and

1990 for this report. Where habitat problems were found, additional stream segments above fish-bearing reaches were walked to investigate causes of habitat damage. This report also incorporates observations contained in a Hylebos/Lower Puget Sound habitat study performed by Metro in 1987 (Ridge-Cooney, 1988) and information supplied by the Puyallup Tribe of Indians and local residents.

Recent History of Fish Use

At the present time, most salmon spawning in the Hylebos Creek system takes place in the West Branch, although small numbers of fish--mostly coho--still spawn in the East Branch where it flows through a wooded ravine north of Milton. Until the mid-1980s moderate numbers of chum and coho, plus a few steelhead, chinook, and cutthroat also spawned in the north fork of the West Branch. Chinook and steelhead have virtually disappeared in this tributary since an oil spill thought to have occurred in 1986, and spawning by other species has been greatly reduced due to episodes of severe sedimentation from excessive peak flows and poor erosion control at upstream construction sites. Losses of spawning habitat due to erosive peak flows have also recently occurred in the lower half mile of tributary 0015.

Annual salmon spawner counts have been conducted in Hylebos Creek and its tributaries by the Puyallup Tribe of Indians since 1980, and a few counts were made before that by the Washington Department of Fisheries (WDF). Figures 3.8.1a and b identify salmonid spawning areas in the West and East Branches of Hylebos Creek. These counts document that the West Branch now supports mainly chum salmon, with smaller numbers of coho and chinook and occasional steelhead also present. Mainstem Hylebos Creek supports small numbers of coho, although a few chum spawn there as well. As shown in Tables 3.8.1a and b, chum salmon spawner survey counts have varied considerably over the past 15 years; the highest weekly peak survey count was 90 chum salmon in the West Branch in January 1987. By contrast, coho spawner counts have fallen off sharply in both Hylebos sub-basins since the late 1970s; the highest peak weekly count was 84 fish in the West Branch in January 1977. At the present time, populations of both chum and coho are believed to be sustained largely by the out-planting of salmon fry reared at the Puyallup tribal hatchery. Table 3.8.2 summarizes the fry out-planting records for the Hylebos Creek system. It can be presumed that substantial numbers of returning fish from these out-plantings are harvested by Indian and non-Indian fisheries in Canadian and Puget Sound waters during their migration as adults back to Hylebos Creek.

Table 3.8.1a

SPAWNER SURVEYS OF
WEST BRANCH HYLEBOS CREEK
(0013, RM 1.5-1.7)

PEAK SPAWNER COUNTS*

YEAR	SURVEYED BY**	COHO	CHUM	CHINOOK	PEAK COUNT SURVEY DATE
1976-77	WDF	84	--	--	01-03-77
1979-80	WDF	7	2	--	11-16-79
1980-81	PT	20	20	--	12-09-80
1981-82	PT	2	1	--	12-08-81
1982-83	PT	6	22	--	01-20-82
1983-84	PT	8	46	--	12-15-83 Chum
1984-85	PT	5	78	7	12-06-84; 10-02-
1985-86	PT	4	11	0	12-04-85 84
1986-87	PT	0	90	0	01-23-87 Chum
1987-88	PT	5	13	8	11-19-87; 10-28-
1988-89	PT	5	3	0	11-30-88 87

* These counts represent maximum spawners observed during a single survey, within a series of weekly surveys.

** WDF = Washington Department of Fisheries
PT = Puyallup Tribe of Indians

Table 3.8.1b

SPAWNER SURVEYS OF
EAST BRANCH HYLEBOS CREEK
(0006, RM 5.5-5.7; 0015, RM 0.0-0.5)

PEAK SPAWNER COUNTS*

YEAR	SURVEYED BY**	COHO	CHUM	PEAK COUNT SURVEY DATE
1980-81	PT	15	1	12-17-80
1981-82	PT	4	1	12-17-81 Coho 11-17-81 Chum
1982-83	PT	2	0	12-08-82
1983-84	PT	3	0	12-06-83
1986-87	PT	0	7	12-29-86
1989-90	KC	6	0	12-13-89

* These counts represent maximum spawners observed during a single survey within a series of weekly surveys.

** WDF = Washington Department of Fisheries
PT = Puyallup Tribe of Indians

Table 3.8.2

FISH PLANTED IN HYLEBOS TRIBUTARIES
BY PUYALLUP TRIBE OF INDIANS

WRIA	SPECIES	BROOD YEAR	PLANTING DATE	APPROX. NO./FISH POUND	POUNDS PLANTED	NO. FISH PLANTED
0006	Chum	1976	4/26/77	450	239.7	107,865
0013	Chum	1976	4/26/77	480	302.8	145,350
0006	Chum	1977	4/27/78	400	109.1	43,625
0013	Chum	1977	4/27/78	375	34.4	12,900
0006	Coho	1977	4/11/78	550	33.0	18,150
0006	Coho	1977	4/11/78	650	30.5	19,825
0013	Coho	1977	4/11/78	650	34.5	22,425
0013	Steelhead	1980	1/22-23/81	13	412.5	5,363
0006	Coho	1981	3/30/82	321	91.8	29,452
0013	Coho	1981	3/30/82	321	81.5	26,060
0006	Coho	1982	4/12/83	398	69.0	27,402
0013	Coho	1982	4/12/83	398	89.0	35,352
0006	Coho	1984	3/07/85	629	54	33,966
0013	Coho	1984	3/07/85	689	53	33,337
0006	Coho	1985	4/09/86	1,400	16	22,400
0013	Coho	1985	4/09/86	1,400	16	22,400
0013	Chum	1986	5/07/87	694	63	43,722
0006	Coho	1986	2/17/87	927	20	18,540
0013	Coho	1986	2/17/87	927	21	19,467
0006	?	1987	2/25/88	1,050	20	19,480
0013	?	1987	2/25/88	974	20	21,000
0013	Chum	1988	4/04/89	1,090	26	28,340

CONDITIONS

Current Habitat Conditions

At present, fish and wildlife habitats in the Hylebos Creek and Lower Puget Sound basins vary from good to very poor. While some good instream, riparian, and wetland habitats remain, development-related habitat problems are common. For example, instream habitat in the East Branch was damaged when part of the West Branch was diverted into its headwaters in the mid-1960s during construction of I-5. Fish habitat in the East Branch has since been affected by high-volume flows, erosion, and pollution. Much of what was the most productive spawning habitat in the system--in the vicinity of S 373rd Street on the West Branch--has been devastated by sedimentation of the stream channel by gravel, sand and silt from erosional areas upstream. This reach has also been repeatedly disturbed by channelization and dredging, removal of habitat-forming LOD and riparian vegetation, and bank trampling by cattle.

Habitat in the headwaters of the Hylebos Creek and Lower Puget Sound systems has been decreased or eliminated by the routing of long stream segments inside culverts, and by alterations in flow regimes that cause headwater areas to dry up in the summer and during low flow winter periods in dry years. Habitat in the lower mainstem of Hylebos Creek has been harmed by channelization and dredging, and by encroachment into the riparian zone by roads, bridges, and inadequate building setbacks.

Several tributaries of the Hylebos Creek and Lower Puget Sound systems are at present ephemeral (e.g., tributaries 0014A, 0014C) or intermittent (tributaries 0016 and 0016A and upper 0386 and 0387). The cause is unknown but suspected to be due at least in part to a decrease in upland groundwater recharge, groundwater withdrawals for water-supply use, or disconnection of these headwater areas from former perennial groundwater discharge zones. In terms of fish habitat, low or non-existent summer flows have resulted in severe limitations in the quantity and volume of juvenile rearing areas during the summer months.

Intertidal habitat at the former mouth of Hylebos Creek originally consisted of a network of small, dendritic channels draining through vast mudflats fringing Commencement Bay. Starting in the 1920s, over 90 percent of this habitat was filled or dredged during construction of docks and industrial sites on Hylebos Waterway. Since then, the waterway has been regularly dredged to accommodate marine vessel traffic. Restoration of wood-waste and arsenic-contaminated areas at the head and outlet of the waterway is currently planned as part of the ongoing EPA Superfund cleanup of Commencement Bay (see Section 3.7 for further discussion). Intertidal habitat has also been lost along the Puget Sound shoreline due to bulkheading of marine shoreline areas streambank armoring near the mouths of streams that has disrupted formation of alluvial tideflats.

At least half the freshwater wetlands in both basins have been eliminated or significantly altered by filling and removal of native vegetation. Examination of aerial photographs from 1936 and 1988 shows a 30 percent loss of wetlands in the Hylebos Creek basin and a 21 percent loss in the Lower Puget Sound basin during this period alone. A prime example of the complex consequences of wetland loss is illustrated by alterations to Panther Lake that have degraded habitat not only in the lake itself, but far downstream as well. Over the years about half of the 18 acres of palustrine wetlands within and surrounding the lake have been filled to convert this formerly hydrologically isolated, shallow,

seasonal pond into a retention/detention facility with an outlet routed into West Branch Hylebos Creek. Over this same period of time, several other wetlands in nearby subcatchments were also partially or completely filled, with runoff from the resulting impervious surfaces routed into Panther Lake. With the influx of stormwater and erosion from construction sites, water quality in the lake has declined due to turbidity and other pollutants, and sediments have accumulated on the lake bottom, decreasing the lake's flood storage capacity. The accumulation of bottom sediments also appears to be interfering with the lake's ability to infiltrate stormwater back into the underlying groundwater. As a result, the lake discharges high volumes of poor-quality water into Hylebos Creek during storms, causing flooding, erosion, and siltation of wetlands and streambeds for miles downstream. The lake may also be an important groundwater recharge area for subsurface flows that discharge within the West Hylebos Wetland. Disruption of these hydrological connections could cause this important wetland to dry up in the summer, further stressing its plant community, which is already experiencing stress from increased frequencies and durations of flooding during winter storms.

Although urbanization has taken a heavy toll, good habitats can still be found in a few places. For example, there is productive rearing habitat for fish and good wildlife habitat within a wide, relatively undisturbed riparian corridor on West Branch Hylebos Creek between I-5 and SR 99 south of S 373rd Street. In tributary 0013 downstream from S 359th Street to the confluence of the West Branch, fish and wildlife habitats are buffered by a large forested wetland that helps absorb excessive stormflows and dampens the erosive forces that have crippled habitat elsewhere in the basin. This segment of tributary 0013 currently represents the only remaining portion of the Hylebos Creek stream system containing both spawning and rearing habitat, although, as mentioned above, it is currently underutilized by anadromous fish. Small patches of excellent estuarine habitat can be found at the outlet of Inner Hylebos Waterway and in Dumas Bay.

Dumas Bay

Dumas Bay is a 253 acre intertidal sandflat that receives discharge from five small streams that drain the upland plateau: Joes and Lakota Creeks, and three unnamed streams (0390A, 0390B, 0390C). The three unnamed streams drain into Dumas Bay through a freshwater emergent wetland with adjacent deep marsh and forested habitats. Both wetlands are considered unique and outstanding by King County.

Dumas Bay and similar estuarine embayments throughout Puget Sound provide important nursery, breeding and feeding areas for a variety of species, many of commercial interest, others of importance for their ecological role. Such estuarine bays are extraordinarily productive areas for marine algae, seagrasses, plankton, and the creatures that feed upon them, including crab and juvenile fish. Dumas Bay contains extensive eelgrass (*Zostera marina*) beds that are critical habitat areas for juvenile fish. Native seagrass is of much concern to scientists as its extent seems to be declining in Puget Sound for as yet unknown reasons. An estimated 90% of commercial species of crab, shellfish and finfish harvested from Puget Sound depend on estuarine bays for some phase of their life cycle. Commercially important species known to reside in Dumas Bay include: dungeness crab, littleneck clam, manila clam, geoduck, English sole, sand sole and juveniles of pink, chum, coho and chinook salmon. Other species of interest that occur in Dumas Bay and are dependent upon its productivity are:

the great blue heron--a rookery of some 30 to 40 nests occurs adjacent to the bay and herons can regularly be observed feeding on the flats; black brant which feed on the eelgrass beds of the bay and are a "species of national concern" to the US Fish and Wildlife Service, and a "sensitive species" to the Washington Department of Wildlife; bald eagle, which has "threatened" status in Washington; and harbor seals and occasional northern sea lions.

The deep marsh habitat of the freshwater marsh is dominated by cattail, yellow iris, nightshade, softstem bulrush, and various species of willow. The forested habitat contains stands of western red cedar, western hemlock, and red alder. Avian species observed in the marsh include: belted kingfisher, sharp-shinned hawk, green heron, rufous hummingbird, and red-winged blackbird.

During the last decade, extensive development on the bluffs and slopes surrounding the bay has encroached on the bay's shoreline and on the northern edge of the freshwater marsh. In particular, delivery of sediment to the marsh has increased with increasing disturbance of the uplands and slopes surrounding the ravines of streams 0390A and 0390B. The easternmost portions of the marsh and forested areas continue to receive significant amounts of fine sand with each winter storm. The ravines have become increasingly unstable and will continue to erode for some time, particularly as the volume of stormwater increases from the developed areas on the uplands. The deep marsh, with its open water habitat, is particularly vulnerable to this deposition. The change in bottom elevation with deposition will cause loss of the deepwater habitat in a much shorter time than would occur under natural conditions. Encroachment on the northern edge of the marsh occurred in 1987 when fill was placed for single family dwellings. No further filling is expected in this area and the southern border of the marsh is protected as a King County park and wildlife preserve.

The bay itself has suffered direct impact from shoreline protection measures such as bulkheading and rip-rapping, especially along its northern shoreline near the mouths of Lakota and Joes Creeks. Bulkheading has been employed in an attempt to stabilize the toe of the steep bluffs that rise above the beach. Slope failures remain quite common in this area, however, and may be exacerbated by slope clearing and improper drainage over the bluff edge. Recent slope clearing, presumably for improved views, can affect the diversity and stability of surrounding fish and wildlife habitat.

In the northeastern quadrant of Dumas Bay, near the mouth of Lakota Creek, a wastewater treatment plant discharges some 1,000 million gallons per year of secondary sewage effluent into the bay. Until 1988, the plant discharged wastewater which had undergone only primary treatment. Dumas Bay lies at the end of south-trending surface and sub-surface currents, and is a major depositional area for sand conveyed south by longshore transport. It may also be on the eastern edge of a local tidal/current gyre in lower East Passage which tends to provide sediment deposition as well as nutrient recirculation. Though convincing evidence is lacking, the plant outfall may be a contributer of nutrients, metals and coliform bacteria to the bay. The Puget Sound Environmental Atlas lists five heavy metals found in Dumas Bay sediments:

METAL	CONCENTRATION
Cadmium	85 ppb*
Copper	3 ppm**
Mercury	6 ppb
Lead	5 ppm
Zinc	24 ppm

* ppb = parts per billion
** ppm = parts per million

These concentrations are not considered harmful to humans, but that they were found at all is somewhat disturbing, although not altogether unexpected. How these metals are transmitted through the food web of the bay, if they are, is largely unknown. The bay is permanently closed to commercial shellfish harvesting, as are all eastern Puget Sound beaches from Meadowdale in Snohomish County to Commencement Bay in Pierce County, due to water quality degradation.

KEY FINDINGS

Summary of Current Habitat Conditions

- Approximately 90 percent of the estuarine habitat formerly associated with lower Hylebos Creek has been eliminated due to construction of docks and industrial sites on Hylebos Waterway. Estuarine habitats in Dumas Bay are threatened by excessive sedimentation from upstream erosional areas.

- The filling of wetlands has directly reduced the quality and quantity of areas for fish and wildlife breeding, nesting, feeding, and predator escape. Numerous habitats have also been damaged indirectly by loss of wetland functions such as flood storage, sediment trapping, water quality protection, groundwater exchange, and resulting impacts of increased peak flows on instream and riparian habitats.

- Elimination of native riparian vegetation to the stream edge has occurred in many segments of the Hylebos and Lower Puget Sound stream systems due to logging, agricultural practices, channelization for flood control, construction of stream crossings and buildings, and landscaping. Even where dense riparian vegetation remains there has been wholesale replacement of conifers by smaller deciduous trees and shrubs in many areas.

- The quality and quantity of instream habitat in many parts of the Hylebos and Lower Puget Sound stream systems has been degraded or eliminated by channelization and removal of LOD, resulting in loss of channel diversity and sediment storage capacity.

- Damage to habitats from excessive peak flows is widespread in the drainages. In many portions of the Hylebos and Lower Puget Sound stream systems, low or non-existent summer flows have resulted in severe limitations in the volume and quality of juvenile fish rearing areas and wildlife habitats during the summer months and during winter low flow periods of dry years. The cause is unknown but suspected to be due at least in part to a decrease in upland groundwater recharge, groundwater withdrawals for water-supply use, or disconnection of these headwater areas from former perennial groundwater discharge zones.

- Continued increases in the intensity and magnitude of peak flows will reduce or eliminate remaining instream habitats. Over the long term these impacts to habitat may be compounded by the combined effect from rising sea level and land subsidence.

SECTION 3.9 PUBLIC/PRIVATE SECTOR ACTIONS AND FUTURE DIRECTIONS

INTRODUCTION

There are many local, state, and federal agencies, as well as tribal and community programs, working to prevent and correct surface and groundwater problems in the Hylebos Creek and Lower Puget Sound basins. Among them are the Conservation Districts, the Soil Conservation Service, the State Departments of Ecology, Fisheries, Game, Natural Resources, the King County Cooperative Extension Service, Environmental Protection Agency; local governments; citizens' groups; and many separate other individuals and agencies. However, despite some gains made from these many efforts, conditions have continued to deteriorate. A major reason for the decline is the lack of a common blueprint of objectives and actions for the basins that a basin plan can provide. Entities at all levels are focused on their mandates to protect specific resources or provide specific services to their service area. This condition is a principal factor in the absence of a clear direction for the basins, and therefore, the lack of a unified effort to resolve its problems.

This section discusses factors that underlie the physical conditions in the basins including the roles government agencies, development activity, and the general public have in the Hylebos Creek and Lower Puget Sound basins. This discussion also identifies the functions of the basin plan as a means of improving past approaches to surface water management in these basins. Table 3.9.1 lists and describes the roles the federal and state agencies, tribes, special purpose districts, and other resource agencies with a role in surface water management in the basins.

CONDITIONS

Local Governments

One of the most important factors contributing to the current conditions in the basins are local land use plans and development codes. The intensity and density of land uses allowed and the ability of codes to effectively mitigate development impacts, are crucial elements of preventive surface water management. However, there are broad differences among local entities in the effectiveness of these plans and codes in managing surface water problems.

The planning area includes eight local governments: Des Moines, Federal Way, Fife, Kent, King County, Milton, Pierce County, and Tacoma. While all of these jurisdictions have land use plans and regulations for stormwater detention and some regulations for protecting steep slopes and for filling and grading activities, the land use plans and ordinances of some jurisdictions are more restrictive than others. This is especially true for stream and wetlands management. Resource managers have learned only relatively recently that protecting stream systems and wetlands often necessitates strict setback requirements and low-density zoning to be effective. Most local land use plans and codes in the basins were developed prior to this information becoming generally available; therefore, many codes do not include these types of provisions. However, some local entities are attempting to reverse this trend, including Federal Way, who has enacted several important sensitive area requirements that will help conserve these resource areas and mitigate future storm flows. Des Moines is

Table 3.9.1

ROLES OF STATE AND FEDERAL AGENCIES, TRIBES, REGIONAL AGENCIES, AND SPECIAL PURPOSE DISTRICTS IN MANAGING RESOURCES IN THE HYLEBOS CREEK AND LOWER PUGET SOUND BASINS

Federal Agencies:	
Federal Emergency Management Administration (FEMA)	Provide technical assistance on flood prevention and management to local governments; determine requirements for participation in the federal flood insurance program; administers flood insurance funds.
U.S. Army Corps of Engineers	Administers regulations for dredging in Hylebos Waterway, Commencement Bay, and Puget Sound; administers regulations for projects involving placement of dredged and fill material in wetlands and waters of the United States Environmental Protection Agency.
U.S. Environmental Protection Agency	Develops and jointly enforces federal wetlands regulations administered with the U.S. Army Corps of Engineers; funds and manages the Commencement Bay Superfund Clean-up.
U.S. Fish and Wildlife Service	Administers resource protection regulations for federally protected threatened and endangered species; reviews and comments on actions affecting wetlands and waters of the United States, including Commencement Bay and Puget Sound.
U.S. Soil Conservation Service	Provides technical service and financial assistance to commercial agriculture operators for preventing and correcting soil erosion problems.
Indian Tribes:	
Muckelshoot Tribe	Receiving waters in Commencement Bay and Puget Sound are part of the Tribe's usual and accustomed fishing grounds.
Puyallup Tribe	Receiving waters in Commencement Bay and Puget Sound are part of the Tribe's usual and accustomed fishing grounds; monitor spawning activity in the basins, and conduct a fish enhancement program in Hylebos Creek.
Regional Agencies:	
Metro	Monitors water quality in the planning area; monitors water quality in Steel Lake; participates in the Southwest King County Groundwater study.
Special Purpose Districts:	
Federal Way Water and Sewer District	Provides sewer and water service to its service area; monitors surface water quality; participates in the development of the South King County Groundwater Management Plan.

Table 3.9.1 (Cont.)

Pierce County Drainage Districts 21 and 23	Implement drainage projects to prevent stormwater from flooding properties within the District service areas.
Port of Tacoma	Manages development of Port lands and facilities and maintains navigation corridors within their jurisdiction; participates in the Lower Puyallup River Watershed Action Plan and Commencement Bay Superfund Clean-up.
State Agencies:	
Department of Ecology (Ecology)	Administers state water quality regulations; provides technical assistance and oversight to local governments in the administration of the State Shoreline Management Act; reviews and comments on actions affecting wetlands; provides technical assistance to local governments in wetlands management of wetlands, nonpoint source pollution, and stormwater; approves local groundwater management plans.
Department of Social and Health Services	Administers drinking water standards and septic system permit requirements for large developments.
Departments of Fisheries and Wildlife	Administer regulations for activities within the ordinary high water mark of streams and lakes, and Puget Sound.
Department of Natural Resources	Owns and regulates activities in the aquatic lands of Commencement Bay and Puget Sound; administers commercial forest practices regulations.
Department of Wildlife	Administers regulations to protect threatened and endangered wildlife species.
Pierce and King County Conservation Districts	Provide technical services and public educational programs for preventing and correcting sedimentation and water quality problems from soil erosion and animal keeping practices.
Puget Sound Water Quality Authority (PSWQA)	Develops and oversees implementation plans to protect and restore water quality from point and nonpoint sources in Puget Sound and its tributary areas, including requirements for local governments to develop stormwater management programs and basinwide nonpoint source management plans; provides funding for public information and education programs.
Washington State Department of Transportation	Constructs and maintains state highways, including I-5, SR 18, SR 99, SR 161, SR 509, and SR 514.
Washington State Parks and Recreation Commission	Operates Dash Point and Saltwater State Parks; is developing an environmental interpretive center in the West Hylebos Wetland.

considering a comprehensive sensitive area ordinance, while King County is also considering major amendments to its sensitive areas ordinance.

Another factor contributing to conditions in the basins is the level and effectiveness of enforcement of regulations. Local enforcement programs can also vary according to the jurisdiction. For example, some entities may have more personnel than others to enforce sensitive areas ordinances or construction and maintenance standards for stormwater systems. Another variable among local stormwater management programs is that some jurisdictions may have a dedicated source of funds, such as the King County or a Federal Way stormwater utility, which enables them to more readily provide needed facilities and services for the public stormwater system.

Due to the wide variation in surface water management programs among local governments, efforts to improve conditions in the basins at this level must be well coordinated. For example, what may be done by upstream jurisdictions to reduce surface water volumes or improve its quality, if not highly coordinated, may be unintentionally undone by the policies and actions of downstream entities. In the same way, preventive or corrective measures taken by downstream entities may be compromised by upstream actions as well.

Prior to initiating the Hylebos Creek and Lower Puget Sound Basin Plan, no vehicle was available to systematically coordinate both local actions in the basins and those of state and federal agencies and Indian tribes. This basin plan provides the framework through which common objectives and solutions can be agreed upon and implemented in a unified way.

State and Federal Agencies

Of the many state and federal agencies identified in Table 3.9.1, most function to protect natural resources from the effects of development activity by conditioning permits according to agency policies and regulations and through enforcement actions. For example, the State Department of Ecology, the U.S. Environmental Protection Agency, and the U.S. Corps of Engineers regulate water quality or wetlands-related actions. Some agencies, such as the Department of Ecology, have no regulatory authority for certain actions, such as wetlands protection, but they often provide important research and technical assistance roles in these areas.

Table 3.9.1 shows that different agencies address different resource concerns; however, for some resource issues, there may be gaps where little or no regulatory direction exists, as is the case with nonpoint water quality and wetlands management. Sometimes an agency's ability to correct problem conditions may result from insufficient technical know-how to mitigate for development impacts, but all too often it results from the lack of adequate fiscal resources to keep pace with rapidly expanding development pressures. Also, different agencies can operate under divergent objectives that may conflict. For example, the Department of Natural Resources issues permits for forest practices as part of its mandate to manage commercial forest activities; such practices, however, can result in increases in sediment loading to nearby streams, which conflict with the water quality objectives of the Department of Ecology. A multiplicity of the regulations and objectives in some cases can lead to inconsistent management of the resources.

While procedures are in place for coordinating permit activities among local, state, and federal entities, a consistent unifying direction to manage basin

resources among these entities does not exist. The basin planning process provides the means to achieve that objective.

Development Activity

Development activity has influenced surface water conditions in the planning area significantly. For example, construction practices in which erosion and sedimentation measures and other types of Best Management Practices are not properly installed or maintained have enabled large volumes of soil to be carried to nearby surface waters, adding to the heavy loads of sediment from instream erosion in the basins.

A recent study to assess the effectiveness of Best Management Practices on construction sites throughout King County was conducted by the King County Conservation District (Tiffany et al., 1990). Eighty-six site visits were made to sixty construction sites. The study found that three sites (5%) had effective controls in place during the study period. The primary reasons specified for the remaining 95 percent having ineffective controls included inadequate installation, poor timing of installation with respect to weather conditions, and insufficient maintenance.

In the past ten years, King County has issued over 6,000 construction permits in the planning area with requirements for erosion and sedimentation controls (King County Planning Division, 1989). On the basis of the King County Conservation District findings, a likely conclusion is that the vast majority of these sites may have contributed to the erosion and sedimentation in the basins during this period.

It is recognized that much of the problem of poor soil conservation practices in construction sites may stem from insufficient knowledge on the part of developers and construction workers in the use of Best Management Practices. In many instances, however, this information has been available, but has not been implemented in practice due to inadequate enforcement staff, a lack of attention to the conditions by the development community, or both.

Individual Actions

In addition to regulatory considerations and development-related activities, the decline in these basins can be traced to the daily activities of the thousands of individuals in the general public whose often inadvertent or well-intentioned actions can harm stream and wetland systems. Filling of wetlands, rerouting of stream channels, removal of instream habitat forming debris or streamside vegetation, heavy reliance on automobiles, excessive use of fertilizers and pesticides, poor animal-keeping practices, and poor handling of toxics and other contaminants, have collectively had a substantial impact on the quality and flow conditions of the streams and wetlands in the basins today.

Comprehensive Planning

In the future, it will be essential to ensure that the preventive and corrective actions of all entities and the public in the basins are well integrated to improve on historic approaches to surface water management. The Hylebos Creek and Lower Puget Sound Basin Plan is one of several major planning and action-oriented efforts under way in the basins to achieve this objective. The other endeavors described in Table 3.9.2 include the South King County Groundwater

Management Plan, the Pierce County Public Works Hylebos Creek Basin Surface Water Management Plan, the Lower Puyallup River Watershed Action Plan, and the U.S. Environmental Protection Agency Commencement Bay Superfund Clean-Up. Each of these projects addresses a specific aspect of surface- or groundwater-conditions in a portion of the basins. For example, the Superfund Clean-Up is working to reduce nonpoint source pollution in the vicinity of Hylebos Waterway, which flows into Commencement Bay, while the Pierce County Stormwater Master Plan is focused on solutions to storm flows in the Pierce County portion of Hylebos Creek.

The Hylebos Creek and Lower Puget Sound Basin Plan will compliment these efforts by providing comprehensive surface water management solutions to stormwater flows, as well as water quality degradation, and habitat conditions in both basins. The recommendations will include capital improvement projects, development codes, and public education programs. The plan recommendations will be closely coordinated with the other planning projects in the basins for consistency. The combined results of these projects will significantly affect how regulatory agencies, development community, and the general public will directly and indirectly affect the conditions in Hylebos Creek and the Lower Puget Sound basins in the future.

Implementation of each of these planning efforts has the potential to provide an important framework for future cooperative action among the entities, the general public, and the private sector in the affected portions of the Hylebos Creek and Lower Puget Sound basins. However, it is not clear whether the sustained resources needed will be made available to implement these efforts. In addition, while there currently appears to be a movement among the public to change individual life styles that harm the environment, it is unclear whether this trend will continue to take hold, or that it will be sufficiently strong to help these more comprehensive efforts succeed.

KEY FINDINGS

- Among the local governments in the basins, there are varying regulations and surface water management programs that without a high degree of coordination have the potential to conflict with each other. This can create inefficiencies in the delivery of stormwater facilities and services which could be avoided with joint or coordinated actions.

- Many local, state, and federal regulations are in place to deal with stormwater problems; however, insufficient funding, lack of regulatory authority in some cases, and the rapid pace of development are hampering their effectiveness.

- Conditions in the basins have been degraded not only by development activity, but also by the daily activities of residents who can unknowingly contribute to the problems. Public education throughout the basins is needed to overcome this problem.

- Several major watershed based plans are in progress, in addition to the Hylebos Creek and Lower Puget Sound Basin Plan, and each has the potential of guiding future actions in the basins more effectively than in the past.

Table 3.9.2

SURFACE AND GROUNDWATER MANAGEMENT PROJECTS IN THE HYLEBOS CREEK AND LOWER PUGET SOUND BASIN PLAN AREA

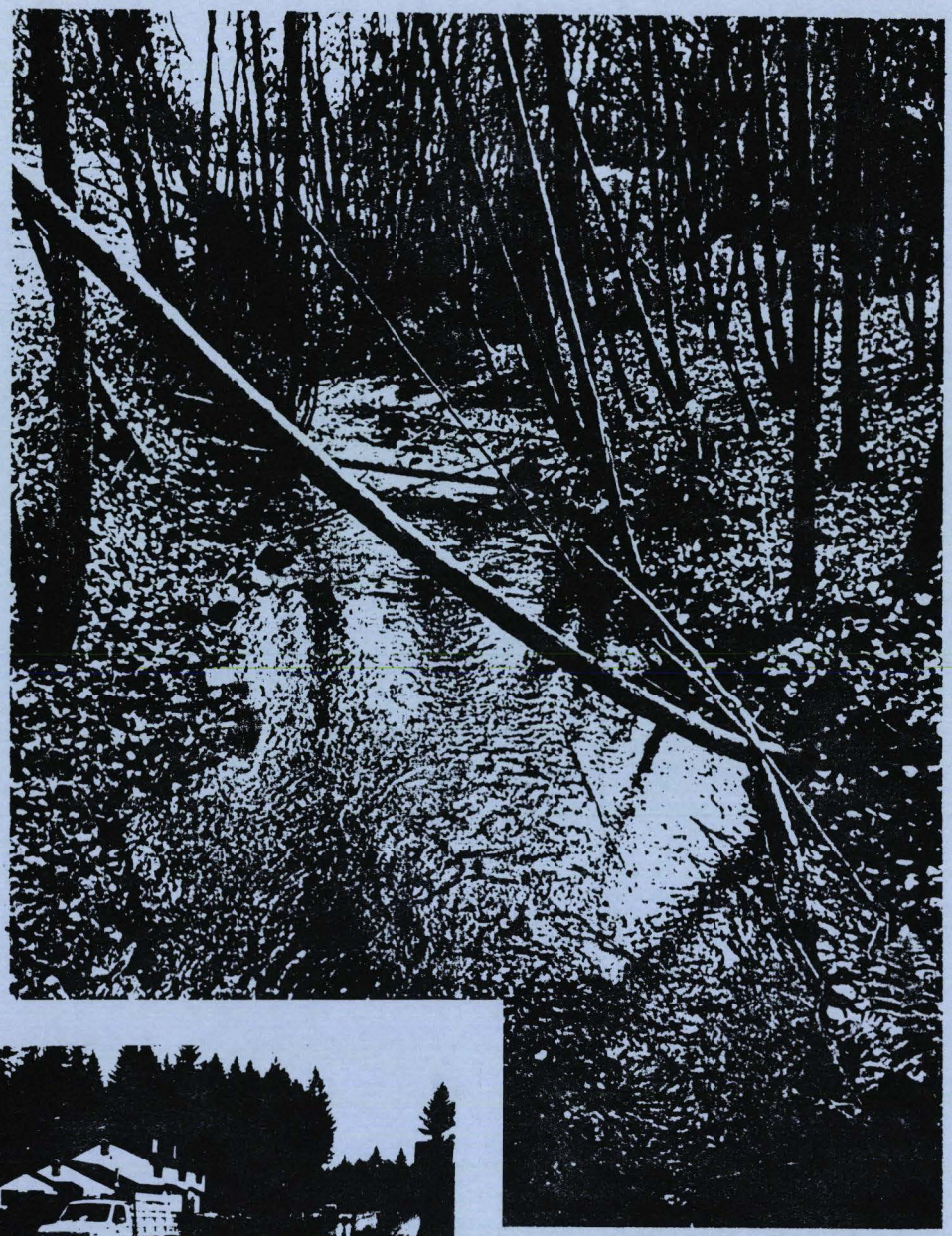
The South King County Groundwater Management Plan: The South King County Groundwater Management Plan is a cooperative effort by water purveyors and local and state agencies that is being prepared in two phases. In Phase I, information is being collected on the quality and quantity of groundwater in the project area. This phase was expected to be completed in 1989. Phase II will identify the policies and programs needed to manage groundwater supplies and protect their quality in the future. The Hylebos Creek and Lower Puget Sound basins are both within this planning area. See also Section 3.5, Groundwater, and Section 3.7, Water Quality, for further information on this study.

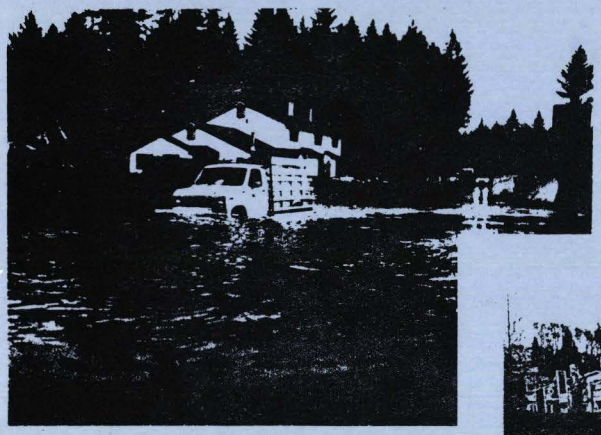
The Pierce County Public Works Department Stormwater Master Plan: The Pierce County Storm-Water Master Plan is a cooperative planning process among entities in Pierce and King County to identify surface water management needs within the Pierce County portion of the Hylebos Creek basin. This study is part of an initial countywide assessment intended to provide preliminary cost estimates for purposes of establishing a stormwater utility and rate structure in Pierce County. It is expected that a more detailed study of this portion of the Hylebos Creek basin will be needed prior to implementation of this plan. (In contrast, the Hylebos Creek and Lower Puget Sound Basin Plan, being developed for the King County/Federal Way portion of the Hylebos Creek basin, is an intentionally more detailed study that will identify solutions which can be designed and implemented following plan adoption.) The Pierce County Hylebos Creek Basin Plan portion of the countywide plan is expected to be completed in August 1990.

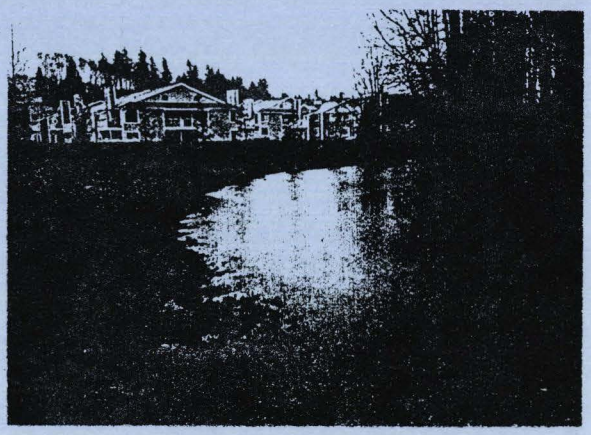
The Lower Puyallup River Watershed Action Plan: The Pierce County Planning and Natural Resource Management Department is the lead agency for the Lower Puyallup Watershed Action Plan. This is a highly coordinated effort among all jurisdictions, agencies, and the public to develop a framework of strategies for managing nonpoint source pollution in the watersheds of Lower Puyallup River, including all of the Hylebos Creek basin in King and Pierce County. Completion of the study is expected in mid-1992. All entities in the planning area will be asked to authorize a statement of concurrence which commits that entity to implementing specific actions. The nonpoint sources to be addressed include failing onsite septic systems, agricultural practices, stormwater, forest practices, and marinas and boats.

U.S. Environmental Protection Agency Commencement Bay Nearshore/Tideflats Integrated Action Plan (commonly known as the Commencement Bay Superfund Clean-up): The Commencement Bay Superfund Clean-up is a cooperative effort by the State Department of Ecology, the Port of Tacoma, the City of Tacoma, and the Tacoma-Pierce County Health Department to clean-up toxic sediments and sources of hazardous pollutants entering Commencement Bay, including those from the industrial area in the vicinity of Hylebos Waterway. The project has identified numerous point and nonpoint sources contributing to the pollution in Commencement Bay. This information was used to develop a clean-up plan for each identified source. The clean-up plans are currently being implemented. Full implementation of the action plan is expected to be completed by 1995 and monitoring will continue indefinitely. Therefore, significant new sources of pollution contributed by Hylebos Creek will be cause for concern by these agencies. See also Section 3.7, Water Quality, for further information on this study.

Sub-Basin Conditions







CHAPTER 4

SUB-BASIN CONDITIONS

SECTION 4.1 INTRODUCTION

The planning area contains six sub-basins. Each exhibits different natural characteristics with respect to the mix of geology, soils, and habitat. Consequently, when exposed to the varying land use and storm flow patterns, important differences emerge that must be considered in determining effective solutions for that sub-basin. This chapter contains interdisciplinary analyses of conditions for each of the sub-basins in the planning area: West Branch Hylebos Creek (4.2), East Branch Hylebos Creek (4.3), Lower Hylebos Creek (4.4), and Lower Puget Sound (4.5), which includes discussions of the North, Central, and South Lower Puget Sound sub-basins. Disciplinary perspectives included in these analyses are geology, drainage and flooding, habitat, and water quality.

SECTION 4.2 WEST BRANCH HYLEBOS CREEK

INTRODUCTION

The West Branch Hylebos Creek sub-basin contains some of the best remaining habitat in the Hylebos Creek and Lower Puget Sound basins, the West Hylebos Wetland a significant resource county-wide, and important recharge areas for the Federal Way groundwater supplies. This sub-basin also has the highest land-use density in the Hylebos Creek and Lower Puget Sound basins, which has resulted in significant flooding, instream erosion, nonpoint source pollution, and a much degraded fishery resource.

SUB-BASIN DESCRIPTION

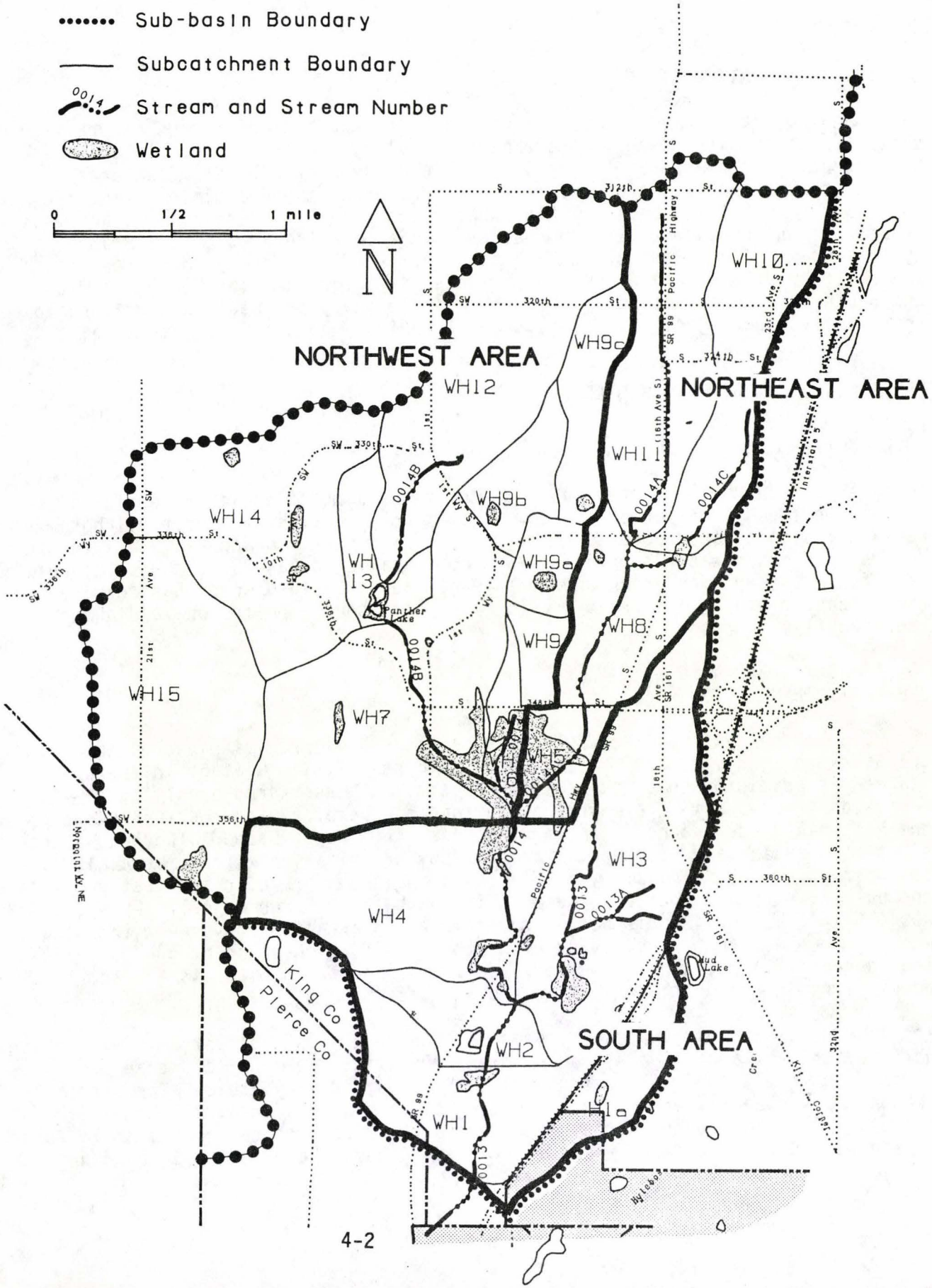
The West Branch Hylebos Creek sub-basin consists of approximately 4300 acres tributary to 9.7 miles of stream channel (Figure 4.2.1). Geology in the upper reaches is primarily composed of till deposits with scattered overlying recessional outwash with a mainly subsurface tongue of advance outwash known as the Milton-Redondo Channel trending southeast from Puget Sound. The headwaters of the sub-basin have been heavily altered by urbanization with commercial, business park, and multifamily developments and a network of roads that generate the bulk of nonpoint source pollutants in the basin. Three major tributaries, 0014, 0014A, and 0014B, discharge from this urban area and converge within the West Hylebos Wetland. Because of high storm flows, high nonpoint source pollutant concentrations, and low summer base flows, aquatic habitat is limited or nonexistent in the northern half of the sub-basin.

The land use south of the West Hylebos Wetland contrasts substantially with that north of the Wetland. Overall development densities are much less than the north area with large tracts of undisturbed forest in many areas. The stream channels have been altered to a lesser degree, although several stretches of tributary 0014 have been encroached upon and the upper reaches of the north fork of the West Branch (tributary 0013) have been piped. Despite the lower den-

Figure 4.2.1

West Branch Hylebos Creek

SUB-BASIN MAP



sities, streams in the southern half of the sub-basin continue to be severely impacted by the cumulative effects of high flows, pollutants, and sediments transported from the northern half of the sub-basin. Aquatic habitat in the West Branch currently exists between Brook Lake in the West Hylebos Wetland and the confluence of tributary 0013 with the East Branch Hylebos Creek, and in tributary 0013 south of S 359th Street. Historical accounts indicate that the Hylebos Creek system may have been one of the most productive small stream systems in central Puget Sound, supporting large numbers and a wide diversity of anadromous and resident species. Currently, the West Branch supports mainly chum salmon, sustained largely by out-planting, and cutthroat trout.

CONDITIONS

Current

To facilitate this discussion, the West Branch Hylebos Creek sub-basin was divided into three areas: the Northeast, Northwest, and South. The Northeast area consists of tributaries 0014A and 0014C, and includes the heavily urbanized area along S 320th Street and part of the West Campus Office Park. The Northwest area consists of the area tributary to 0014B and tributary 0014 north of S 356th Street. This area includes Panther Lake and an area of high infiltration northwest of Panther Lake. The South area includes the rest of the basin south of S 356th Street. This area is lower in existing development density than the north sub-basins and contains the majority of the viable fish habitat. The following sections describe the conditions of the West Branch under current land-use conditions.

Northeast Tributary Area - The northeast tributary area is the most densely developed in the planning area. This portion of the sub-basin has 40 percent impervious surface compared to 19 percent for the entire West Hylebos sub-basin. The streams within this area receive runoff from the commercial uses along S 320th Street, which include the Sea Tac Mall and SR 99. Runoff from the commercial corridor along S 320th Street (subcatchments WH10 and WH11) has resulted in nearly a tripling of peak flow runoff over predeveloped conditions despite onsite detention controls (see Figure 4.2.2). Wetlands located at the southeast and southwest corners of S 336th Street currently attenuate these flows; however, filling and encroachment has reduced the flow and pollutant buffering capacity.

SR 99 occupies what historically was the stream channel of tributary 0014A north of S 336th Street. Runoff from SR 99 and the adjacent commercial areas is conveyed downstream via a culvert system beneath the highway. Flow and pollutant reduction is therefore minimal along this reach of stream. Flows from tributary 0014A constitute over 85% of the storm flows entering the West Hylebos Wetland. Stream damage from high flows is most severe along tributary 0014A downstream of S 336th Street with severe channel incision interspersed with local zones of gravel deposition. High metal and fecal bacteria concentrations were measured in Tributary 0014A at S 336th Street (see Figure 4.2.3). During storm events, water at this site was noted as cream colored and carried a significant oil/grease sheen.

Existing onsite detention ponds in the east tributary area provide negligible detention compared to what is actually needed to reduce flows and pollutants to non-damaging levels. Many sites were developed prior to King County detention

Figure 4.2.2

West Branch Hylebos Creek Sub-basin

Relative Flow Increases From Original Forested Condition To 1987 Land Use

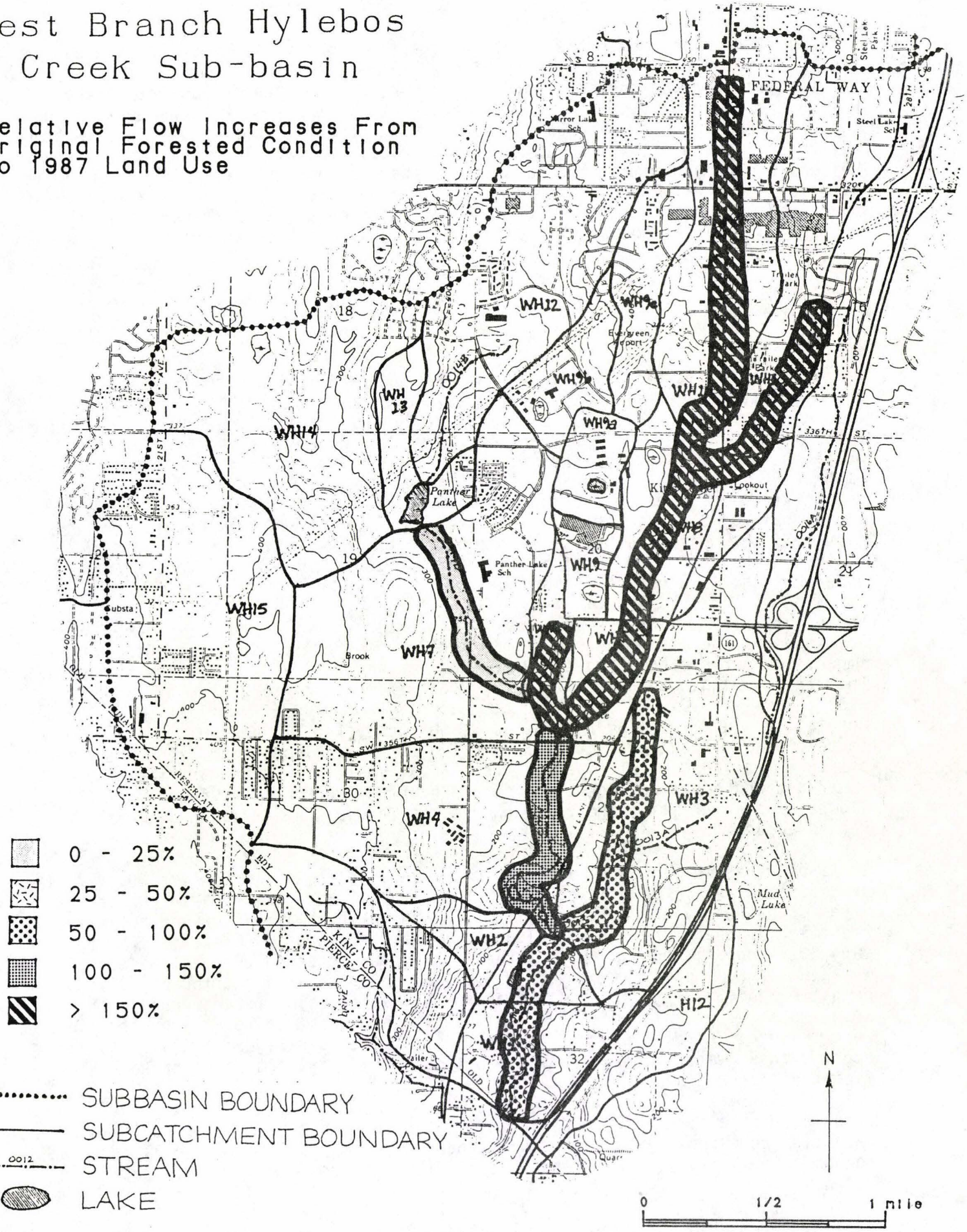
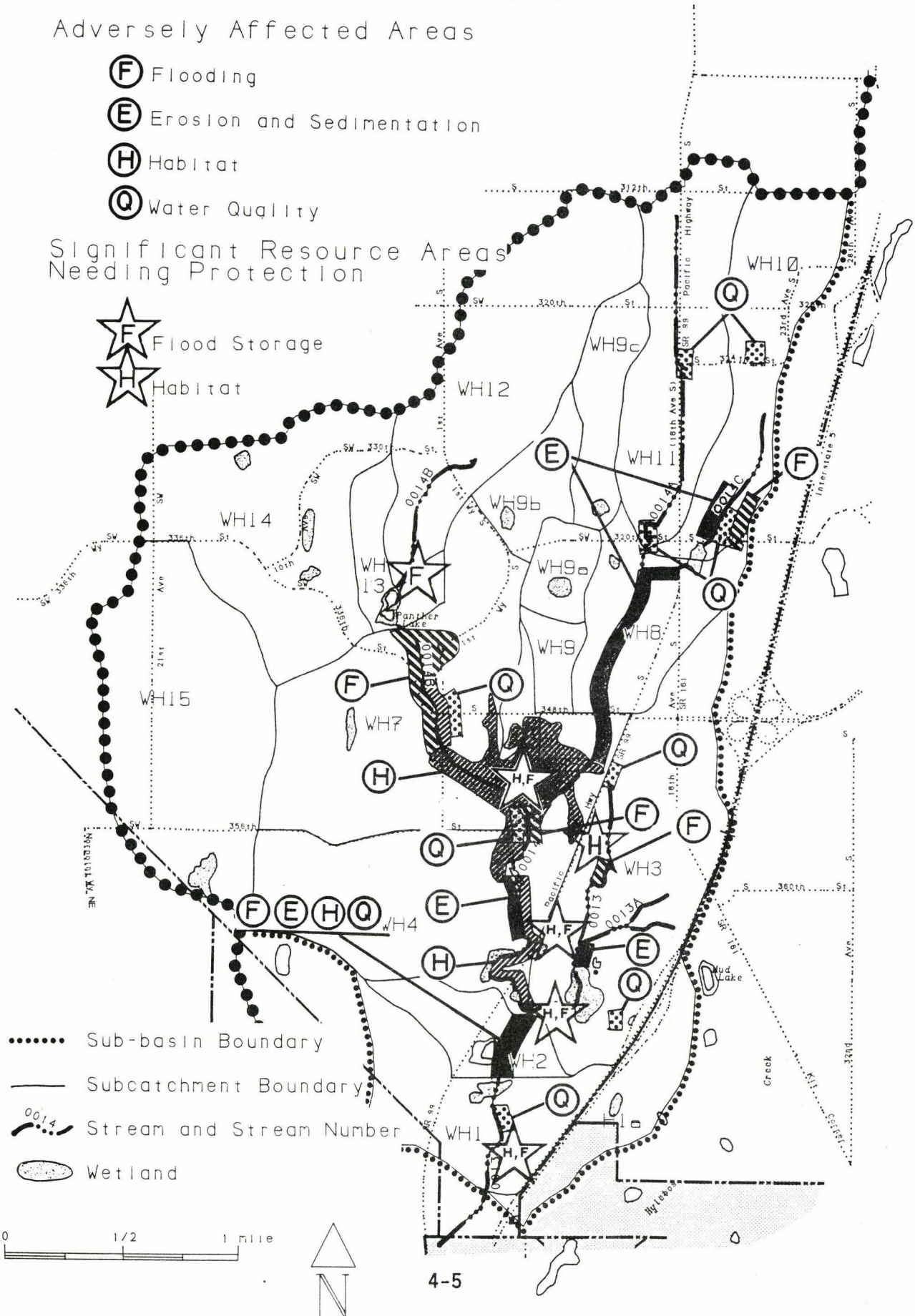


Figure 4.2.3

West Branch Hylebos Creek

COMPOSITE EXISTING CONDITIONS MAP



ordinances. Several of the developments along S 320th Street including the Sea-Tac mall have on-site detention ponds, however, many appear to be too small, or designed with too large of a release rate, so that the majority of storm flows are not detained. The detention pond at Sea-Tac Mall near the headwaters of tributary 0014C appears to have sufficient volume to attenuate flows from even large storms, however, the outlet pipe is so large that only four out of fifteen feet of pond storage were actually used during the 50-year January 1990 storm.

King County has identified three potential sites for regional detention to reduce flows entering the West Hylebos Wetland, reduce flooding on S 336th Street, reduce flooding along SR 99 south of S 336th Street, and improve water quality. These projects are located in the wetlands on tributaries 0014A and 0014C at S 336th Street. Filter berms and biofiltration will be included in the project designs to reduce pollutant loadings to the downstream system including the West Hylebos Wetland.

Northwest Tributary Area - Flows entering the West Hylebos Wetland from tributary 0014 are remarkably small, considering that the tributary area is heavily developed at multifamily and commercial densities. The majority of this development is contained within the West Campus Master Planned Development, which has retention/detention ponds that currently reduce storm peak flows. These ponds are located in highly permeable soils and infiltrate much of the runoff discharging to them.

The Panther Lake tributary area (subcatchments WH15, WH14, WH13, and WH12) has historically been a closed depression. Surface runoff from the surrounding, relatively impervious till areas in the uplands of subcatchment WH12 was infiltrated into Panther Lake and its surrounding pervious outwash deposits. In the late 1970s, the West Campus Master Planned Development began using Panther Lake as a stormwater detention facility and installed an outlet pipe to carry flows above a 25-year recurrence interval to tributary 0014B. Subcatchment WH15, upstream of Panther Lake, also was a closed depression historically, infiltrating surface runoff into a depressional wetland formerly located at the northern end of the subcatchment. The filling of and subsequent construction on this wetland has resulted in the addition of 480 acres of tributary area to Panther Lake. The additional tributary area, compounded by urbanization and sedimentation of the bottom of Panther Lake from development, has resulted in Panther Lake discharging surface runoff at a 20-year recurrence interval under 1987 land use. This recurrence may have been further reduced in the past few years because of increased sediment loading to Panther Lake.

Sediment transport downstream of Panther Lake in tributary 0014B had been limited in the past because of the infrequent discharge from the Lake. Low gradients along that channel probably will limit the amount of future incision that will occur, but active transport of fine sediment into the West Hylebos Wetland will likely increase with the higher, more frequent discharge from Panther Lake. Expansion of that channel with increased flows already appears to be occurring.

The West Hylebos Wetland is the largest in the Hylebos Creek and Lower Puget Sound basins and represents a significant regional resource. Located at the confluence of tributaries 0014, 0014A, and 0014B, it is sustained by unique physiographic, hydrologic, and habitat conditions which have been affected by urbanization. Increased winter storm flows, especially from tributary 0014A, have deposited silt and pollutants and increased the duration of inundation,

thus adversely affecting some plant species in the wetland. Development and loss of recharge areas in the Panther Lake tributary area, and perhaps the long-term pumping of groundwater from deeper aquifers, may threaten the groundwater supplies that currently sustain the wetland through the summer.

South Tributary Area - Land use south of the West Hylebos Wetland is markedly less dense than to the north, with the contribution of flows, pollutants and sediment being similarly less. However, high runoff rates from the northern part of the sub-basin have resulted in significant damage and flooding to the lower stream system. Riparian vegetation has been reduced by grazing and bank trampling from RM 1.00 to 1.20, by channelization and dredging from RM 1.20 to 1.30, and by bank armoring for flood control at RM 0.24 to 0.44 on tributary 0014.

High flows from the north, combined with loss of riparian corridors and several channelized reaches, has resulted in reduced use of much of the lower mainstem by salmonids. One notable exception is the north fork of the West Branch Hylebos Creek (0013) in subcatchment WH3. This subcatchment contains a relatively wide, undisturbed riparian corridor between I-5 and SR 99 south of S 359th Street. The upper reaches of the subcatchment (north of S 359th Street) is currently developed at commercial densities; however, the diversion of 604 acres of the upper basin into the East Branch Hylebos Creek in the mid 1960s, and an extensive riparian wetland system have helped mitigate the increased peak flow runoff. This reach currently represents the only remaining portion of the Hylebos stream system containing both spawning and rearing habitat, although it is under-utilized. One reason for low fish counts may be poor water quality (e.g., metals and solids) from the urban area in the headwaters (Figure 4.2.3). Limited implementation of Best Management Practices (BMPs) associated with this urban area have resulted in the highest concentrations of pollutant loading to the West Branch Hylebos sub-basin. Excellent riparian vegetation and good rearing habitat also exist in 0013 from RM 0.44 to RM 0.85 in the broad, forested riparian corridor behind Gethsemene Cemetary.

Low channel gradients and high flows have contributed to flooding at several locations in the recent past. One notable example is located near the S 373rd Street crossing of tributary 0013. The stream channel is located in a broad floodplain in which significant amounts of sediment are deposited during high flows. The sediment fills the channelized sections of stream, reducing flow capacity and have caused flooding of one streamside residence and the S 373rd Street bridge. High flows have also caused periodic closure of S 356th Street. High flows, in conjunction with channelization and floodplain encroachment at RM 0.30 on tributary 0014, have also caused instream erosion and flooding at the Montesorri School.

Severe sedimentation from peak flows during the December 5, 1989 and January 9, 1990 storms occurred within former spawning habitat from RM 1.10 to 1.30 in tributary 0013, burying chum and chinook salmon eggs that had been laid in this reach earlier in the fall. In the past spawning habitat within this same reach has been disturbed by channelization and periodic dredging to remove sediment deposited during storms. Spawning and rearing habitat in 0013 from RM 1.80 to 2.30 was also damaged, though to a lesser extent, due to sedimentation and scouring during the January 9, 1990 storm due to the washout of the road fill under S 359th Street. Stream bank armoring for flood control has eliminated most of the spawning and rearing habitat in tributary 0014 from RM 0.19 to 0.25. Further upstream from RM 0.57 to 0.71, erosive flows have replaced former

spawning gravels with unsuitably large cobbles and reducing rearing habitat in pools.

Future Conditions

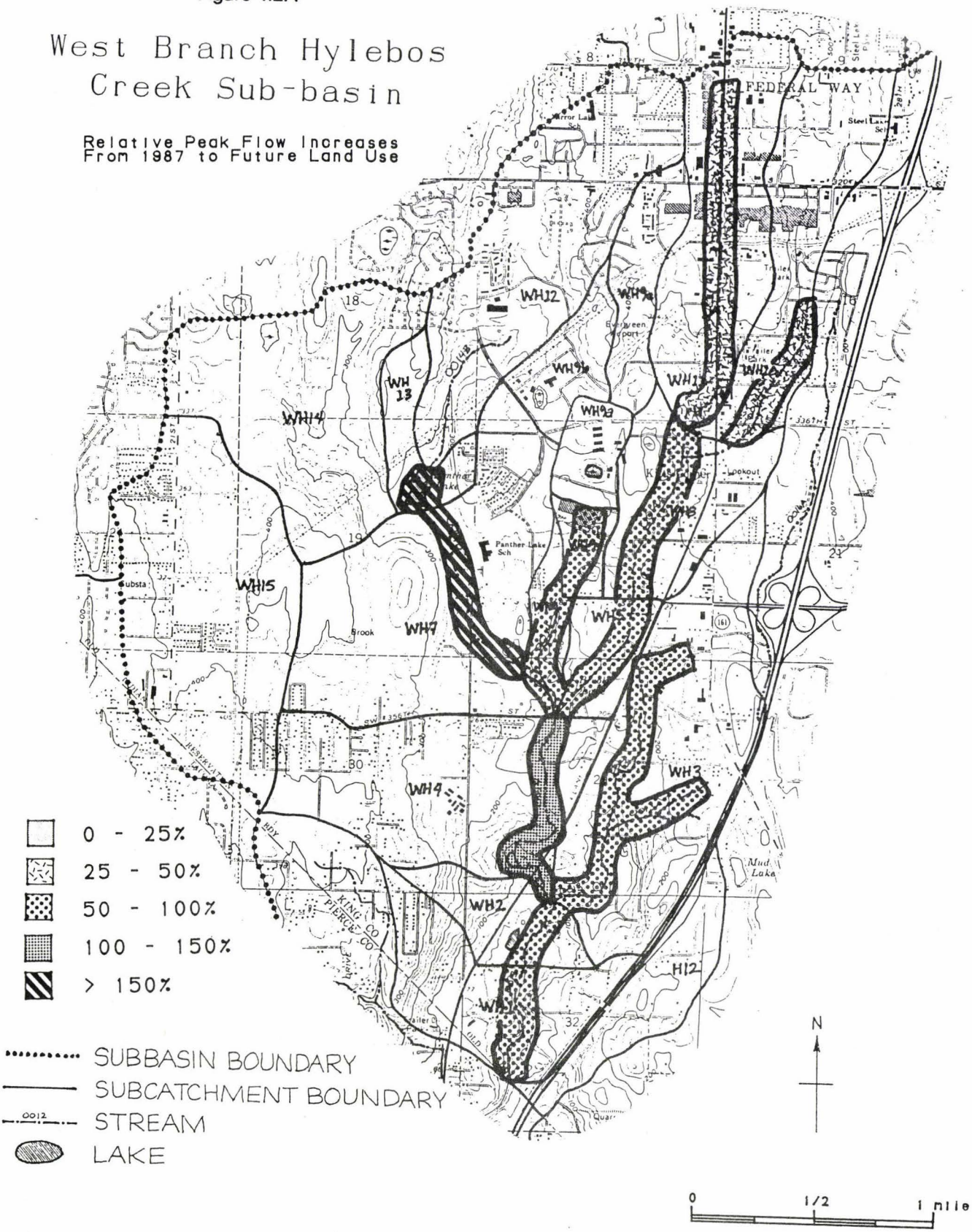
Land use under build-out conditions in the West Hylebos sub-basin is the most intense in the study area. The majority of the north half of the sub-basin is designated to be developed at multifamily, business park, and commercial densities. The southern half is zoned for high-density single family, with some rural zoning in the extreme south. Increased damage with urbanization could be dramatic in the West Hylebos sub-basin, because roughly 50 percent of the sub-basin still remains forested under 1987 land use. Flows at the outlet of the West Hylebos Creek basin are predicted to nearly double, with increases of greater than 150 percent expected from the Panther Lake subcatchment (tributary 0014B) (Figure 4.2.4). Elsewhere in the basin, flow increases in the range of 50 to 100 percent over 1987 land use predominate. If adequate surface water controls are not in place to mitigate increased runoff and nonpoint source pollution, the frequency and magnitude of existing flooding will increase, areas that historically did not flood will begin to do so, and the already imperiled fishery resource will simply cease to exist. The following sections discuss the area-specific effects of future land use on the West Branch Hylebos Creek sub-basin.

Northeast Tributary Area - Peak flow increases in the headwaters of tributary 0014A are predicted to be the smallest, because the upper basin is already developed at commercial densities. South of S 336th Street, however, conversion of undeveloped and low-density land to commercial and office park densities may increase flows in 0014A by 50 percent. Existing erosion in this reach between S 348th and S 336th Streets will likely worsen, to the detriment of the West Hylebos Wetland located downstream.

Northwest Tributary Area - Loss of infiltration areas in the Panther Lake drainage is predicted to increase the magnitude and frequency of discharge from Panther Lake. Under future land use, Panther Lake is predicted to release surface flows at more than an annual occurrence, with a flow of 78 cfs at the annual recurrence interval. Under 1987 conditions, in contrast, it discharged only at about once in a 20-year frequency and was otherwise devoid of any discharge and a maximum runoff event from the 39-year model simulation of 170 cfs. Pollutant loading (e.g. fertilizer from lawns, oils, and heavy metals) associated with these higher flows will be greatly increased and may significantly impact salmonid spawning and rearing downstream. Increased erosion in tributary 0014B between Panther Lake and the West Hylebos Wetland, and the subsequent deposition of sediment in the wetland, will occur as the stream channel adjusts to the higher flow regime. In addition, aging septic systems and sewer lines over the next decade may increase fecal coliform loadings.

South Tributary Area - Flows in tributary 0014 downstream of the West Hylebos Wetland are predicted to increase by 125 percent under the future land-use scenario assuming no mitigation. Flow increases will aggravate existing erosion problems through a channelized section on tributary 0014 upstream of SR 99 at the Montesorri School. Flooding of S 356th Street will increase from a 10-year recurrence interval currently to less than a 2-year event under future conditions, and flooding at S 373rd will increase from a 100-year recurrence inter-

Figure 4.2.4


West Branch Hylebos Creek Sub-basin
Relative Peak Flow Increases From 1987 to Future Land Use
FEDERAL WAY
WH12
WH9a
WH9b
WH9c
WH13
WH14
WH15
WH7
WH5
WH3
WH4
WH2
H12
Panther Lake Sch
Mud Lake
0 - 25%
25 - 50%
50 - 100%
100 - 150%
> 150%
SUBBASIN BOUNDARY
SUBCATCHMENT BOUNDARY
STREAM
LAKE
N
0
1/2
1 mile

val to only a 5-year event. High flows during storm events, instream erosion and sedimentation, and the reduction of base flows will continue to degrade the already damaged stream habitat downstream of S 356th Street on tributary 0014.

The conversion of forested vegetation to high-density single-family residences in the north fork of West Branch Hylebos Creek (tributary 0013) is predicted to increase flows by 75 percent over 1987 land use. This subcatchment also contains 104 acres of wetlands not currently inventoried. These wetlands provide significant base flow in summer through groundwater discharge.

Without future detention, the remaining spawning habitat in tributary 0013 from RM 1.10 to 1.30 will continue to undergo massive periodic sedimentation during major storms. Habitat is expected to stabilize by installation of additional detention above S 359th Street. Placement of a 72-inch culvert under the road should also open usable fish habitat upstream. Future flooding could necessitate additional bank armoring for flood control in 0014 from RM 0.24 to 0.44, and possibly in reaches immediately upstream and downstream, rendering this stream segment virtually unusable by fish for either spawning or rearing. Deposition of sediment from upstream sources could also damage the existing high quality rearing habitat in 0013 from RM 0.80 to 1.10.

KEY FINDINGS

- West Branch Hylebos Creek has the most dense land-use zoning of any sub-basin in the Hylebos Creek and Lower Puget Sound basins. Runoff from the commercial area along S 320th Street, and to a lesser degree the West Campus Office Park, have resulted in erosion in upper tributary reaches and deposition of sediments and pollutants in the West Hylebos Wetland.

- Flows discharging from the Panther Lake basin have increased in frequency and magnitude in recent years and are predicted to cause damage to the West Hylebos Wetland and tributary 0014B between Panther Lake and the West Hylebos Wetland under future land use. Predicted flow increases from tributary 0014B account for 50 percent of the flow increase downstream of the West Hylebos Wetland.

- Loss of groundwater recharge in the Panther Lake tributary area may cause reductions in groundwater levels that sustain the West Hylebos Wetland in the summer months.

- Frequent flooding at several locations, including tributary 0013 at S 373rd Street, tributary 0014 at S 356th Street, and tributary 0014B at 1st Avenue S will dramatically increase in frequency and magnitude without mitigation.

- The West Branch Hylebos Creek sub-basin had some of the highest metal (i.e., copper and zinc) concentrations measured during the King County SWM supplemental storm event monitoring program.

SECTION 4.3 EAST BRANCH HYLEBOS CREEK SUB-BASIN

INTRODUCTION

The East Branch Hylebos Creek sub-basin contains the largest portion of unincorporated King County in the planning area. As the least urbanized area of the six sub-basins, it is predicted to have some of the highest, unmitigated flow increases under future build-out land use. Although approximately sixty-one percent of the sub-basin is forested, existing levels of stormwater runoff in conjunction with highly erodable stream channels and urban pollutants have greatly reduced the aquatic resource that this sub-basin had historically supported.

SUB-BASIN DESCRIPTION

The East Hylebos Creek sub-basin, shown in Figure 4.3.1, includes the East Branch Hylebos Creek (tributary 0006) and its three major tributaries (0015, 0016, and 0016A). Tributary 0006 originates at Lake Killarney, whereas North Lake is the headwater area for tributary 0016. Bisected by State Route 161, the upper and lower portions of this sub-basin strongly contrast with each other. Upstream of the highway, the tributaries flow over a relatively flat upland till surface. The low channel gradients have yielded minimal stream erosion and only localized zones of fine-sediment deposition. Downstream of the highway, channel gradients steepen as the streams flow over an underlying deposit of easily erodible sand and gravel of the Vashon advance outwash. Sediments are carried to the mouth of the resulting ravine where they are deposited in the flat valley floodplain.

A major modification of the stream system occurred when the construction of I-5 diverted flow from the upper reach of West Branch tributary 0013 into the East Branch tributary 0016A. Residential development and other land-use changes, such as a quarry operation near the ravine by tributary 0006, I-5, an abandoned King County landfill, and the Weyerhauser Headquarters, have brought increased flows in the streams. Increased flows have caused some local drainage problems in the upper low-gradient portions of the sub-basin but have the greatest effect in the more erodible lower reaches in the ravines. The East Branch Hylebos Creek sub-basin generates over half of the estimate peak flow that enters the Lower Hylebos sub-basin. These flows, together with pollutants from urban areas and I-5, SR 18, and SR 161 road drainage, have degraded the aquatic resource of this sub-basin. Historically, excellent spawning and rearing habitat for salmonids existed in the ravine areas below SR 161. A small remaining spawning area in tribuary 0006, just north of Milton, is the sole remaining evidence of the magnitude of habitat loss attributable to urbanization.

CONDITIONS

Existing damage is widespread along the tributary channels of this sub-basin even though Lake Killarney and North Lake provide some buffering of peak flows. Both lakes are currently providing significant flow attenuation, but because of their location in the headwaters, their buffering affects only a limited area. Without mitigation, increased future flows from those subcatchments (H7 and

Figure 4.3.1

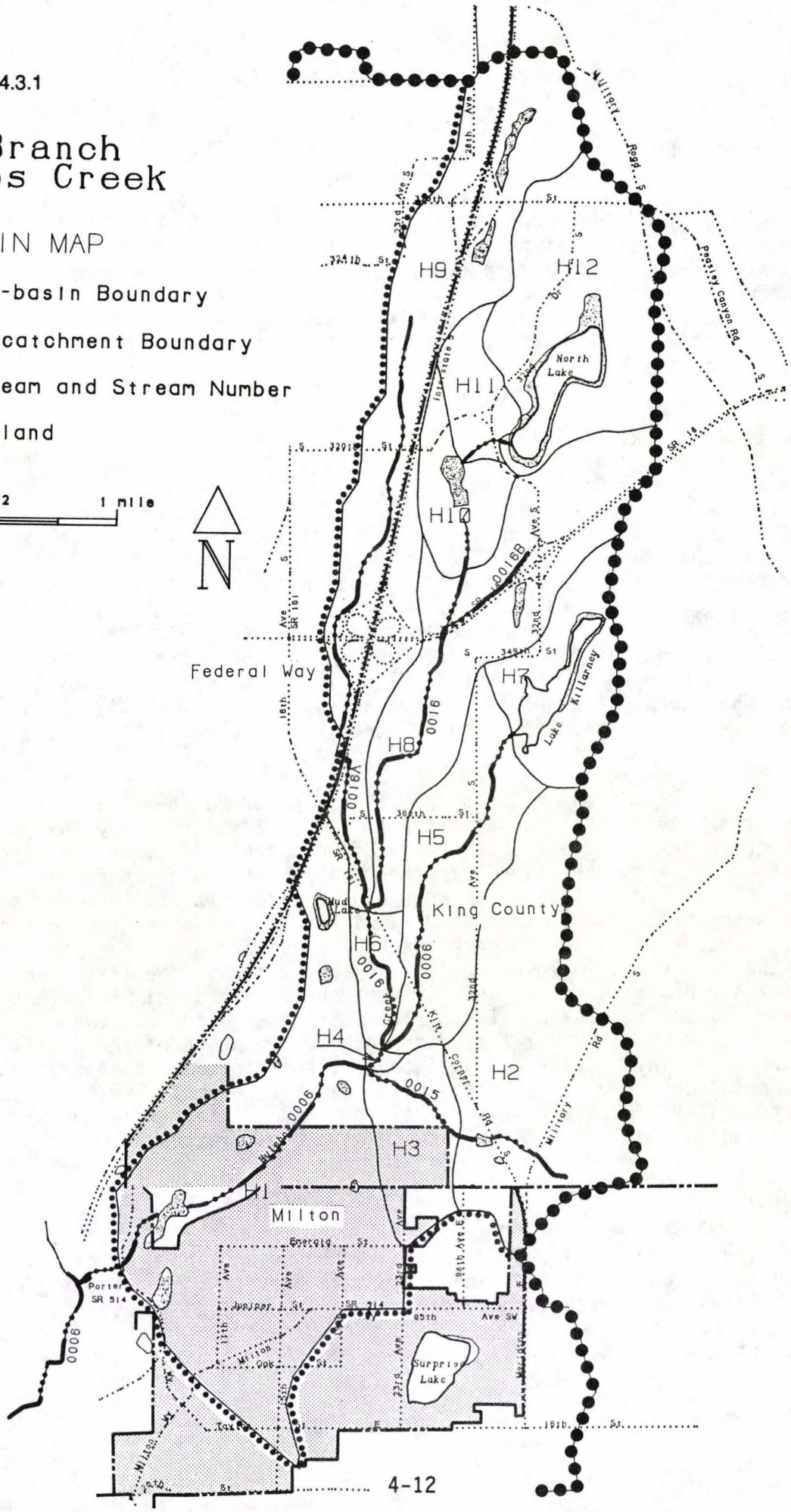
East Branch Hylebos Creek

SUB-BASIN MAP

- Sub-basin Boundary
- Subcatchment Boundary
- Stream and Stream Number
- Wetland

0 1/2 1 mile

N



H12), as illustrated in Figure 4.3.2 at build-out, will be nearly fifty percent, but the magnitude of increase is small, 3.5 to 4.5 cfs respectively, at the 100-year flow frequency.

Development along lake shorelines may experience future flooding such as occurred elsewhere in the planning area during the January 1990 storm, when lake levels rise in response to increased surface runoff. For example, the flood stage in the outlet channel of Lake Killarney currently reaches a depth of one foot on average once every 40 years. Under future conditions, this will occur on average once every 5 to 7 years.

Flow increases from areas downstream of the lakes, especially subcatchments H5 and H8, are responsible for the majority of future peak flow increases in the East Branch Hylebos Creek. In general, future flows will as much as double current (1987) flows in all reaches of the East Branch tributaries with the exception of tributary 0015 (subcatchments H2 and H3) and tributary 0016 (subcatchments H10 and H11), which show over 150 percent increases. These dramatic flow increases and their resultant channel erosion, combined with poor quality water have severely degraded the streams in the East Hylebos Creek sub-basin. These adverse conditions and the remaining resource areas of the sub-basin are identified in Figure 4.3.3.

According to computer modeling, nearly a two-fold increase in peak flows has occurred since forested conditions. These increased peak flows have caused flooding in a few locations within the sub-basin and if unmitigated, future peak flows will worsen these problems and cause new areas of flooding.

During the January 1990 storm, flows from tributary 0016A flooded streets and one home in a portion of the subdivision at S 363rd Place and 20th Place S. The home had water nearly 4 feet deep in the first floor. Tributary 0016 also flows through a portion of this subdivision but its flood flow was attenuated during the storm by significant upstream detention at Evergreen Vale Apartments (RM 1.0). Existing detention ponds, such as the Evergreen Vale facility, do not have additional storage volume for the predicted future flow increases.

Peak flow increases within the individual tributaries will also cause road overtopping as culverts become undersized in comparison to the new, higher flows. Of the four streams that cross SR 161 (0006, 0015, 0016, and 0016A), tributary 0015 has the largest predicted increase (160 percent) and the others are expected to have from 50 to 100 percent increases. None of these four culverts are currently sized to handle the predicted future 25-year flow without mitigation. Tributary 0015 in subcatchments H2 and H3, and tributary 0016 in subcatchments H10 and H11, are areas that currently do not have severe flooding problems but in the future will most likely experience significant flooding.

Channel erosion in the steep gradient reaches downstream of SR 161 has resulted because of increased peak flows. Tributary 0015 west of 28th Avenue S descends through a narrow valley over numerous recent knickpoints, or vertical steps, in the channel bed. Small channel-bank landslides, and at least one recent large valley-side failure, are evident. Tributary 0016 appears to be undergoing recent and rapid degradation, particularly knickpoint migration, channel incision, and cementation of streambed gravels by fine sediment. These same reaches were described in 1986 as relatively problem-free by the Basin Reconnaissance report.

Figure 4.3.2

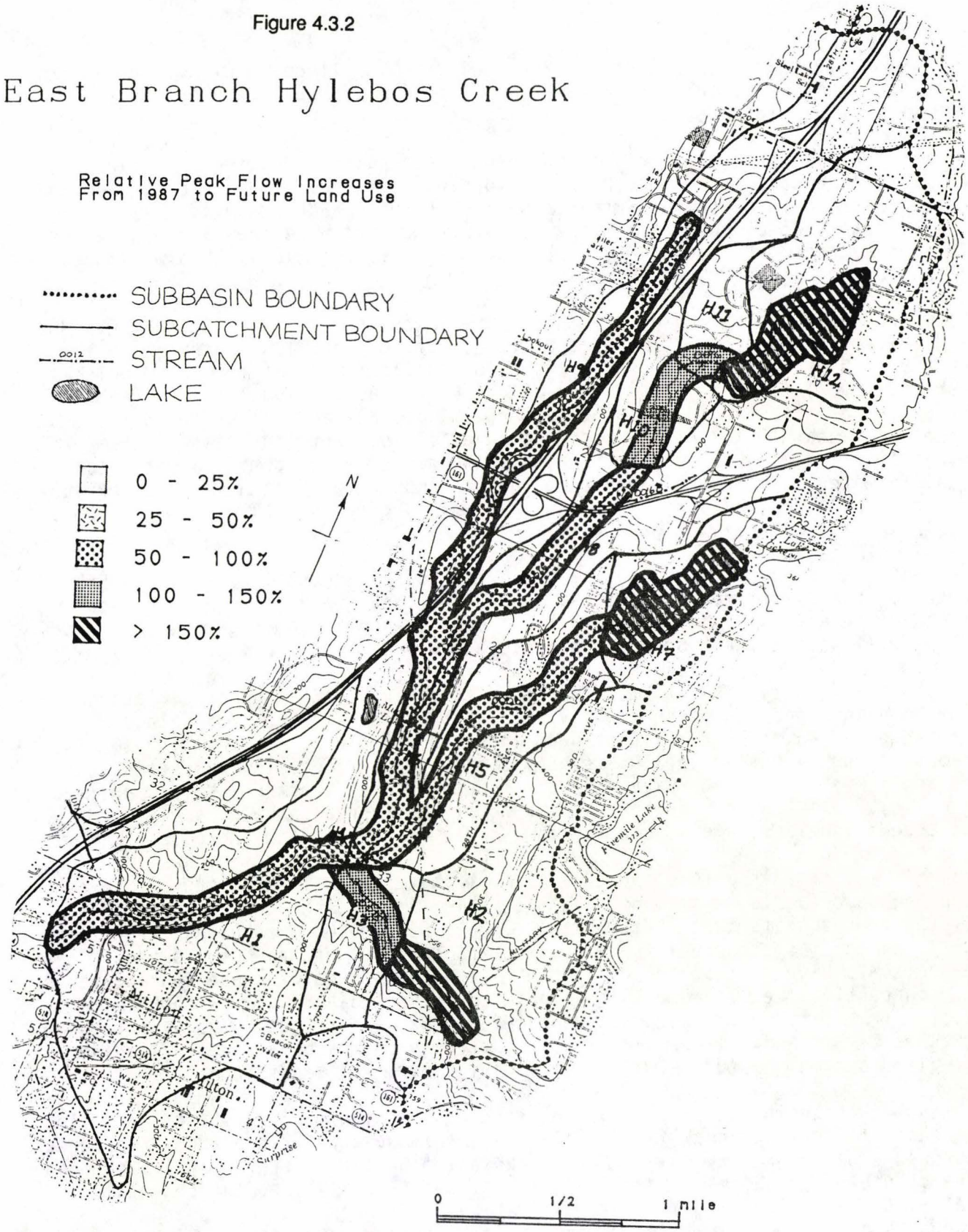

East Branch Hylebos Creek
Relative Peak Flow Increases
From 1987 to Future Land Use
SUBBASIN BOUNDARY
SUBCATCHMENT BOUNDARY
STREAM
LAKE
0 - 25%
25 - 50%
50 - 100%
100 - 150%
> 150%
N
H1
H2
H3
H5
H7
H8
H11
H12
Milton
Fawcett Lake
0
1/2
1 mile

Figure 4.3.3

East Branch Hylebos Creek

COMPOSITE EXISTING CONDITIONS MAP

Adversely Affected Areas

- (F) Flooding
- (E) Erosion and Sedimentation
- (H) Habitat
- (Q) Water Quality

Significant Resource Areas Needing Protection

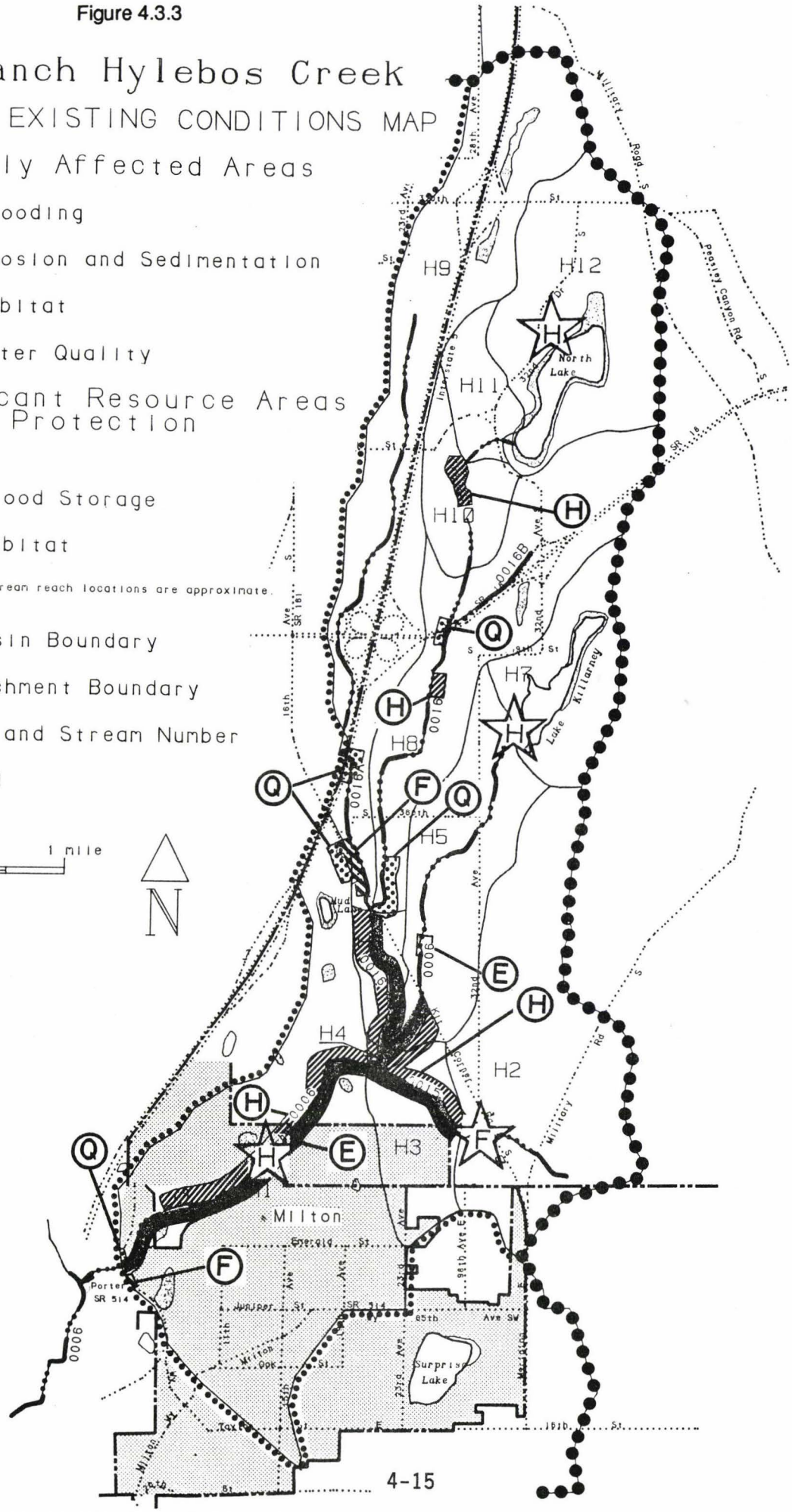
- (F) Flood Storage
- (H) Habitat

Designated point and stream reach locations are approximate.

- Sub-basin Boundary
- Subcatchment Boundary
- 0006 Stream and Stream Number
- Wetland

0 1/2 1 mile

N



Tributary 0006, although only a secondary flow contributor upstream of its confluence with 0016, exhibits severe bank erosion, with failures commonly up to several feet high. Downstream of the confluence of 0006 and 0016, more limited erosion and active gravel transport gradually give way to deposition of progressively finer sediment, particularly at and downstream of the quarry at RM 5.8. Bank erosion from lateral migration of the stream channel still occurs, but the dominant process here and downstream to the confluence of the two branches of Hylebos Creek is deposition.

Because the channels are so steep downstream of SR 161, flows of almost any size will have high erosive potential. Incision in these particular streams is now dramatic, because the underlying geologic deposit is easily erodible sand and gravel of the Vashon advance outwash and because upstream development has substantially increased flows in these tributaries and so washes out the woody debris that previously would have stabilized the channel. That process is now pernicious--incision smooths the channel and eliminates debris from the water flow; the loss of channel roughness allows that same water flow to be even more erosive on the sediment of the bed and banks.

This activity is particularly well documented in this area. Along 0015 and 0016, three stations have been monitored for the last year in order to measure the rate of channel changes. Both were heavily impacted by the January 9, 1990 storm, so the results reflect the effects of large flow events as well as long-term discharges from urbanization. On 0015, a 5-foot-high knickpoint was measured near the confluence with 0006, in an area of erosion-susceptible sediments and abundant examples of existing stream-channel downcutting. The January 1990 storm completely obliterated this station; numerous hillside failures introduced much debris and sediment into the flow and completely altered the bed and bank characteristics. On 0016, two areas were monitored for channel downcutting. At the upstream site, just below the access road into the Regency Woods development off of SR 161, migration of a 4-5' high knickpoint occurred during both the period January-June 1989 and as a result of flows during the winter of 1989-90. In total, over 30' of upstream migration has occurred, with about 1/4 of that distance being covered in the first interval and the remainder during the January storm. Downstream a few hundred yards, a sewer pipe that crosses this tributary has provided a convenient marker for the channel bed. In the last 14 months (1/89-3/90), the bed has lowered almost 1.5 feet at this location, as measured by the clearance between the bottom of the (now-exposed) pipe and the channel bed. This degree of channel activity and degradation hold serious implications for any present or future efforts to stabilize or rehabilitate this section of the East Branch.

The consequence of increased flows and longer flow durations is continued bank erosion, further channel incision, and greater numbers of landslides within the ravine areas. As channnel erosion occurs, more sediment is carried downstream to depositional areas in the floodplain valley causing clogging of culverts and siltation of spawning gravels.

The East Branch Hylebos Creek once provided excellent spawning and rearing habitat for anadromous fish up to approximately RM 7.0 on tributary 0006, RM 0.5 on 0015, and RM 0.4 on 0016, with some resident fish and cutthroat trout habitat in upstream headwaters. Increased flows by the additional tributary area of 0016A and development in the headwater areas have created an unstable flow regime that causes erosion and carries poor water quality. The quality and quantity of instream habitat has been further degraded by the removal of large organic

debris (LOD) and loss of perennial stream flow. Low or nonexistent summer flows, such as those which occur in the mid- and upper reaches of 0016 and 0016A, have resulted in severe reductions in the volume of juvenile rearing areas during the summer months. Tributaries 0006, 0015, and 0016 in the lower half of the sub-basin have a year-round groundwater supply from springs and seeps in the exposed layer of Vashon advance outwash in the ravine. This baseflow supplies cool and clean water to the reach, which in past history had been a spawning area for coho.

Future flow increases in a system already in an unstable flow regime will surely degrade remaining instream habitat. Degradation of rearing areas will occur not only from greater and more frequent flows but also in the further decrease in diversity from lack of large organic debris (LOD). As eroded soils are deposited in the lower reach of tributary 0006, gravel beds will be further silted, limiting successful spawning. In conjunction with these impacts is the increased concentration of pollutants may limit fish growth and production as well as directly cause fish kills. In December 1989, forty-seven yellow perch were found moribund or dead along RM 5.3 to 6.7 in tributary 0006.

As impervious surface area increases in the sub-basin and about its perimeter, less area is available for groundwater recharge. As recharging diminishes, baseflow may be lowered or become nonexistent, reducing the quantity and quality of instream habitat. Nonpoint pollutants, such as nutrients and suspended solids, typically increase as a basin urbanizes creating the potential for groundwater contamination in areas with high recharge zones. In this area, the aquifer known as the Milton-Redondo Channel is less susceptible to such contamination than other more shallow aquifers.

Four areas within the sub-basin have been identified that adversely affect water quality. The first is residential development and destruction of riparian zones immediately upstream of SR 161 and within the Evergreen Vale development, which are contributing high concentrations of nutrients, metals, and fecal coliform densities to the East Branch Hylebos Creek. Upstream of SR 161, along tributaries 0016 and 0016A, driveways have been built over the streams, and yards and gardens are immediately adjacent to the banks. Direct inputs of oil, greases, metals from automobiles, pet wastes, and nutrients are occurring. This sub-basin had the highest mean nitrate + nitrite - nitrogen concentrations of any sampling site in the King County SWM storm event monitoring program.

The second is poor waste management practices at a bird pond, and sanitary and stormwater piping systems at Enchanted Village Amusement Park which resulted in extremely high concentrations of total phosphorus (0.70 mg/l) and fecal coliforms densities (37,000 organisms/100 ml) when sampled during storm events in late 1989 and early 1990. When these results were provided to the Park management, the stormwater system was connected to the sanitary sewer. One subsequent storm event sampling session indicated pollutant loadings fell within acceptable limits. It is unknown at this time, however, whether a significant problem still exists. Follow-up studies are needed to evaluate the status of the implementation of Best Management Practices and to conduct additional storm event monitoring. Also, the Federal Way Water and Sewer District and the Washington State Department of Ecology are needed to further evaluate any ongoing downstream impacts to East Branch Hylebos Creek.

The third is sediment loading and high concentrations of metals, which were sampled at the Regency Woods development near SR 161 and S 368th Way. Total

suspended solids concentrations (297 mg/l and 285 mg/l) were obtained from the development's retention/detention pond outlets. These samples were the third and fourth highest concentrations observed during the King County SWM storm event monitoring program. The high concentrations indicate that water is not being detained and is flowing directly through the ponds.

The fourth is lack of erosion control and encroachment into the riparian corridor along tributary 0006. The quarry operation is contributing high sediment loads to the stream system. These sediment loads are carried to the outlet of the ravine on tributary 0006 and are deposited in a low gradient floodplain area (RM 5.5 to 6.0).

The valley area of the East Branch Hylebos Creek experiences regional flooding which extends into the Lower Hylebos sub-basin. During the January 1990 storm, high flows flooded four homes near 5th Avenue in Milton. Flows at the sub-basin outlet (subcatchment H1) are predicted to increase by 76 percent. This significant future flow increase will excerabate the regional flooding already occurring in the southern end of the sub-basin as well as impact the Lower Hylebos sub-basin.

KEY FINDINGS

- The East Branch Hylebos sub-basin has some of the highest concentrations of pollutants sampled during the King County SWM basinwide stormwater monitoring program.

- Areas currently experiencing flooding are a subdivision along tributary 0016A upstream of SR 161 and the low gradient area in the lower reach of tributary 0006 near the sub-basin outlet.

- Two areas, tributary 0015 (subcatchments H2 and H3) and tributary 0016 (subcatchments H10 and H11), that currently do not have severe flooding problems are predicted to have over a 150 percent increase in peak flows at build-out. These increased flows will likely cause future flooding along tributary 0016 between SR 18 and SR 161 and along tributary 0015 near SR 161 and Military Road.

- Tributary 0015 near the confluence of 0006 is an area of erosion-susceptible sediments resulting in migrating knickpoints, channel downcutting, and numerous hillside failures.

- Increased flows, sediment-ladened gravels, pollutants, and trash in the stream channels have dramatically reduced the quantity and quality of aquatic habitats.

SECTION 4.4 LOWER HYLEBOS CREEK SUB-BASIN

INTRODUCTION

The Lower Hylebos Creek sub-basin shown in Figure 4.4.1 encompasses the portion of the mainstem tributary 0006 from its mouth at Commencement Bay to RM 5.4, tributary 0009 and Surprise Lake, tributary 0013B, and a short reach of tributary 0013 that extends to the King-Pierce County line. A detailed hydrologic analysis of the Lower Hylebos sub-basin is not a part of this report. However, limited field investigations were conducted and background studies were reviewed to gain understanding of the Hylebos Creek system in its entirety. A Stormwater Master Plan is currently being completed by James M. Montgomery and Associates for Pierce County Surface Water Management Division, which includes the Hylebos Creek system in both the incorporated and unincorporated areas of Pierce County. This Master Plan, expected to be available in August 1990, will provide more complete information on existing stormwater conditions in this sub-basin.

SUB-BASIN DESCRIPTION

The Lower Hylebos Creek sub-basin is characterized by a broad floodplain area that extends from Hylebos Waterway to an even wider, flat valley in its central portion. One plateau area borders the northern side of the lowermost reach of Hylebos Creek. Another plateau, split by the ravine which carries the Surprise Lake tributary, composes the most easterly portion of the sub-basin. Last modified by glaciation about 15,000 years ago, the plateaus are capped by Vashon-age till with the northerly plateau bordered by recessional outwash on its east and west slopes. The remainder of the deposits in the sub-basin are lake-bed silt and clay, deposited during the waning stages of the last glaciation, overlain by riverine deposits delivered from the East and West Hylebos branches as they descend from the much steeper gradient upstream reaches onto the flat, central lake-bed area. The lake sediments then merge with the Puyallup River alluvium near the confluence of the mainstem and the Surprise Lake tributary. This alluvium extends along the lowermost reach of Hylebos Creek bordering the southern edge of the sub-basin.

Some portions of this sub-basin have experienced tremendous changes in land uses, as illustrated by the conversion of the Puyallup estuary to a deep water industrial port. Once a saltwater estuary of Commencement Bay, this area has been filled along the first three river miles to create an industrial area for Tacoma and Pierce County. This industrial area continues within Pierce County along the mainstem (tributary 0006) to the confluence with the Surprise Lake tributary (0009). Low density and agricultural land uses are prevalent in the floodplain of tributary 0009 and along the mainstem. Draining to these reaches are residential development in the upland plateaus. These reaches are crisscrossed by the jurisdictional boundaries of Fife, Milton and King County. Along with these jurisdictions, waters of the Hylebos system are within the usual and accustomed fishing area of the Puyallup and Muckleshoot Tribes. Historically, coho, chum, and chinook salmon, as well as steelhead and cutthroat trout thrived in Hylebos Creek. The numbers of these species has dramatically declined as a result of land-use changes throughout the basin.

The effects of the urbanization are also seen in the degraded water quality and the increased runoff this sub-basin receives from not only its tributary area,

Figure 4.4.1

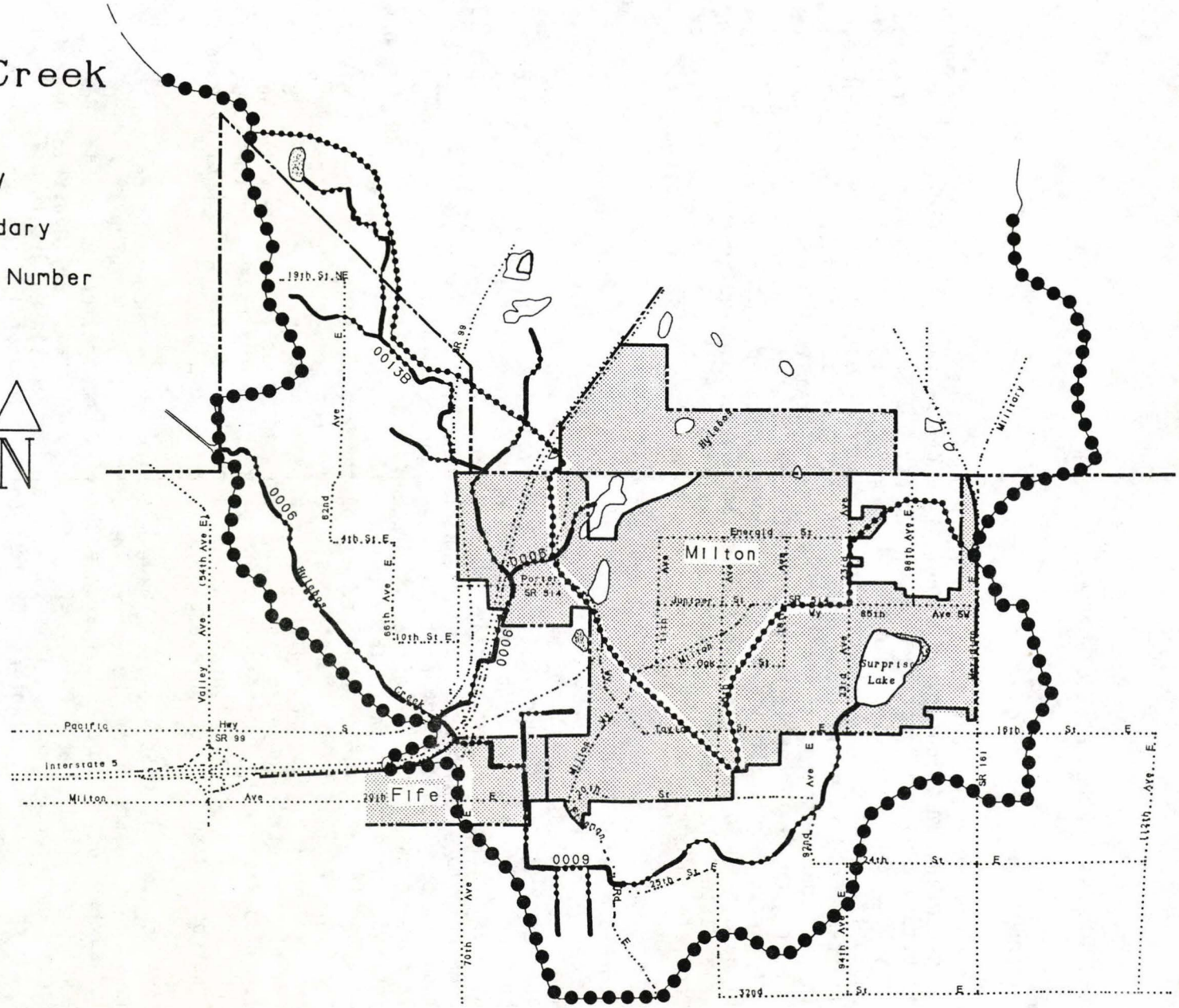
Lower Hylebos Creek

SUB-BASIN MAP

- Sub-basin Boundary
- Subcatchment Boundary
- Stream and Stream Number
- Wetland

0 1/2 1 mile

N



but also the entirety of the Hylebos system. Water quality in this sub-basin is dominated by cumlative impacts from upstream, I-5 and SR 99 runoff, development in Fife and Milton, and the industrial complex in Hylebos Waterway which is currently designated as an EPA Superfund clean-up site. This sub-basin experiences regional flooding in all stream reaches except the ravine area of tributary 0009 upstream to Surprise Lake.

CONDITIONS

The majority of flow delivered to this sub-basin orginates from the East and West Branches of Hylebos Creek. Hydrologic analysis for this report extends to the confluence of these two branches. Flow estimates for the mainstem of Hylebos Creek (RM 0.0 to 5.15) and the two tributaries interior to the sub-basin (0009 and 0013B) were not included in the analysis. The estimated flows at the confluence in combination with field investigations and previous studies are the basis for a qualitative review of the conditions in this sub-basin.

Resource areas such as flood storage and spawning and rearing areas for salmonids still remain in the sub-basin. These resource areas and locations where channel conditions have been adversely affected by development within and upslope of the sub-basin are shown in Figure 4.4.2.

Tributary 0013 above the confluence with the mainstem (tributary 0006) is in fairly good condition despite a model computed doubling of flows since forested conditions. Tributary 0013 between RM 0.44 and 0.85 contains some of the best fish rearing habitat in the Hylebos system as well as excellent wildlife habitat. Freshwater mussel beds, an indicator of good water quality, are present in this tributary at RM 0.06 and 0.50. Base flow sampling has shown that good water quality is present to support these mussels. However, sampling during storm events has indicated much lower water quality. Continued degradation of the water quality, particularly by increased concentrations of metals, will most likely result in the loss of these mussels.

Increased flows in tributary 0013 are somewhat ameliorated by wetlands that provide some flood storage. During the January 1990 storm, these wetlands were impacted by large amounts of sediment transported by erosive flows in tributary 0013B, which drains the rapidly developing Fife Heights area in the northwestern portion of the sub-basin. These sediments clogged culverts, causing flows to overtop and wash out road shoulders along SR 99. Gravels from the road shoulders and bedload from the stream were then deposited at the confluence of tributaries 0013 and 0013B.

The mainstem tributary (0006) upstream of its confluence with tributary 0013 has been severely degraded by increased flows and sediment deposition. The low gradient of this reach and tidal influence caused flooding of several streamside residences and deposition of fine sediments. These sediments and high concentrations of pollutants, such as total phosphorus, copper, and fecal coliforms, are generated from upstream sources in the East Hylebos Creek sub-basin. Toxicity, sediment, and channelization have severely reduced rearing habitat. This low-quality water combines with flows from tributary 0013 and is delivered to the wide floodplain area of the central sub-basin.

The wide floodplain of the central sub-basin area is an important element of flood storage. Recent flooding in January 1990 demonstrated the ability of this

Figure 4.4.2

Lower Hylebos Creek

COMPOSITE EXISTING CONDITIONS MAP

Adversely Affected Areas

- (F) Flooding
- (E) Erosion and Sedimentation
- (H) Habitat
- (Q) Water Quality

Significant Resource Areas Needing Protection

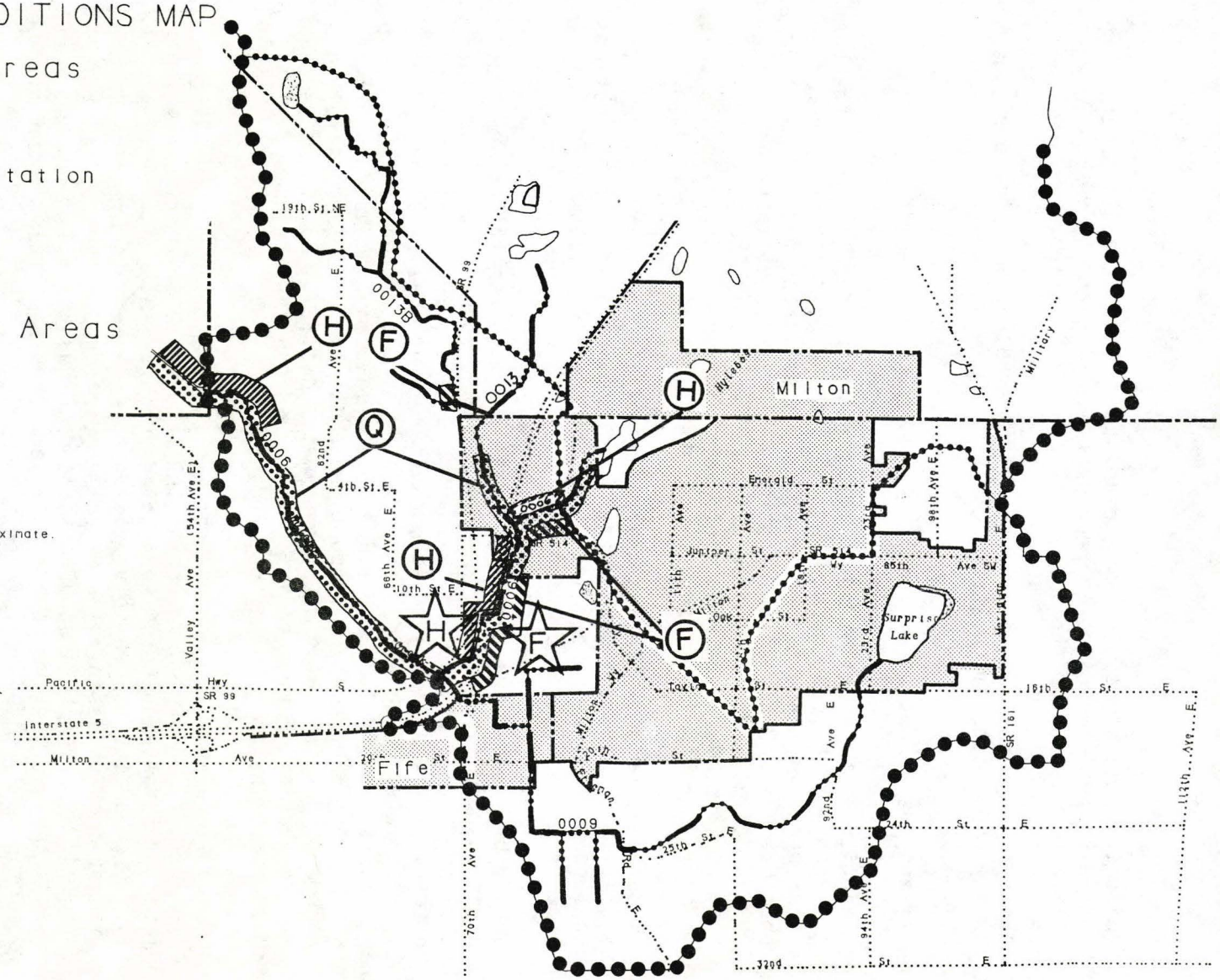
- (F) Flood Storage
- (H) Habitat

Designated point and stream reach locations are approximate.

- Sub-basin Boundary
- Subcatchment Boundary
- 0016 Stream and Stream Number
- Wetland

0 1/2 1 mile

N



area to detain flood waters and so not exacerabate flooding in the lower 4.5 miles of Hylebos Creek. Although two lanes of Interstate 5 were inundated, flooding west of the highway was not as severe. In general, overbank areas can provide refuge for fish during storm events and also allow sediments to settle out in slow, backwatered areas.

Although the valley areas of the sub-basin would naturally flood in the undeveloped condition, the sub-basin is now experiencing more frequent and larger volume floods. A 1981 Flood Insurance Study for Milton estimated the 100-year flow at the confluence of tributaries 0006 and 0013 as 310 cubic feet per second. The HSPF model computed this flow rate as 556 cfs based on 1987 land use, nearly an eighty percent difference. If detention for increased runoff is not applied, the future 100-year flow could increase to 970 cfs (see Figure 4.4.3). This increase in flow would increase greatly flood-related property damages and public risk. Higher water surface elevations from increased flows would be exacerbated further by predicted sea level rise and land subsidence in the sub-basin. Sea-level rise currently averages about one inch per decade. Together they may increase up to a total of 1.5 feet of relative submergence over the next 50 years (Shipman, 1990). Continued filling of floodplains will result in additional increases in water surface elevations upstream of the fill sites as well as produce locally greater velocities. Displaced volumes of water would contribute to increased flooding downstream.

Replacement of natural floodplain and estuary areas with structures for human use inevitably increases flood hazards. Constrictions such as those imposed on Hylebos Creek at RM 4.5 (at I-5, SR 99, and a fill on the right overbank) are direct causes of flooding. Filling and channelization also destroy aquatic habitat. Major alteration of the physical stream system in conjunction with added pollutants and more frequent flooding have severely degraded the aquatic habitat. Once supporting several species of salmonids, only chum and coho are present and only due to the Puyallup Tribe's salmon fry out-planting program.

Hylebos Waterway and the lower reach of the mainstem (RM 3.0 to 5.0) serves largely as a transport zone for salmonids migrating to upstream spawning grounds. Near the mouth of Hylebos Waterway, there are some small patches of excellent estuarine habitat which is vital to juvenile fish during their transition from fresh to salt water. Incremental channel modifications, such as illegal filling and dredging, could reduce further the quantity and quality of salmonid habitat.

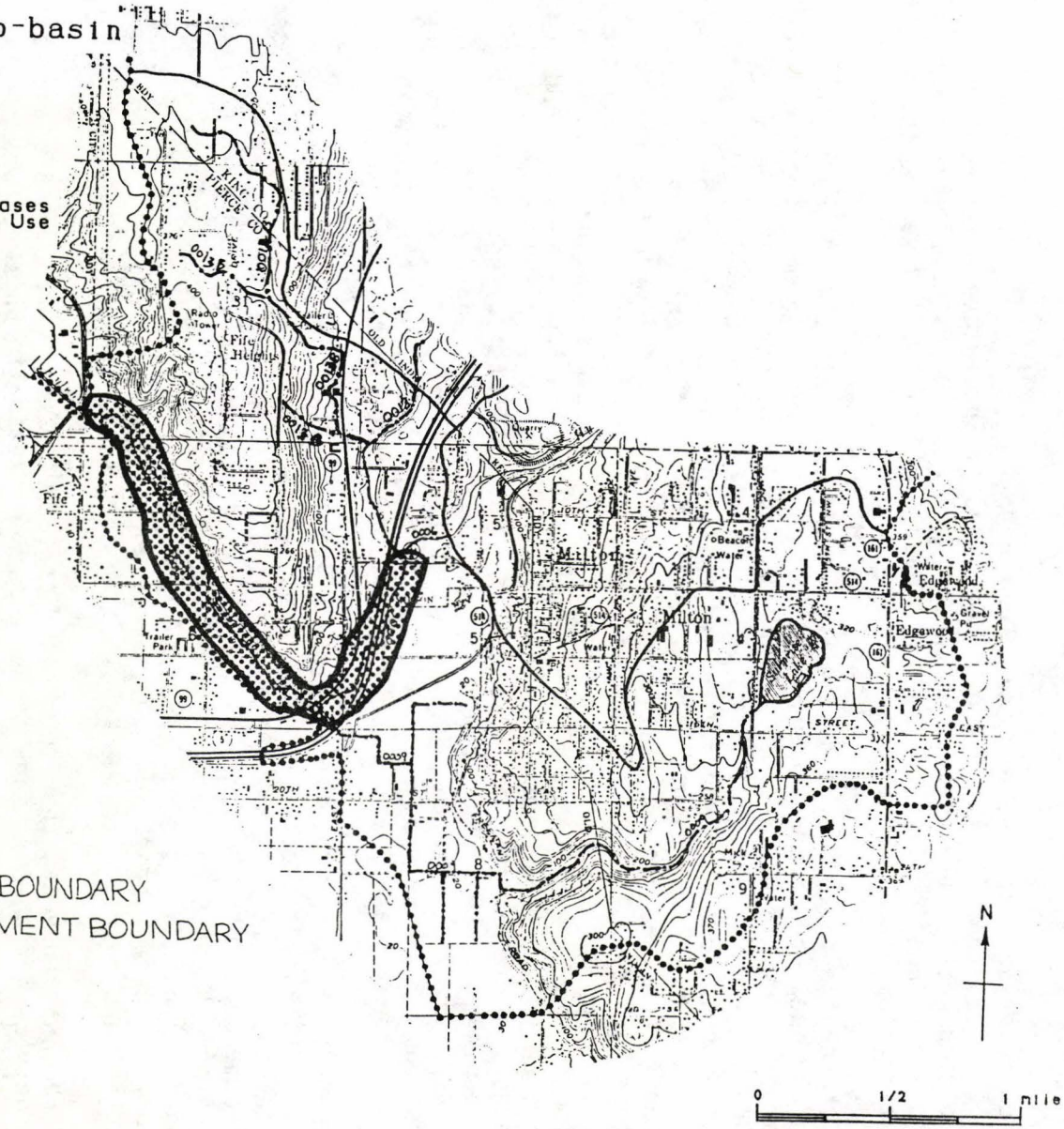
Efforts by the Puyallup Tribe and other interested parties to maintain and improve habitat will prove fruitful only if increased flows can be mitigated, floodplain encroachments prohibited, and pollutants eliminated. Unless new regulations are adopted and implemented quickly, the salmonid resource will continue to be sustained by juvenile out-planting, and most likely would experience a further decline or even total loss.

Pollutants within the lower reach of Hylebos Creek not only degrade aquatic habitat but are a public health risk. Commencement Bay was targeted for Superfund action in 1981, when the EPA listed 115 top-priority hazardous waste sites. Hazardous waste sites along Hylebos Waterway near RM 2.8 could be cleaned up in the future as a result of the Superfund Program; however, high concentrations of pollutants from new upstream sources could become a renewed cause for concern.

Figure 4.4.3

Lower Hylebos Sub-basin

Relative Peak Flow Increases
From 1987 to Future Land Use



Previous water quality studies in Lower Hylebos Creek (see Section 3.7, Water Quality) have cited several significant problems. Contaminated commercial and industrial facilities, wastewater discharges, storm drains, and contaminated sediments are associated with industrial activities within Commencement Bay. High temperatures, low dissolved oxygen concentrations, and high dissolved arsenic, copper, mercury, and zinc concentrations are present in the Fife Ditch. High arsenic concentrations are also associated with the United States Gypsum and B & L Landfills, and the Surprise Lake drainage (tributary 0009).

Concentrations of pollutants, such as nutrients, metals, and suspended solids, will increase as the sub-basin and its upstream tributary area become more urbanized. With a reduction in open space and increased construction, there will likely be increased pollutant loadings of turbidity and sediment. Additionally, as onsite septic systems and sewer lines age, there is an increased potential for system failures. Highway construction on I-5 to accommodate High Occupancy Vehicle (HOV) lanes will add to construction impacts of sediments entering the stream and will contribute additional oil and grease from roadway runoff.

KEY FINDINGS

- Some of the best rearing areas and wildlife habitat in the Hylebos system exists in tributary 0013 along RM 0.44 to 0.85. Freshwater mussel beds exist at RM 0.06 and 0.50.
- Flooding in the central valley of the sub-basin has been exacerbated by increased flows, sediment deposition, and fill on floodplain areas.
- Future flows without mitigation are predicted to increased nearly 75 percent.
- Predicted sea-level rise and land subsidence may cause 1.5 feet of relative submergence in the next 50 years.
- The quantity and quality of aquatic habitat has greatly diminished from historical levels; minimal salmonid populations exist mainly from an outplanting program conducted by the Puyallup Tribe.
- Water quality is significantly degraded because of upstream pollutant sources, I-5 and SR 99 road runoff, and industrial and commercial activities within Commencement Bay and the Hylebos Waterway.
- Pollutants delivered to the sub-basin in combinations with hazardous wastes, specifically a EPA Superfund site along Hylebos Waterway, are a significant risk to public health.

SECTION 4.5 LOWER PUGET SOUND BASIN

INTRODUCTION

The Lower Puget Sound basin is an amalgam of six individual streams and innumerable smaller drainageways. For purposes of this discussion the basin has been divided into three tributary areas--the North, Central, and South Lower Puget Sound sub-basins. All waters in these sub-basins flow from the upland plateau draining westward and northward into Puget Sound. Unlike most of the channels in the Hylebos Creek basin, the streams here flow through steeply incised valleys. Wave erosion on the shoreline following deglaciation of the region 14,000 years ago has established and maintained steep bluffs between the upland plateau and the Sound. These steep bluff faces are sporadically interrupted, primarily by stream valleys but also by a few zones of large-scale, and primarily inactive, landsliding.

SUB-BASIN DESCRIPTION

The plateau and the bluff areas that together compose the Lower Puget Sound basin display very different geologic materials and processes. The plateau is underlain by till, deposited at the base of the ice sheet that last occupied the region. In many parts of the basin, particularly in the southwest, the till is overlain by sandy outwash deposited by water melted off the retreating ice sheet. This recessional outwash is up to several tens of feet thick in many areas, providing a pervious layer to absorb surface runoff and release it slowly above the relatively impervious till.

The bluff offers a view into the geologic layers beneath the till of the upland plateau. In the south and west, thick deposits of advance outwash were laid down by rivers emerging from the snout of the ice sheet as it first advanced. These sediments are now exposed down to sea level in places. Farther north, a sequence of older underlying deposits, both sandy and clayey, are sporadically exposed.

Landsliding in the Lower Puget Sound basin is an inevitable result of wave-steepened hillslopes and interlayered coarse and fine-grained deposits. Four such slides, all immediately adjacent to the shoreline, are particularly prominent and were first mapped almost 30 years ago (Waldron, 1961). Of these four, the largest (the "Woodmont Slide", at about S 274th Street) has a recent history of movement and has a number of occupied houses on its downdropped, and possibly still episodically moving, block. The others are presently undeveloped, but one that is platted (at about 9th Avenue SW) shows unequivocal evidence of historic movement, one just west was reactivated in 1986 by runoff from adjoining property, and the western-most one (at about 24th Avenue SW) is largely undisturbed. In addition, several zones of less discrete hillslope movement are evident in the basin. One, just north of Redondo, appears fully stable; the other, in the Buenna area, has shown some modest instability adjacent to seeps and drainage courses.

Existing land use in the basin has profoundly affected pattern and quantities of surface-water runoff. In many subcatchments, the upland plateau is almost fully developed, primarily in high-density single-family residences. Therefore, the local channels now display most of the problems that they ever are likely to

experience from development-induced flows. These subcatchments also provide a regional example of the consequences of inadequately mitigated urbanization--nearly barren flume-like channels with only limited opportunity for restoration or remediation.

Only parts of Joes Creek (0388) have thus far escaped the impacts of urban development: as a result, parts of the lower channel still provide some resource value. Yet these same subcatchments are predicted to experience some of the highest future flow increases in the entire basin planning area without effective mitigation of the urbanization impacts.

CONDITIONS

North Lower Puget Sound Sub-basin

The two drainages in the North Lower Puget Sound sub-basin, shown in Figures 4.5.1 and 4.5.2, are in fair condition, protected from more intense degradation by only moderate upper basin development to date and an extensive outwash deposit at the headwaters of McSorley Creek (0381) which buffers flow increases. Some lateral erosion is evident along this creek, particularly between about RM 1.10 and its confluence with tributary 0382 downstream. Old hillside landslides are also evident at several locations along this valley, but in general they do not appear to affect the creek directly nor are their occurrences directly related to recent stream-channel erosion.

The slope of McSorley Creek undergoes a pronounced flattening as it approaches Puget Sound. For the lowermost thousand feet or more, the channel has built a delta out into the Sound, filling its valley with sediment brought down by the flow. It is a deposition zone for sediment, one which will persist irrespective of changes in future flow. Saltwater State Park is now constructed on that delta, which is generally inactive but which suffered significant innundation during the January 1990 storm. Deposition of sediment in the channel and at the constriction at the access road culvert forced water out of its normally confined path and across the lower part of the delta (and the lower part of the Park).

The upper part of this tributary is also the site of chronic flooding problems in the vicinity of S 272nd Avenue. Recent development on the south side of that road has channelized drainage, decreased infiltration, and increased runoff peaks and volumes. As a result, previously undefined surface and subsurface flow now overwhelm the drainage detention and conveyance system in this area, leading to numerous complaints annually and a now pending King County Drainage Investigation study.

Under normal conditions, tributary 0382 contributes relatively little to either the flow or the sediment load of tributary 0381, but upstream of their confluence recent development in the headwaters of tributary 0382 has resulted in a very high concentration of fine sediment in the gravels on the bed of the channel. In addition, a drainage outfall from the Midway Landfill detention pond which collects storm flows from both the Landfill and I-5 enters the stream system on tributary 0382 just above its confluence with 0381. The contribution of this discharge to flow in McSorley Creek is under dispute, with regard to the January 1990 flooding of Saltwater State Park. No additional information is presently available.

Figure 4.5.1

North Lower Puget Sound

SUB-BASIN MAP

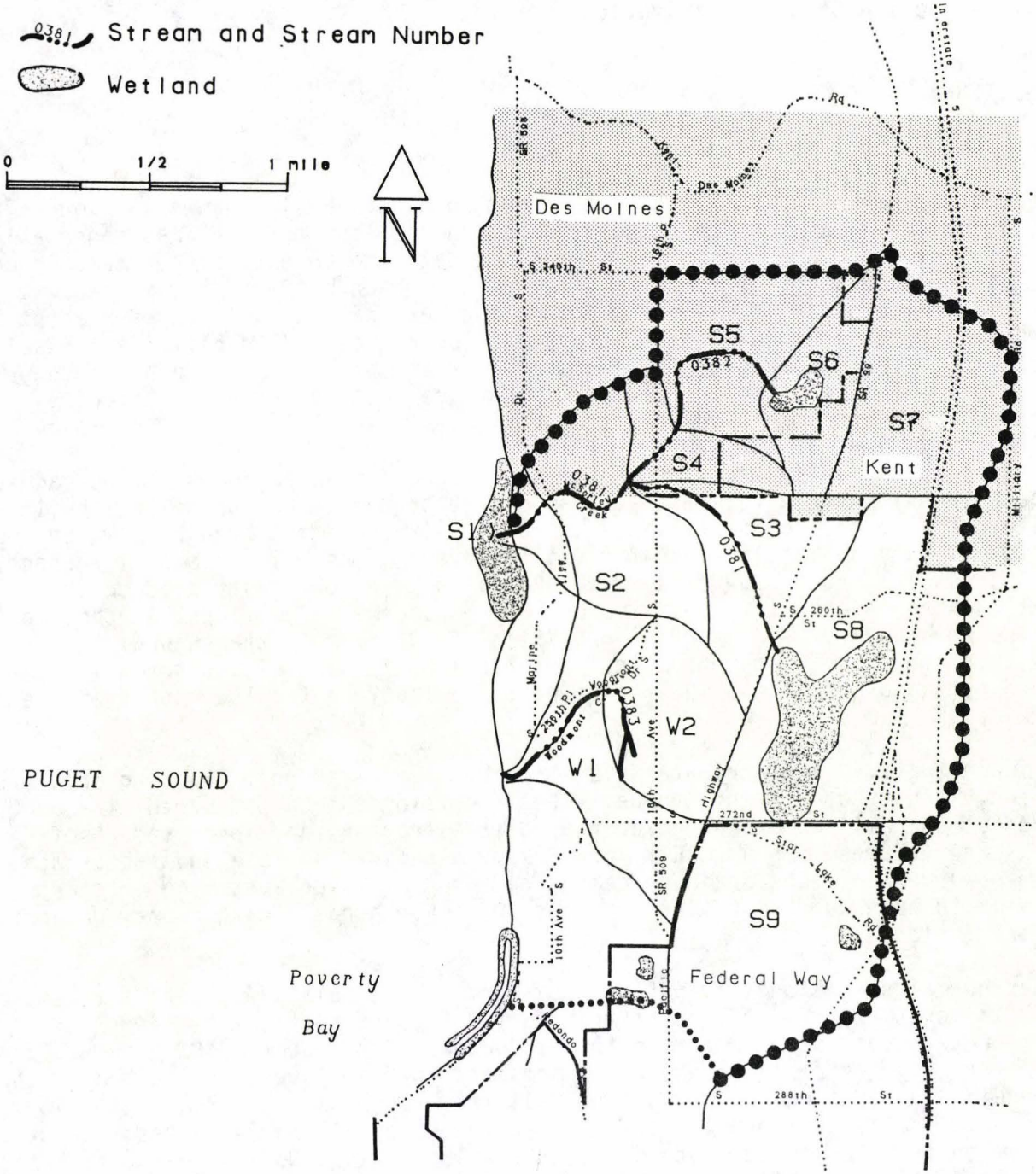


Figure 4.5.2

North Lower Puget Sound

COMPOSITE EXISTING CONDITIONS MAP

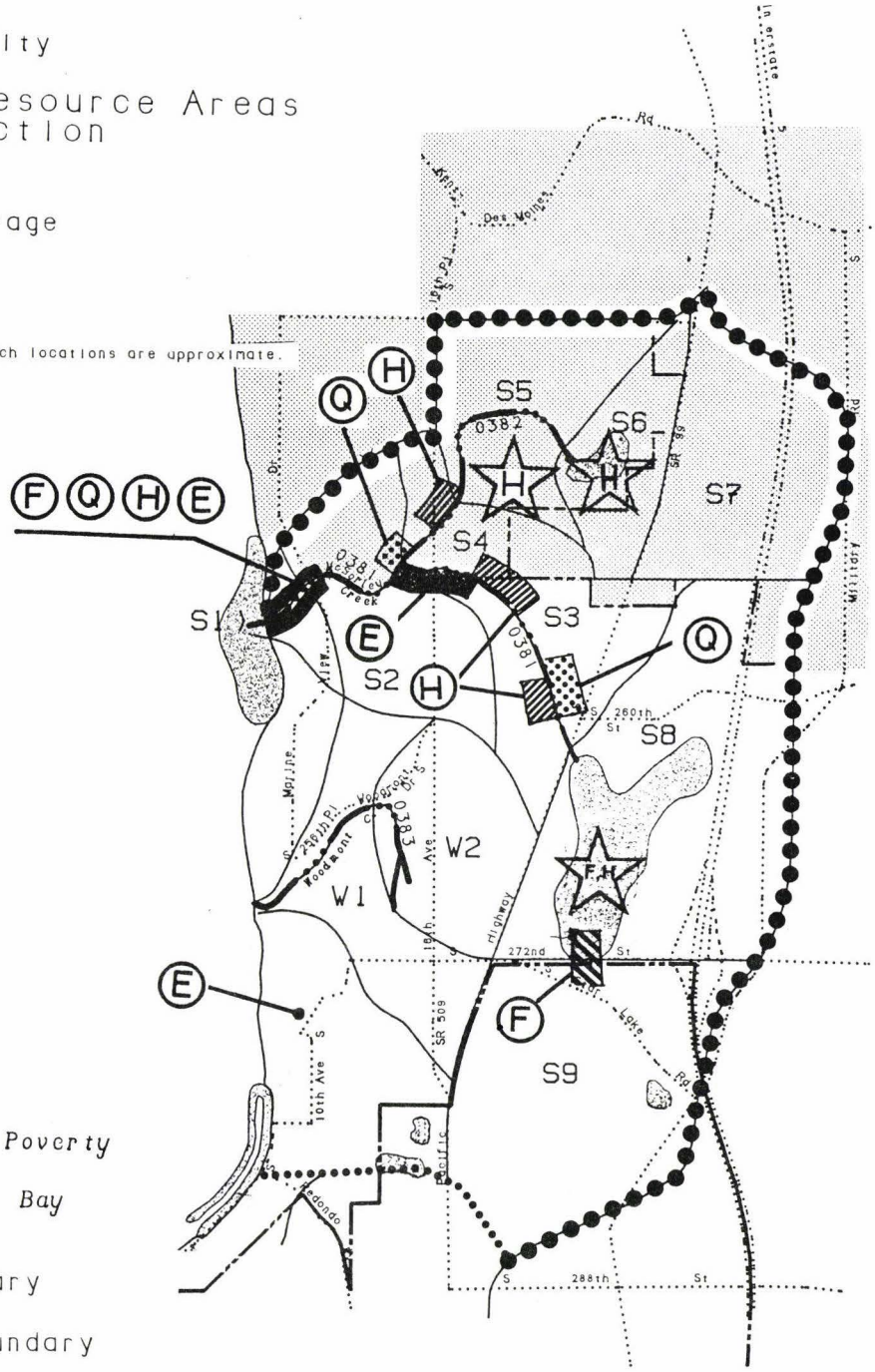
Adversely Affected Areas

- (F) Flooding
- (E) Erosion and Sedimentation
- (H) Habitat
- (Q) Water Quality

Significant Resource Areas Needing Protection

- (F) Flood Storage
- (H) Habitat

Designated point and stream reach locations are approximate.



The January 1990 storm also plugged the culvert crossing of tributary 0382 under 20th Avenue S, near S 245th Place, with debris and sediment. The out-of-channel flows damaged both public and private property at the road crossing and for several lots downstream.

Water quality in McSorley Creek strongly reflects existing land use. This creek showed the highest concentration of total phosphorous of any station in the 1989-1990 King County SWM storm event monitoring basin-wide. High total phosphorus and copper concentrations, and fecal coliform densities in tributary 0381 at S 260th Street (Station QM2) probably originate from SR 99 runoff and impervious, commercial, and multifamily land-use areas immediately east. This station was always observed with oily sheens and hydrocarbon smells during storm events.

High fecal densities, nutrients (e.g., nitrate + nitrite - nitrogen and total phosphorus), and metal (e.g., copper, lead, and zinc) concentrations in tributary 0382 at S 251st Street and 16th Avenue S were measured at Station 11 (City of Kent) and probably originate from: 1) high-density single-family residences west and north of 20th Avenue S; 2) impervious/commercial areas west of 20th Avenue S; and 3) SR 99 runoff and associated impervious areas. Since monthly monitoring by the Green River Community College began in 1986, this station has experienced very low dissolved oxygen (D.O.) concentrations during the summer months, with typical values of about 5 to 7 mg/L and as low as 4.7 mg/L in 1987.

Fish habitat is limited in McSorley Creek. There are good spawning gravels and cobbles throughout much of the channel from RM 0.20 up to the crossing of SR 99 (RM 1.41), which forms the upper extent of salmonid habitat. The lower one-tenth mile has much higher fines than occurs in most places upstream. Canopy and overhanging vegetation is good upstream of RM 0.20 where the stream is buffered by wide slopes of mixed second-growth forest and brush. However, most of this system lacks large organic debris (LOD) and pools.

The mouth of McSorley Creek to RM 0.90 is dominated by shallow riffles with virtually no pools. A series of mass failures has occurred from RM 0.30 to 1.20; they vary in volume from a few hundred to over 10,000 cubic feet. The channel is choked by several dozen recent tree falls upstream of RM 0.90 for 0.2 miles due to the 1989 and 1990 floods, one of which may be impassable to fish at all flows. There is no cover over most of the lower 0.20 miles through the picnicking and camping areas of Saltwater State Park. From RM 0.12-0.20 there are 2-3' high berms of cobble, gravel, and sand alluvium, which was presumably dredged out of the channel since the January 1990 flood. These berms have not yet eroded into the channel significantly but are likely to do so over time. This potential sediment source, together with unstable and unvegetated deposits associated with the new failures from RM 0.30-1.20, will continue to add to the existing load in the stream. Most of these failures will also likely enlarge during future storms. The system will become increasingly riffle dominated, and the small pools remaining in the upper reaches will decrease in size with aggradation. Although four juvenile salmonids were seen near the mouth of tributary 0382 in April 1990, even limited future degradation would represent a significant impact to the marginal habitat that remains.

Woodmont Creek (tributary 0383) functions as little more than a conveyance channel. Owing to its limited drainage area and resistant substrate, flows have not significantly incised the channel deposits. Filling of the stream valley for placement of Woodmont Beach Road, however, has severely constrained the

historic stream channel and so encouraged lateral migration and resulting bank failures. Local bank armoring has been apparently successful at reducing normal maintenance, but the storm of January 1986 eroded a portion of the roadway surface. Other major problems have been neither identified by this investigation nor reported by stream-side residents.

Flows in all these tributaries are predicted to increase by about 50 percent or more without mitigation (see Figure 4.5.3). As a result, 100-year flow events under 1987 conditions would increase in frequency 10- to 20-fold in the future.

Central Lower Puget Sound Sub-basin

Both of the major channels in this sub-basin, shown in Figures 4.5.4 and 4.5.5, have been heavily impacted by development in their upstream reaches and along the channels themselves. Simulated flow increases from past development are among the greatest in the basin plan area, with increase of 3- to 4-fold common over most of the channels' length. These channels also have the steepest gradients of any in the basin planning area, with average slopes approaching 10 percent over their lowermost mile. The erosivity of this (greatly increased) water flow is therefore maximized. The use of these channels by anadromous fish has probably been severely curtailed by such gradients, even in predevelopment time.

Redondo Creek (0384) has three distinct segments. Between Steel Lake and SR 509, the channel gradient is dictated by the low slope of the upland till surface. Both sediment transport and erosion problems are quite low. Downstream of SR 509, the channel incises into easily erodible deposits of the advance outwash as it simultaneously increases in gradient. As a result, incision is dramatic and recent; tree roots entirely bridging the top of the channel, presumably below the ground level at some time in the past, are now suspended four feet above the channel bottom. Predicted future flow increases of about 25 percent along this reach will intensify this activity.

In its third segment, downstream of about 13th Avenue S, the channel is severely constrained by the roadway. Bank armoring, including several hundred feet of piping, have been largely successful at limiting further erosion downstream to Puget Sound. Yet the steep deposits on the flanking hillsides remain largely unprotected from uncontrolled upland drainage, which has resulted in a roadway-blocking slide in January 1986 originating along a utility trench at RM 0.40 and active incision up to 20 feet deep on the north valley walls at RM 0.50. The lowermost 500 feet of channel are piped, likely presenting an impassible barrier to migrating fish. Upstream of this barrier, habitat conditions are little improved, with only a short reach of relatively undisturbed channel at about RM 0.20.

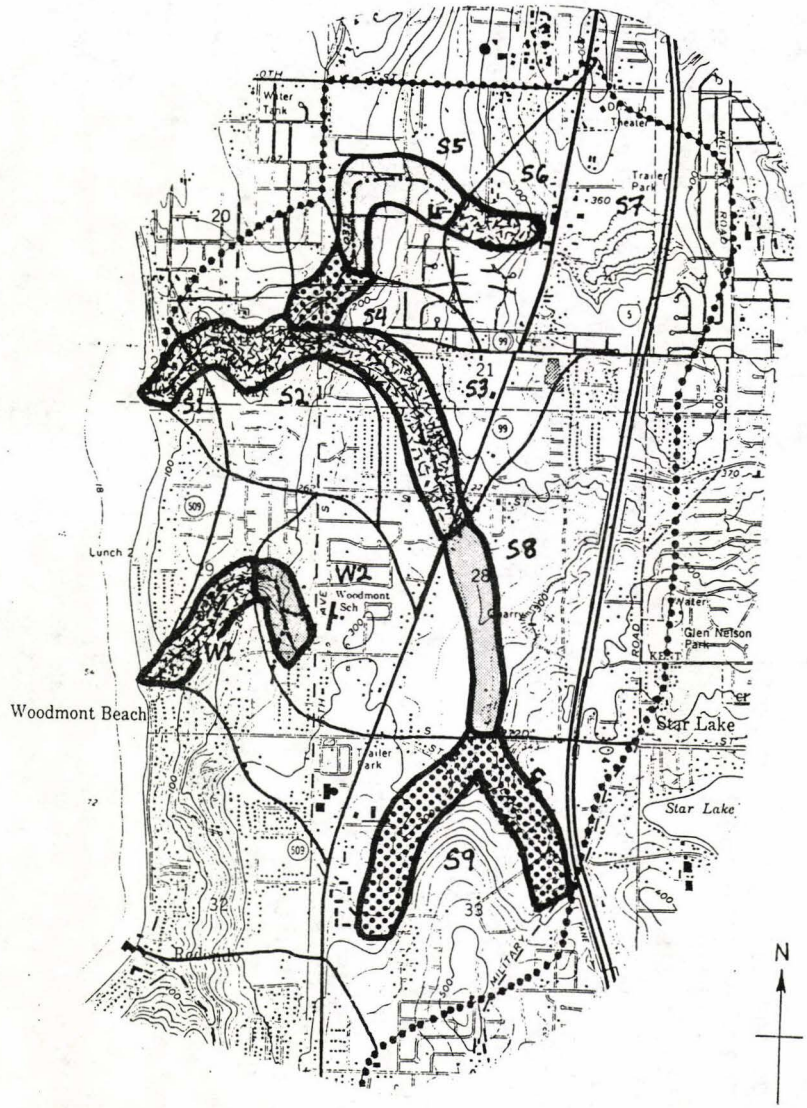
Cold Creek (0385) is either piped, channelized, or actively incising along nearly its entire length. Because of substantial flow increases from dense development in its headwaters, many reaches of the creek have been stripped of their diversity: pools, riffles, and bends have been largely replaced by steep bare walls and a uniform planar bed. The numerous pipe and culvert inlets have restricted the magnitude of channel incision by holding the bed elevation constant at those points. This stabilization, however, has been at the expense of other stream functions and potential values. Modest fish habitat persists for about 1/3 mile upstream of the Redondo Sewage Treatment Plant, although the

Figure 4.5.3

North Lower Puget Sound Sub-basin

Relative Peak Flow Increases From 1987 to Future Land Use

- 0 - 25%
- 25 - 50%
- 50 - 100%
- 100 - 150%
- > 150%



- SUBBASIN BOUNDARY
- SUBCATCHMENT BOUNDARY
- STREAM
- LAKE

Figure 4.5.4

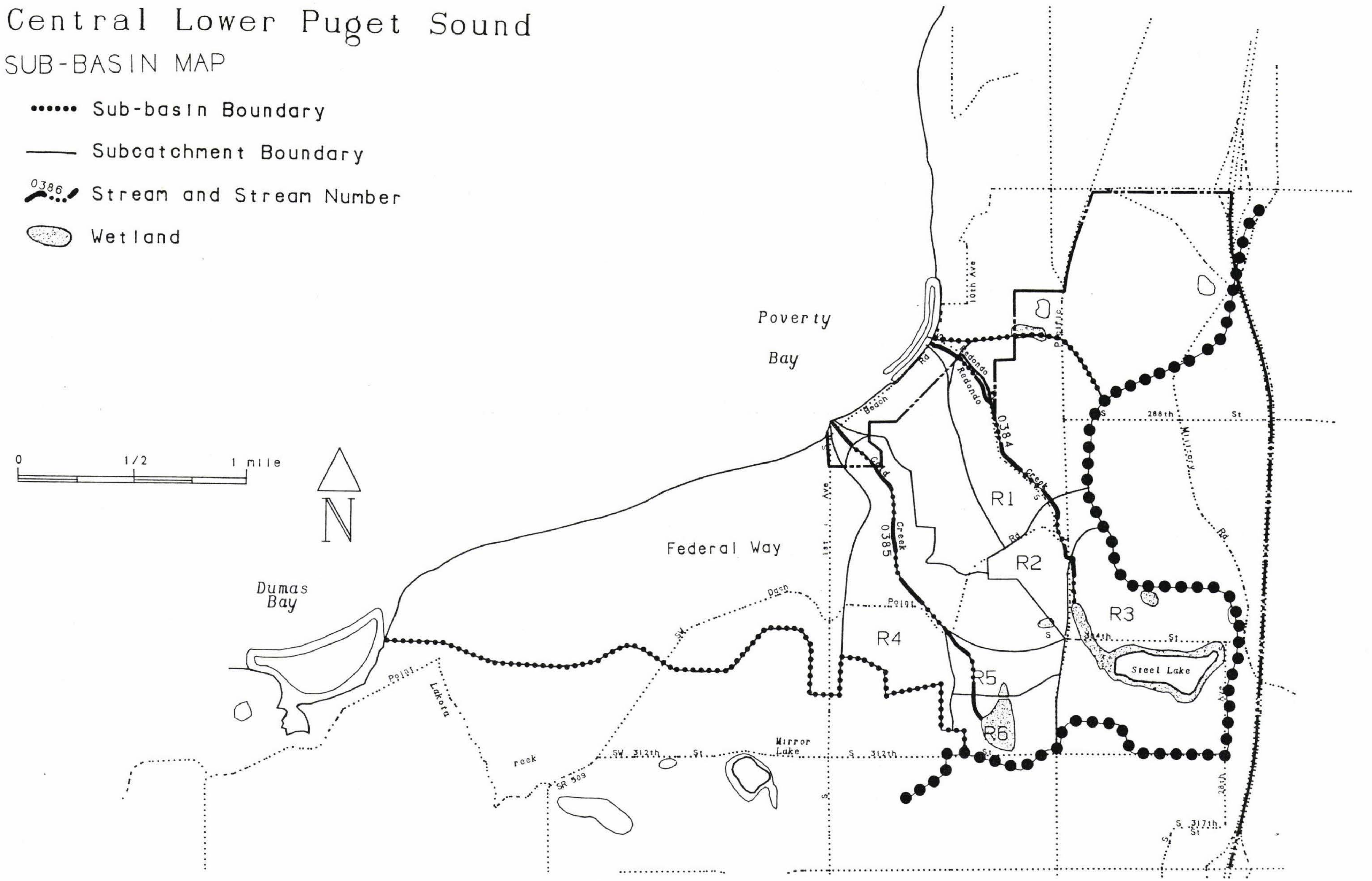

Central Lower Puget Sound
SUB-BASIN MAP
Sub-basin Boundary
Subcatchment Boundary
0386 Stream and Stream Number
Wetland
0
1/2
1 mile
N
Poverty
Bay
Dumas
Bay
Federal Way
R1
R2
R3
R4
R5
R6
0384
0385
Creek
Redondo
Beach
Rd
288th
St
Military
Steel Lake
Mirror
Lake
SW 312th
S. 312th
St
SR 509
Lakota
S. 317th
St
10th Ave
1st Ave
Pacific
Dash
Point

Figure 4.5.5

Central Lower Puget Sound

COMPOSITE EXISTING CONDITIONS MAP

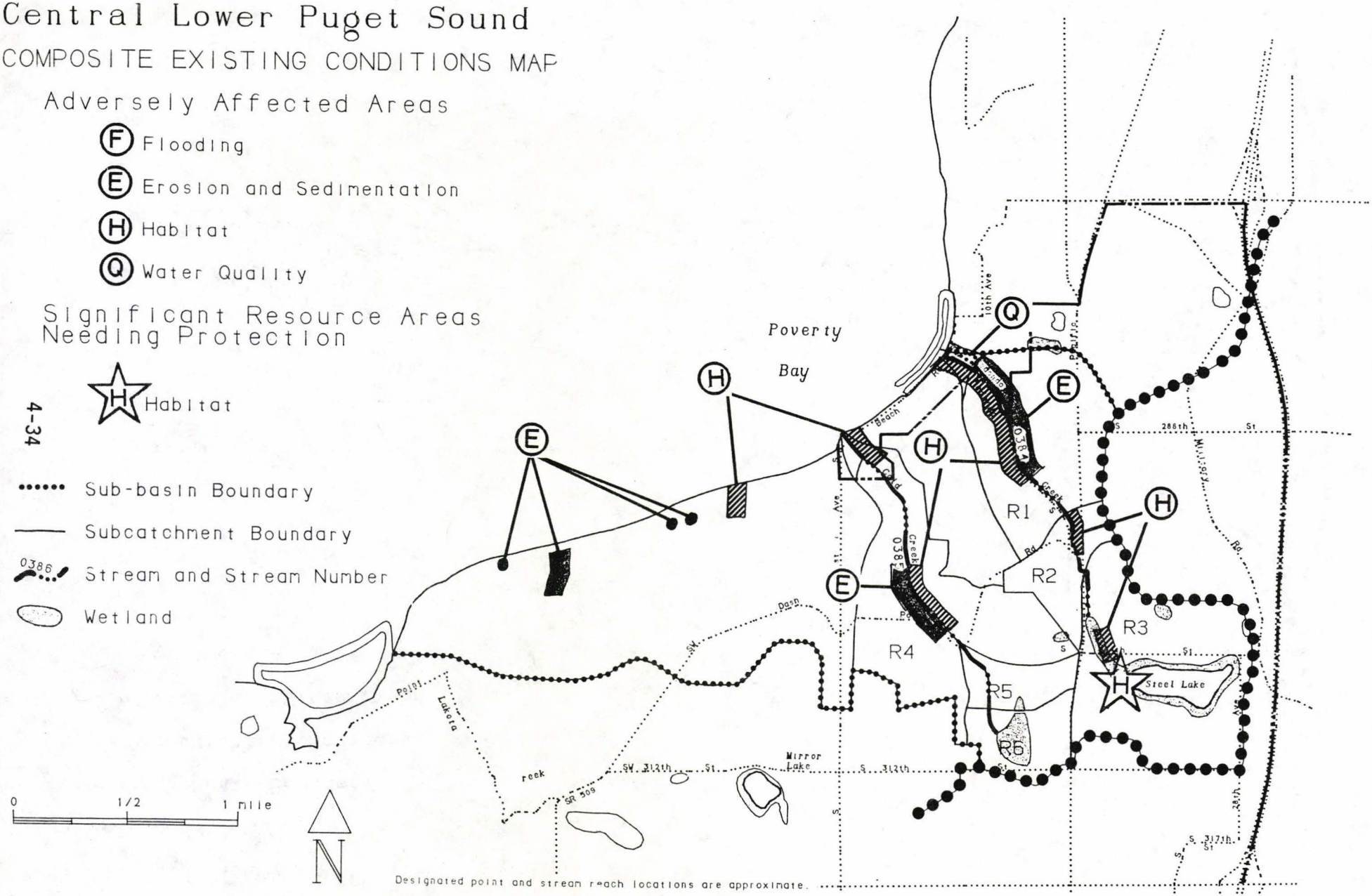
Adversely Affected Areas

- (F) Flooding
- (E) Erosion and Sedimentation
- (H) Habitat
- (Q) Water Quality

Significant Resource Areas Needing Protection

- (H) Habitat

- Sub-basin Boundary
- Subcatchment Boundary
- 0386 Stream and Stream Number
- Wetland



Designated point and stream reach locations are approximate.

weirs and pools in the channel here may be a migration obstacle and the channel through the mobile home park is devoid of cover. Predicted future flow increases are not substantial along this tributary, but even existing flows are sufficient to maintain active upstream erosion and consequent downstream deposition (see Figure 4.5.6).

A variety of other problems have occurred in and adjacent to this sub-basin but are not associated with any named channel. One in particular, the washout of a private culvert at the base of 20th Avenue SW in Adelaide, reflects the potential for sediment mobilization, downstream deposition, and subsequent blockage of constructed drainage facilities in any of these small but steeply sloping drainageways.

Water quality conditions in this basin affect both streams and lakes. High measured fecal coliform densities and copper and zinc concentrations probably originate from high-density single-family residences (Station QC3, Figure 3.7.1b), and from SR 99 runoff and associated impervious and commercial areas (Station QC2, Figure 3.7.1b). Station QC2 was always observed with oily sheens and hydrocarbon smells during storm events. A gasoline service station at the corner of SR 99 and SR 509 is immediately upstream of Station QC2 on Redondo Creek; petrochemicals were apparently disposed here in the 1940s as well. This sub-basin had the highest mean concentration (75 mg/L) for total suspended solids of any in the 1989-90 storm-event sampling basin-wide.

Steel Lake, the 46-acre lake at the head of Redondo Creek, is characterized by tea-colored water and shallow depths. Historically, this lake has been classified as mesotrophic (i.e., middle-aged when concentrations of phosphorus and algae levels increase, and water clarity decreases). The 1988 data used to classify the lake indicate a similar condition (Metro, 1988). A recent (February 17, 1990) sample from Steel Lake at 1-meter depth revealed a relatively high chlorophyll a concentration (13.95 mg/L). This level usually characterizes algal blooms and may be associated with lake turnover, but this is not an expected late-winter occurrence. Although surrounding development is almost complete, the lake may continue to degrade over time as the bottom sediments accumulate additional phosphorus and then release it annually to overlying waters. The lake is not deep and so not well-suited to buffer additional sediment loading.

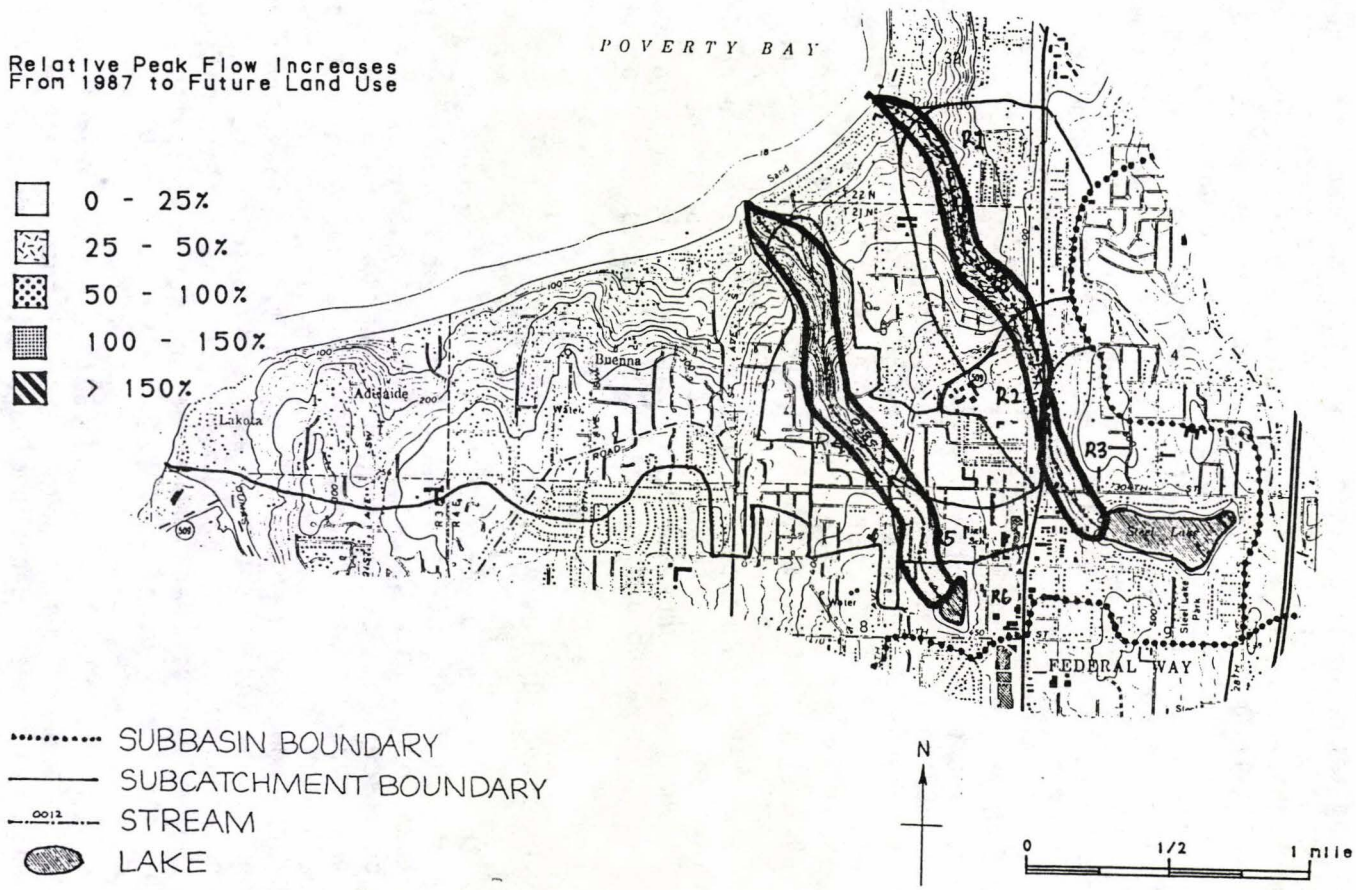
South Lower Puget Sound Sub-basin

The streams of this sub-basin, shown in Figures 4.5.7 and 4.5.8, drop steeply off the till-and-outwash upland plateau through about 200 feet of underlying erodible sandy outwash deposits. As elsewhere in this basin, and in the region as a whole, erosion susceptibility is heightened wherever these deposits are exposed along the course of stream channels. In a sub-basin where development activity has been high, such problems can be very common. Flows in Lakota Creek and Joes Creek are among those showing the greatest increases over predevelopment conditions, and thus the problems now evident are likely to approximate future conditions as well. Localized exceptions to this pattern in upper Joes Creek, however, suggest that some areas are still likely to experience dramatic future impacts (see Figures 4.5.9).

The tributaries of Lakota Creek (0386 and 0387) exhibit markedly different levels of channel activity and erosion. Above the confluence of the two forks, tributary 0386 exhibits only modest degrees of erosion over most of its length,

Figure 4.5.6

Central Lower Puget Sound Sub-basin



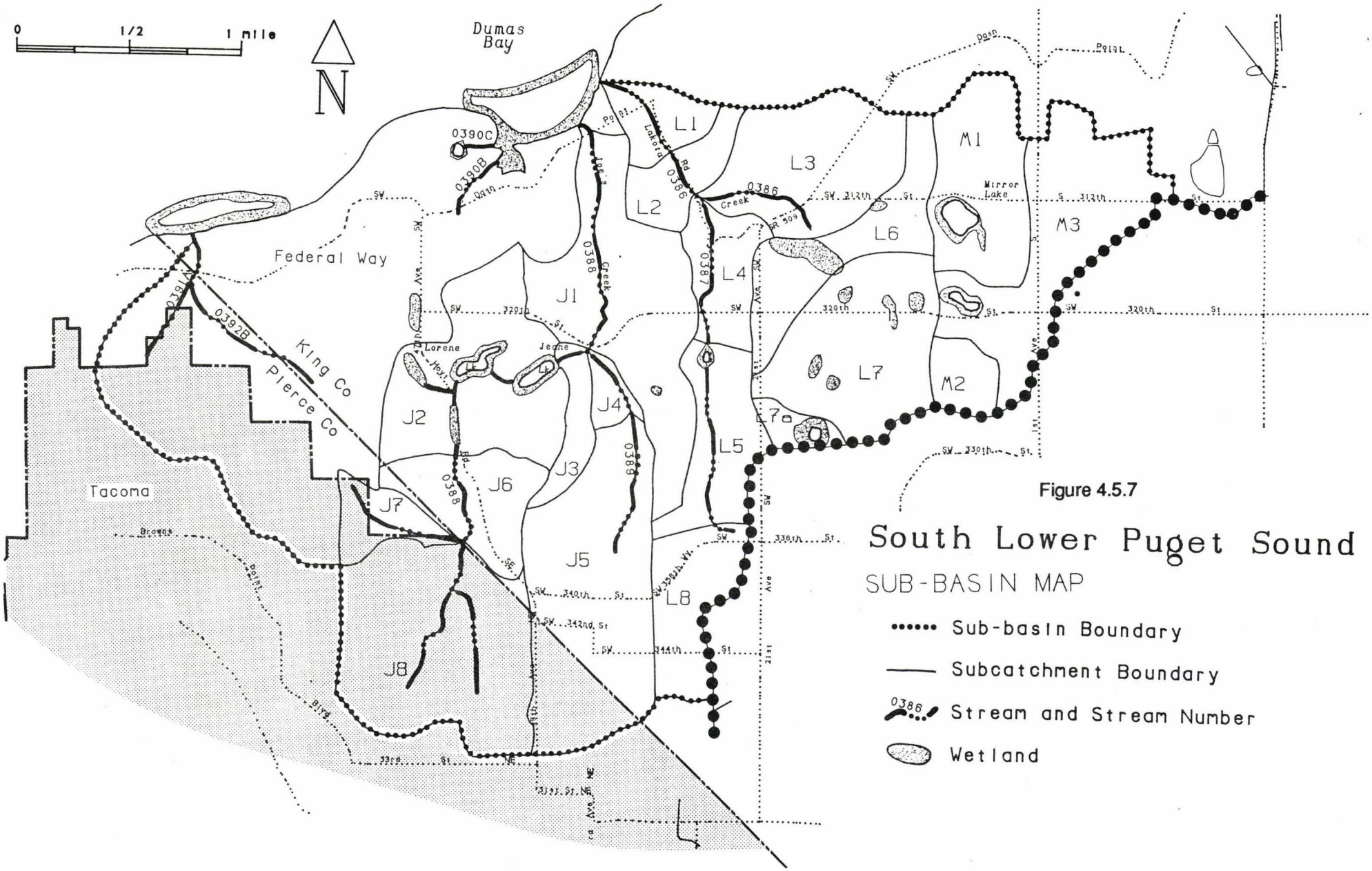


Figure 4.5.7

South Lower Puget Sound

SUB-BASIN MAP

Sub-basin Boundary

Subcatchment Boundary

Stream and Stream Number

Wetland

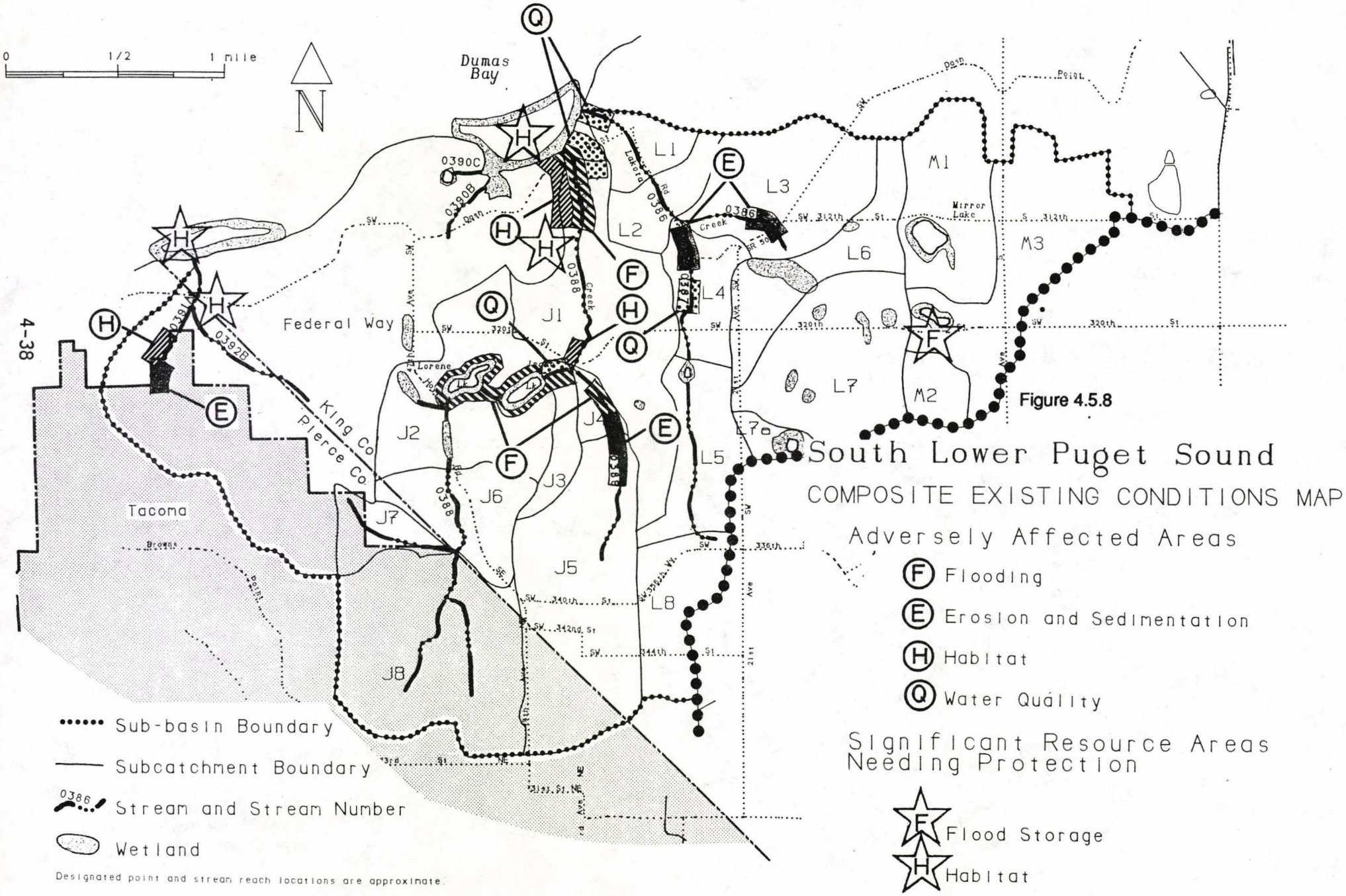
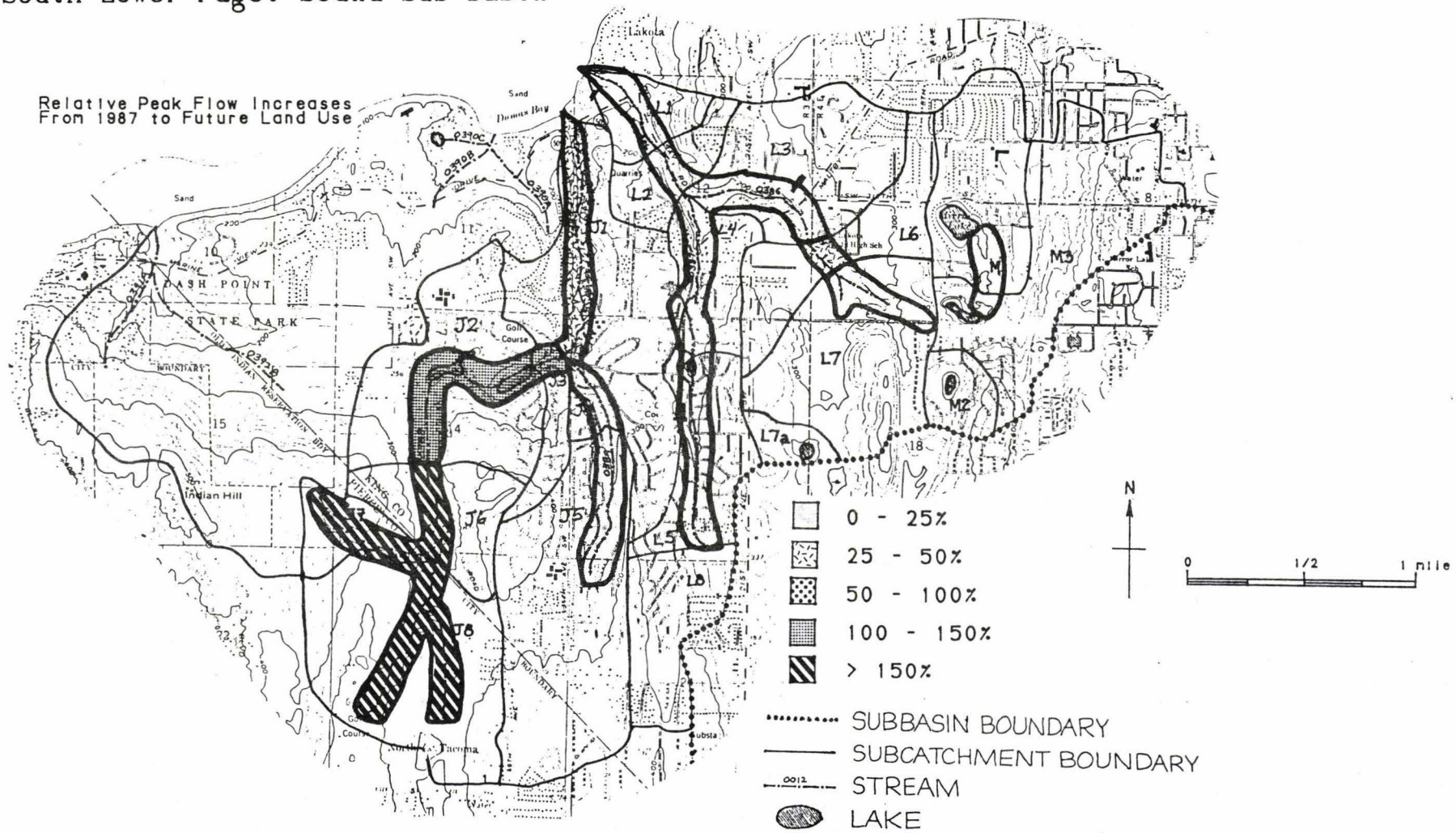

0 1/2 1 mile
N
Dumas Bay
0390C
0390B
0391
0392B
0388
0386
Federal Way
Tacoma
King Co
Pierce Co
Lorene
Lake
Creek
Mirror Lake
L1
L2
L3
L4
L5
L6
L7
L7a
L8
M1
M2
M3
J1
J2
J3
J4
J5
J6
J7
J8
Sub-basin Boundary
Subcatchment Boundary
Stream and Stream Number
Wetland
Designated point and stream reach locations are approximate.
South Lower Puget Sound
COMPOSITE EXISTING CONDITIONS MAP
Adversely Affected Areas
Flooding
Erosion and Sedimentation
Habitat
Water Quality
Significant Resource Areas Needing Protection
Flood Storage
Habitat

Figure 4.5.8

Figure 4.5.9

South Lower Puget Sound Sub-basin



mainly local bank failures. Incision is quite active, however, in the first several hundred yards downstream of its crossing of SR 509 at Lakota Junior High School. Channel erosion is much more common along tributary 0387 downstream of S 320th Street, particularly alongside Decatur High School and again downstream of SR 509. Neither of these branches are likely to see greatly increased levels of erosion, because their headwater areas are largely built out. Flow increases of at most 10-20 percent are anticipated.

Downstream of the confluence at SR 509, reduced channel gradients drop the stream below a level of chronic erosivity. One significant hillside failure and a number of zones of minor bank erosion occur along this reach, but most of this activity is simply associated with the attempted lateral migration of the stream between constraining banks, occurring where the stream's gravel load is depositing onto narrow point bars and consequently deflecting flow. The potential for stream restoration would be high if not for the physical constraints imposed by sharing the valley bottom with SR 509 and the Federal Way Sewer and Water District sewage treatment plant. In addition to physical constraints, the high-flow bypass pipe of the treatment plant attracts up-migrating fish away from the channels; the upstream culvert inlet provides a locus of chronic sediment deposition. Nevertheless, some fish and spawning activity have been observed in these lower reaches, with sediment deposition at the bypass culvert inlet providing some protection to habitat downstream.

Upstream of the western tributary of Lakota Creek, the closed basin around Fisher's Bog and Mirror Lake provides significant infiltration of water to subsurface aquifers. Under existing conditions, that basin is simulated to overflow at about the 1.3-year event (30 out of 39 years); it drains into the Lakota High School wetland at the head of tributary 0386, site of a proposed regional detention pond (under design 1990). This area contributes up to 25 percent of the total outflow from the wetland, with decreasing proportional contribution as storm magnitude decreases. Under future land-use conditions, that same overflow is predicted to continue at nearly the same frequency, with discharge in 33 of 39 years. The relative percentage of contribution to the wetland is about the same, and the absolute discharge increase is only 15 percent above existing conditions. In contrast, the simulation under forested conditions showed overflow discharge in only 6 of 39 years.

Joes Creek (0388 and its tributary, 0389) includes the largest drainage area in the Lower Puget Sound basin. It flows through a canyon almost completely walled and floored in sand of the Vashon advance outwash; its upland path also has exposed a significant area of this same material through Olympic View Park along tributary 0389. As elsewhere in the region, channel degradation is well-correlated with zones of this deposit, particularly where the surrounding basin area is highly developed.

The upper part of tributary 0388 is mainly floored in low-gradient till, in a basin that under 1987 conditions had only begun to develop significantly. As a result, modeled flows are small and historic stream activity has been quite minimal. In the southwestern part of the basin, however, future development is predicted to yield the greatest flow increases of any in the basin planning area, resulting in greater than doubling of flows in the downstream channel. Some of these future impacts have already been realized as a result of development since the 1987 calibration period, demonstrated during the January 1990 storm when the level of the Twin Lakes increased sufficiently to flood several homes. Increased flows, and perhaps also loss of lake storage from sedimen-

tation, as a result of upstream development probably contributed to the resulting damage.

Tributary 0389 is floored almost entirely in till, but it locally has incised fully through that deposit to expose a "window" of the underlying sandy advance outwash deposits through Olympic View Park. In this area, chronic incision and consequent downstream deposition has initiated efforts to slow the rate of channel downcutting. Gabion weir dams with overflow structures were built in 1986 to reduce flow velocities, trap sediment, and stabilize the channel. Downstream of these weirs, however, the severity of channel downcutting increases dramatically, probably due to sediment starvation of the channel bed without concurrent reduction in flows. Downcutting is halted only by the piping of the subsequent stream reach beneath SW 325th Street, although the constriction of channel capacity by this culvert has resulted in flooding of the roadway and adjacent property.

Downstream of the confluence with tributary 0389 and the culvert outfall below SW 320th Street, the channel is relatively stable, although an abundant sand supply has resulted in heavy deposition into the gravel bed. Erosion is limited in part because of the large amount of woody debris in the stream and in part because of lower channel gradients. Where flows have been diverted against the banks, however, the effects of increased flows on erodible material is rapid and dramatic, particularly at RM 0.30 where a debris jam has deflected the flow and initiated a large sidehill landslide. Although coarse sediment derived from stream action is deposited on the delta at the mouth of Joes Creek, fine sediment is flushed out farther into Dumas Bay. Continued and accelerating stream erosion along this creek, and in the others draining into this bay (Lakota Creek and tributary 0390), will further the degradation of this near-shore environment.

Existing fish habitat in the Lower Puget Sound basin is largely concentrated in this sub-basin; and most of that can be found only in the lowermost mile of Joes Creek. Most of the lower reaches below SW 320th Street in this tributary have fair to good spawning and rearing habitat. Much of tributaries 0388 and 0389 above SW 320th Street are culverted or sewered; this is the current upstream limit of viable salmonid habitat. The major limiting habitat factors from RM 0.0 to 1.02 are decreased pool volumes due to aggradation, and debris jams, which constitute potential migration barriers. Medium to high amounts of large organic debris (LOD) throughout this lower mile create good cover and complexity, contributing greatly to the stability of the channel. More localized patches of good habitat exist upstream of Twin Lakes, but they cannot presently be accessed by fish.

The channel substrate in the lower mile is predominantly pebbles and cobbles. Localized areas of heavy sand deposition in pools and bars reflect the impact of upstream development, but good spawning occurs through most of this section. Fines are generally less than 20 percent in riffles. There are about eight pools from RM 0.18 to 0.42; all but one are less than 12 square feet in area and 1.5 feet deep. All the pools in this lower mile of Joes Creek are formed by LOD, usually half-buried old cedar logs.

From RM 0.06 to 0.89, Joes Creek runs through a valuable undisturbed corridor 200-500 feet wide of second-growth cedar, hemlock, and Douglas fir, along with alder and cottonwood. The valley floor averages 50-80 feet wide with a 6-12 foot channel width. Trees are up to 28 inches diameter. Dominant understory

species are salmonberry, thimbleberry, vine maple, and sword fern. Slopes are up to 150' high with inclinations of 60 to 90 percent, a testament to the stabilizing effects of this well-vegetated corridor.

Although conditions in this creek are quite good relative to the rest of the basin, significant problems are still evident. Pools are being filled through recent aggradation, largely as a result of bank failures, and several LOD jams may be fish-migration barriers. Three new or recently enlarged slope failures occur from RM 0.80 to 0.86; others occur at RM 0.14 and 0.30, with estimated volumes of up to several thousand cubic feet. Smaller but more numerous failures are located above RM 0.88, as the channel impinges against the fill of the golf course driving range. Wood and metal debris in this area also choke the channel. Several debris jams, composed of medium and large trees and logs, form more pronounced migration barriers farther downstream during most or all flow stages. Probable low-flow barriers are found at RM 0.32 and RM 0.48; jams at RM 0.80 and 0.84 are probably impassable at all but storm flows. An LOD jam at RM 0.66 presents a 1.75-foot-high cascade and is probably impassable at all flows.

Continued aggradation and pool filling is likely, due to the exposed sandy soils in the cut banks and slope failures of the upper reaches of the lower stream mile. Flushing of existing instream fines probably cannot occur for several years (if ever) until and unless these banks heal over. However, higher peak flows resulting from further urbanization and reduced storage upstream could increase both sediment loading and the rate of bank failures. Existing jams will most likely grow or become more watertight with continued aggradation, potentially causing more significant backwatering and undercutting. New development, such as a newly cleared housing development above the north slope at RM 0.72, could provide major sediment input if detention ponds are undersized or conveyance facilities fail.

The other, smaller streams in this sub-basin (tributaries 0390, 0392B, and 0391A) display a suite of both channel problems and habitat opportunities. All three branches of tributary 0390 pass through the wildlife sanctuary at Dumas Bay and provide valuable wetland and upland habitat. Each branch has good canopy and understory cover, but none have any significant LOD, pools, or spawning gravels. The majority of all three channels are stable, with short reaches of downcutting in the middle and west forks. The west fork is impassable due to a 18" drop at the outfall of a 24" culvert, whereas the middle and east forks may provide some fish habitat at flows above baseflow.

In contrast, the Dash Point State Park tributaries (0392B and 0391A) provide more extensive fish habitat but also are experiencing more severe problems. In 0392B, good to excellent canopy and understory cover is found from RM 0.10 to RM 0.42, which is the upper limit of salmonid habitat due to an impassable falls and overly steep channel gradients. LOD is sparse until RM 0.24-0.42, where woody debris stabilizes the banks and provides good instream cover. Some pockets of fair spawning gravels exist upstream of RM 0.10. Except for a creek-paralleling hiking trail, the corridor from RM 0.10 to 0.42 is isolated and provides excellent upland habitat, with narrow wetlands just adjacent to the channel. Good canopy is also found along the lowermost 0.2 miles of tributary 0391A. Both channels, however, suffer from a paucity of pools. In addition, tributary 0391A is experiencing severe erosion in its headward reaches from development-induced flow increases, with attendant sideslope failures and introduction of more sediment into the stream.

Water quality conditions in this sub-basin are similar to but more severe than those observed in the Central Lower Puget Sound sub-basin. This sub-basin was the "worst polluted" sub-basin (considering mean concentrations of 11 variables) during the storm event monitoring program for the entire study area. High fecal coliform densities and metal concentrations were detected in the upper reaches of both Joes and Lakota Creeks. This sub-basin had the highest geometric mean density for fecal coliform and the second highest mean concentration (73 mg/L) for total suspended solids. High concentrations of total phosphorus were also observed at the mouths of both Joes and Lakota Creeks. These high levels are probably originating from the large area of high-density single-family land use in both drainages. Phosphorus is closely associated with high sediment concentrations, which were similarly observed in the steep lower reaches of both creeks. Increased future flows in this creek will probably add to this problem.

Impervious areas associated with large single-family and multifamily developments are contributing large flows and high sediment loads to the Twin Lakes. The lakes are acting as a sink for these contaminants. As a result, acceleration of the eutrophication (i.e., increased nutrient loading and associated aging) is probably ongoing in these lakes. Because of relative flushing rates, Lorene Lake is likely to experience significant water quality problems more quickly than Jeane Lake. Other lakes in this sub-basin also receive nutrients, but whereas the volume of water is five times larger in Mirror Lake than in either of the two Twin Lakes, the annual phosphorous loadings are roughly equivalent. Thus problems are more likely in these two smaller lakes.

Although not a part of the freshwater system that forms the major focus of this study, Dumas Bay is a unique resource of Lower Puget Sound and is directly impacted by drainage off the land surface. Dumas Bay is an 253 acre intertidal sandflat habitat that receives discharge from five small streams that drain the upland plateau: Joes and Lakota Creeks, and three unnamed streams (0390A, 0390B, 0390C). Dumas Bay and similar estuarine embayments throughout Puget Sound provide important nursery, breeding and feeding areas for a variety of species, many of commercial interest, others of importance for their ecological role. Despite its value, however, extensive development has occurred on the bluffs and slopes surrounding the bay and has encroached on the bay's shoreline and on the northern edge of the freshwater marsh. In particular, delivery of sediment to the marsh has increased with increasing disturbance of the uplands and slopes surrounding the ravines of streams 0390A and 0390B. The deep marsh, with its open water habitat, is particularly vulnerable to this deposition.

The bay itself has suffered direct impact from shoreline protection measures such as bulkheading and rip-rapping, especially along its northern shoreline near the mouths of Lakota and Joes Creeks. Often, these techniques have been employed in an attempt to stabilize the toe of the steep bluffs that rise above the beach. Slope failures remain quite common in this area, however, and may be exacerbated by slope clearing and improper drainage over the bluff edge.

In the northeastern quadrant of Dumas Bay, near the mouth of Lakota Creek, a wastewater treatment plant discharges some 1,000 million gallons per year of secondary sewage treatment effluent into the bay. Until 1988, the plant discharged wastewater that had undergone only primary treatment. Though convincing evidence is lacking, the plant outfall may be a contributer of nutrients, metals and coliform bacteria to the bay, together with nonpoint sources documented in this study.

The bay is permanently closed to commercial shellfish harvesting, as are all eastern Puget Sound beaches from Meadowdale in Snohomish County to Commencement Bay in Pierce County, due to fecal coliform bacteria contamination.

KEY FINDINGS

- Deposition in Saltwater State Park is a pre-development condition that has progressed and will worsen with increasing flows in McSorley Creek and its tributaries (0381 and 0382).

- Downcutting along parts of Redondo Creek (0384) has been active and will accelerate. Erosion in other parts of this sub-basin, particularly associated with smaller drainageways and ill-diverted runoff, has been locally substantial.

- Increases in flows in Lakota Creek (0386 and 0387) have caused zones of substantial stream damage. Future development in this sub-basin is not high, but downstream constraints limit stream restoration possibilities.

- Flooding in the Twin Lakes area on Joes Creek (0388) is a recent phenomenon, probably caused by a combination of flow increases and sediment deposition from upstream development. Future development without mitigation will lead to dramatic flow increases, with the frequency of flood-causing events becoming about 20 times more common.

- Joes Creek currently contains the best fish habitat in the Lower Puget Sound basin, but future flow increases predicted for the lower canyon area will severely degrade the channel there.

- Water quality, particularly in the South sub-basin, has been severely impacted by residential development. Fecal coliforms, heavy metals, total suspended sediment, and nutrients are at or near the highest levels measured in the entire planning area.

- Lakota Creek, Joes Creek, and tributary 0390 bring sediment into Dumas Bay. Any future flow increases (particularly as predicted for Joes Creek) will accelerate this influx because of the highly erodable nature of their canyons' walls and beds.

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A P P E N D I X A

HYLEBOS CREEK BASIN
OBSERVED CONDITIONS SUMMARY

HYLEBOS CREEK BASIN
OBSERVED CONDITIONS SUMMARY

DATA SOURCE INDEX

P	1985 and 1988 aerial photos observation
R	Reconnaissance Program Observation
S	Basin Planning Staff Observation
M	Metro Observation Report
K	King County Conservation District Observation
DI	SWM Drainage Investigation Observation
C	Citizen Observation

KEY TO WATER QUALITY CONDITIONS

* = sampling location identifier

NO_3 + NO_2 = Nitrate + Nitrite - Nitrogen

TP = Total Phosphorus

Cu = Copper

Pb = Lead

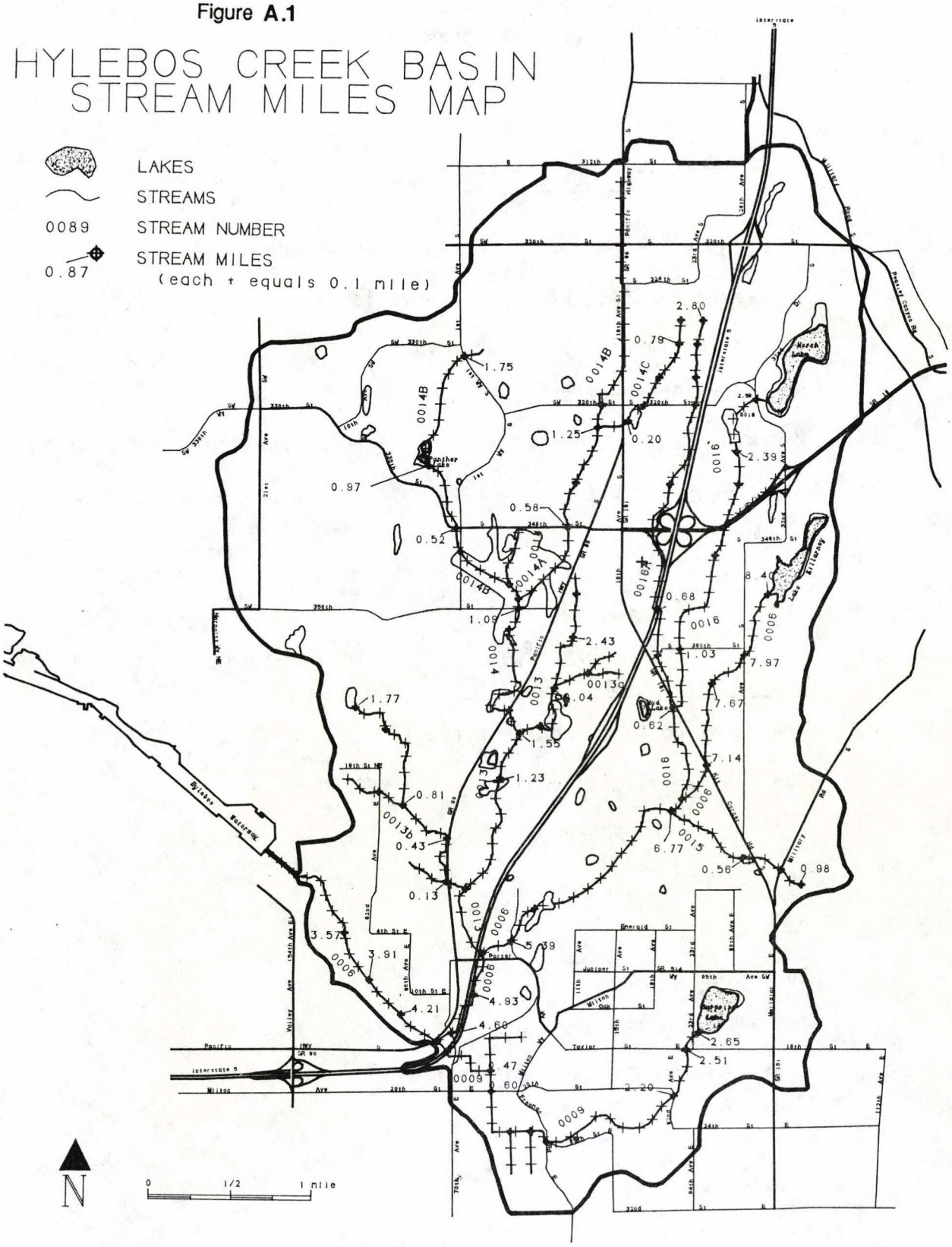
Zn = Zinc

TSS = Total Suspended Solids

Fecal = Fecal Coliform Bacteria

Figure **A.1**

HYLEBOS CREEK BASIN STREAM MILES MAP



HYLEBOS CREEK BASIN
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
1	See Item 47.1, Lower Puget Sound Basin Observed Conditions Report					
1.1		0006 RM 0.0	Habitat[4]	S	Patches of good intertidal habitat on aquatic lands owned by the Puyallup Tribe. Beach seining has shown this area to be highly productive juvenile salmonid habitat. Areas closest to Commencement Bay have eelgrass and unvegetated sand flats grading into low and high salt marshes.	Port of Tacoma
1.2		0006 RM 0.2-2.8	Habitat Water Quality Land Use	S	Intertidal habitat within much of the remainder of Hylebos Waterway and its riparian corridor is highly degraded due to industrial land uses (e.g., log storage, marinas, chemical refineries, wrecking yards), shoreline filling, and shoreline debris (metal scrap, tree bark, bricks, asphalt, cement and marine plastic debris, etc.). Habitat within the waterway is disturbed by regular dredging for ship passage.	Port of Tacoma/ Tacoma
1.3		0006 RM 2.80	Water Quality Land Use	S	Toxic leachate and surface runoff (wood waste/arsenic residue) from EPA Superfund site.	Tacoma
1.4		0006 RM 3.41	Habitat Geology	S	Strong tidal influence; this low-gradient reach is a deposition area for fine sediment. Good emergent and canopy vegetation, and undercut banks provide shading and cover for fish, and good habitat for waterfowl, songbirds, and small mammals.	Pierce County

1 Item Numbers - whole item numbers refer to entries from the 1986-1987 King County Basin Reconnaissance Program. Entries designated with a decimal number supplement and update the Reconnaissance Program.
2 See Figure A.1 for river mile map.
3 RM for Tributary 0006 begins where Hylebos Waterway empties into Commencement Bay in 3E-T21W-S27N.E.
4 Habitat refers to fish and wildlife habitat.

HYLEBOS CREEK BASIN
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
1.5		0006 RM 3.85	Hydrology	S	Flooding of road and several homes during 1/9/90 storm at 8th St. E. crossings. Tidal influence contributes to flooding.	Pierce County
1.6		0006 RM 3.91	Hydrology	S	Local flooding of road and homes at 62nd Ave. E. during 1/9/90 storm.	Pierce County
1.7		0006 RM 4.49-4.87	Habitat Land Use Geology	S	Stream channelization and encroachment into riparian corridor caused by adjacent SR 99; no right bank canopy or bank vegetation. Lower banks armored with concrete pillows; piles of loose sand deposited along roadside during SR 99 guard rail replacement are sliding into stream. Freshwater mussel beds present.	Pierce County
1.8		0006 RM 4.55-5.15	Habitat Land Use Geology	S	Riparian habitat is limited due to past channelization and lack of bank and canopy vegetation. Dominant bank vegetation is reed canary grass. This low-gradient reach is a natural deposition area for fine sediment from upstream sources; substrate is >95% sand and silt; channel is generally devoid of LOD.	Pierce County/ Milton
1.9		0006 RM 4.55-4.65	Habitat Land Use	S	Encroachment into riparian corridor and floodplain due to filling of adjacent wetland to construct heavy equipment storage lot. Adverse impacts include channel dredging, armoring of right bank with ecology blocks, and habitat disturbance caused by repeated collapse of blocks into stream.	Pierce County
1.10		0006 RM 4.48-5.39	Hydrology	S	Flooding of business and residence along the E. side of I-5 from where trib. 0006 crosses 5th Ave., south to where I-5 turns W. Channel conveyance capacity reduced due to sedimentation (primarily sand and silt). Industrial park east of I-5 flooded. Filling in floodplain periphery.	Pierce County/ Milton

HYLEBOS CREEK BASIN
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
1.11		0006 RM 5.05	Habitat Land Use	S	Encroachment into riparian corridor and floodplain due to filling of adjacent wetland to construct truck parking lot.	Pierce County/ Milton
1.12		0006 RM 5.10 Undefined Ditch (QHDD)*	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, NO_3 + NO_2, and fecal densities during storm events. Potential sources include: fertilizers, automobile and truck roadway runoff, two businesses bordering ditch (Truck Repair/ Rental), and wildlife. Potential effects could include eutrophication, reduced spawning success downstream, toxicity to freshwater and marine aquatic species.	Milton
1.13		0006 RM 5.15	Habitat Water Quality Land Use Geology	S	Chronic erosion around bridge abutments during peak flows. Erosion and undercutting of banks noted in channel.	Milton
2		0006 RM 5.15-5.30	Habitat	R	Tides affect water level. Low gradient. Large amount of sand being deposited.	Milton
3	No entry					
3.1		0006 RM 5.20-5.35	Habitat Land Use	S	Encroachment into floodplain due to filling for equipment storage lots.	Milton
3.2		0006 RM 5.29 (QEH1)	Water Quality	M	NO_3 + NO_2 concentrations higher than routinely monitored King County streams during baseflow conditions. No sample for dissolved oxygen (DO), temperature, and pH exceeded DOE Water Quality Criteria - Class A (Excellent) for this baseflow monitoring period.	Milton
3.3		0006 RM 5.29 (QEH1)	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, and fecal densities during storm events. Potential sources include: fertilizers, construction activities, auto wrecking yard, automobiles,	Milton

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					failing onsite septic systems, sewerline leaks, and wildlife. Potential effects could include: eutrophication, reduced spawning success, toxicity to both freshwater and marine aquatic species, and reduced recreational activities.	
4		0006 RM 5.30	Geology	R	Minor erosion and undercutting of banks noted in channel. Some undercut blocks have failed or are falling into stream. Channel cut into peat. Riprap next to yard suggests erosion problem. Recent aggradation of sand in channel, possibly due to upstream quarry pit.	Milton
4.1		0006 RM 5.3-6.7	Water Quality Habitat	S	On 12/13/89, 47 moribund and dead yellow perch; unknown cause; one live and five dead adult coho (dead fish appeared to have spawned out); oil sheen in pool at RM 5.5; numerous signs of wildlife (e.g., racoon, great blue heron, and coyote tracks).	Milton/ King County
4.2	(formerly 5)	0006 RM 5.33	Geology	S	Fresh infinite slope failure on side-slope exposes sand and gravel. Failure is approx. 60 inches from channel. No cause noted. Cause not investigated, but may be construction-related.	Milton
4.3	H1	0006 RM 5.39	Hydrology	S	72 inch cmp filled 1.8 feet of sediment at 5th Ave. on 2/28/90.	Milton
4.4		0006 RM 5.41	Geology	S	Channel size: 1.5 m X 0.60 m.	Milton
5	(see 4.2)					
6		0006 RM 5.48	Geology	R	Undercutting of banks and failure of undercut banks into channel. Channel is still cut into peat.	Milton
7		0006 RM 5.40-5.75	Habitat	R	Riverine wetland and floodplain. Old road washout at RM 5.75.	Milton

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
7.1		0006 RM 5.6-6.7	Habitat Land Use Geology	S	Moderately good habitat structure; numerous patches of good spawning and rearing habitat (riffles with appropriately-sized gravels and small pools). Generally adequate LOD; good canopy and bank vegetation. Worsening habitat upstream: patches of moderately cemented gravels with excessive interstitial sand; slight to moderate downcutting (0.5 to 2 feet), bed scour and deposition of coarse sediment due to excessive peak flows; unstable woody debris jams (some may cause intermittent passage blockages); tires and car bodies in stream; ORV tracks conveying mudflow and human disturbance into stream.	Milton/ King County
8		0006 RM 5.65	Geology	R	Undercutting of banks and failure of undercut banks into channel. Channel is still cut into peat.	Milton
9		0006 RM 5.75	Geology	R	Old road crosses channel. Culvert placed to pass streamflow is plugged crossing is washed out. Till exposed in cuts on both banks.	Milton
10		0006 RM 5.77	Geology	R	Large slump on left sideslope. Heavy seepage, hummocks with trees tilted at base. No evidence of recent movement.	Milton
11		0006 RM 5.90	Geology	R	Numerous bank cuts expose sand. Floodplain 50-100 feet wide. Stream meanders from toe of one to slope of another. Morphology suggests common old slumps.	Milton
12		0006 RM 5.95	Habitat	R	Debris in stream. Possible fish blockage.	Milton
12.1		0006 RM 6.30	Geology	S	Channel size: 4.5 m X 0.50 m. Local bank incision to 3 feet.	King County
13	No entry					
14	No entry					

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
15		0006 RM 6.30	Habitat	R	Habitat in fairly good condition. Incised tributary comes in from west.	King County
16		0006 RM 6.50	Geology	R,S	Large slump on left side with depression formed at top. Possible evidence of recent small movement.	King County
16.1		0006 RM 6.70-6.91	Habitat	S	Excessive peak flows have caused moderate downcutting (2 to 4 feet) channel widening, deposition of coarse sediment, filling in of pools, and formation of large woody debris jams (some may cause intermittent passage blockages). Many tires in stream.	King County
17		0006 RM 6.70	Geology	R,S	Bank erosion on both sides of channel. Width of floodplain is 50 feet. Channel dimensions 5 m X 0.5 m.	King County
18		0006 RM 6.70	Habitat	R	Habitat in good shape. Nice spawning gravel.	King County
19		0006 RM 6.75	Habitat	R	Newly incised channel. No habitat for fish or benthic organisms.	King County
20		0006 RM 6.77	Geology	R,S	Trib. 0006 forms intersection with 0016 with 0006 being a small tributary that continues up main channel. Heavy bank and channel erosion in 0006, with incision up to 6 feet.	King County
20.1		0006 RM 6.81	Geology	S	Channel size: 3.5 m X 0.70 m. Local bank incision to 2 feet; stream gravels cemented with fines.	King County
20.2		0006 RM 6.91	Habitat	S	FWSWD access road, pipe, and manhole in stream.	King County
21		0006 RM 7.10	Geology	R,S	Heavy bank erosion. Stream is dropping off till plain at this point. Channel dimensions 2.0 m X 0.20 m.	King County
21.1		0006 RM 7.14	Hydrology	S	During 1/9/90 storm, discharge from this trib. flowed north along SR 99 and entered trib. 0016 that overflowed into trib. 0016A.	King County

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
21.2		0006 RM 7.19	Habitat Land Use	S	Encroachment into riparian corridor caused by dumping of fill and yard debris on left bank.	King County
21.3		0006 RM 7.25-7.65	Habitat Land Use	S	Encroachment into riparian corridor due to channelization through residential yards and landscaping of streambanks.	King County
21.4		0006 RM 7.33	Geology	S	Stream is silt- and sand-choked.	King County
21.5		0006 RM 7.60	Hydrology Water Quality	S	Small asphalt-lined pond in old plat at 24th Place and 25th Avenue South drains to stream through 24" culvert. Pond appears to be undersized and lacks any kind of shade or biofiltering vegetation.	King County
21.6		0006 RM 7.75	Habitat Geology	S	Streambed consists of silt and patches of small cemented gravels.	King County
22		0006 RM 7.90-8.40	Geology Hydrology Land Use	R	Outlet from Lake Killarney. No flow and no discernible channel. Lower half of reach is bounded by single-family developments with on-site detention systems, which appear to be functioning.	King County
23	No entry					
23.1		0006 Lake	Habitat Land Use	S	Although substantial forested areas remain around Lake Killarney, more than 40% of the lake's former lacustrine and remnant bog wetlands have been eliminated during residential shore line development. The lake supports waterfowl, bass, perch, and rainbow trout.	King County
23.2	H7	Off Channel Lake	Hydrology	DI 89-0247 89-0194 87-0640	Flooding over S. 351st St. & 352nd St. at 28th. - 30th Ave. S., draining to Lake Killarney.	King County
23.3	H7	Off Channel Lake	Hydrology	DI 89-0299	Drainage from 34th Ave. S. at S. 354th St. flowing on private property, draining	King County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					to Lake Killarney.	
23.4		0009 RM 0.0-0.05	Habitat Hydrology	S	Golden Rule Motel encroaches into riparian corridor; chronic ingestion of riparian vegetation by goat tethered on left bank. Motel flooded during 1/9/90 storm.	Pierce County
23.5		0009 Lake	Habitat Water Quality	S	Vegetation has been removed along 90 to 95% of the Surprise Lake shoreline; most remaining native growth is in a thin strip less than 25 feet wide, except for a patch of scrub-shrub vegetation at the south end of the lake. Residential development on shoreline has been accompanied by placement of compacted fill in former lacustrine wetlands. Foot trail less than 50 feet from shoreline in new apartment complex near south end of lake. Lake provides a modest amount of habitat for waterfowl, although runoff of avian feces from lawns is a source of excess nutrients.	Milton
24	No entry					
24.1		0013 RM 0.03-0.06	Habitat	S	Freshwater mussel bed (under I-5).	
24.2		0013 RM 0.05 (QWH1)	Water Quality	S	Relatively high concentrations of $NO_3 + NO_2$, TP, TSS, Cu, and fecal densities during storm events. Potential sources include: fertilizers, agricultural runoff, automobiles, farm animals having access to creeks, failing on-site septic systems, sewerline leaks, wildlife and waterfowl. Potential effects could include: eutrophication, and nuisance growths of algae, reduced spawning success, toxicity to freshwater and marine aquatic species, and reduced recreational activities.	
25		0013 RM 0.10	Geology	R	Stream in wetland area. Channel scour and bank erosion noted. Evidence of	Milton

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					flows four feet above existing water level. Probably some tidal influence.	
26		0013 RM 0.10	Habitat	R	Habitat in good condition. Some fresh-water clams. Exposed roots indicate minor bank erosion.	Milton
26.1		0013 RM 0.20-0.65	Habitat	S	Dense overhanging and moderate canopy vegetation along most of this reach limit intrusion into riparian corridor. Wetlands along both banks perform flood storage, biofiltration, and wildlife habitat functions.	Milton/ Federal Way
27		0013 RM 0.30	Habitat	R,S	Exposed roots indicate minor bank erosion. Considerable amount of sand settles out in bedload. Channel dimensions 2.0 m X 0.80 m.	Milton
27.1		0013 RM 0.32	Hydrology Habitat	S	Local flooding of Birch St. crossing during 1/9/90 storm. Sedimentation of channel (mostly sand) severely reduced conveyance. Emergent and scrub-shrub wetlands are providing wildlife habitat, biofiltration, and flood storage.	Milton
27.2		0013 RM 0.34	Habitat Land Use	S	Filling of wetland adjacent to stream behind Bingo dome parking lot is causing loss of flood storage and biofiltration.	Milton
28		0013 RM 0.40-0.90	Geology	R	Evidence of channel scour.	Milton/ Federal Way
28.1		0013 RM 0.44-0.85	Habitat Geology	S	This reach contains the best rearing habitat in the Hylebos system, as well as excellent wildlife habitat. Abundant LOD, overhanging banks, and luxuriant bank and canopy vegetation maintain bank stability and provide cover for fish and wildlife. Numerous snags (some quite large) are present within and upslope from adjacent wetland. Local residents report sightings of great blue heron, woodpecker spp.,	Milton/ Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					pheasant and grouse, waterfowl, coyote, skunk, and other small mammals. Streambed substrate in this low-gradient reach is largely sand and silt, with occasional patches of fine gravels. Habitat threats include scouring during peak stormflows, and sedimentation of pools.	
28.2		0013 RM 0.50	Habitat	S	Freshwater mussel bed.	Federal Way
28.3		0013 RM 0.70	Geology	S	Channel dimensions: 4.0 m X 0.5 m.	Federal Way
29		0013 RM 0.90-1.20	Habitat	R	Good spawning gravel. Seven dead salmon observed.	Federal Way
29.1		0013 RM 0.96	Geology	S	Channel dimensions: 3.5 m X 0.4 m.	Federal Way
30		0013 RM 1.00	Geology	R	Evidence of channel scour and bank erosion. Some destabilization of steep sideslopes above channel due to erosion at toe of slope.	Federal Way
30.1		0013 RM 1.10-1.20	Habitat Water Quality Land Use Geology	S	Severe bank trampling and overgrazing by cattle in adjacent wetland. Good canopy vegetation in lower end, little canopy vegetation in upper end, and little bank-vegetation throughout. Salmon spawning habitat is being silted in, and water quality is chronically impaired by turbidity and high fecal coliform counts.	Federal Way
30.2		0013 RM 1.10-1.30	Habitat Water Quality Land Use	S	Contains degraded salmonid spawning habitat, but is almost devoid of rearing habitat. Approximately 50 chum salmon observed spawning in fall 1987; smaller numbers were observed in 1989. Habitat is limited by past channelization and dredging, paucity of bank and canopy vegetation, and absence of LOD. Channel stability and capacity are	Federal Way

HYLEBOS CREEK BASIN
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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					severely compromised due to lack of riparian vegetation and extreme sediment deposition from upstream sources during 12/5/89 and 1/9/90 storms. Oily sheen and odor noted by local residents during 1/9/90 storm; possible source Boy Scout property at RM 2.50.	
30.3		0013 RM I.20	Hydrology	S	Stream channel silted in with sand and gravels.	Federal Way
31		0013 RM I.20-1.50	Habitat	R	Stream passes through pastures with overhead canopy removed. Animals eroding bank in places. Sand in bedload. One dead salmon observed.	Federal Way
31.1		0013 RM I.22 Undefined Ditch (QHDD)*	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, and fecal densities during storm events. Potential sources include: fertilizers, agricultural runoff, landfill activities, automobiles, and farm animals having access to creek immediately upstream. Potential effects could include: eutrophication, reduced spawning success, toxicity to freshwater aquatic species, and reduced recreational activities.	Federal Way
31.2		0013 RM I.23	Hydrology	S	Area of chronic flooding. During the 1/9/909 storm at 373rd St. bridge. Water overtopped the road, flooding a residence upstream, and a pasture downstream. Diminished channel capacity due to sedimentation.	
31.3		0013 RM I.23 (QWH3)	Water Quality	M	Temperatures were higher than other stations in the basin during baseflow conditions. TSS concentrations were higher than in other routinely monitored areas in King County. No sample for DO, temperature, pH, and fecal coliform exceeded DOE Water Quality Criteria - Class A (Excellent) for this baseflow monitoring period.	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
32		0013 RM I.50-2.00	Habitat	R	Good habitat. Two dead salmon. Wetland at approx. RM 2.00. Fill being dumped off east side of SR 99. No encroachment in wetland.	Federal Way
32.1		0013 RM I.50	Hydrology Geology	S	Local flooding during the 1/9/90 storm. Severe gravel and debris deposition from the storm.	Federal Way
33		0013 RM I.60-1.90	Geology	R	Channel scour and bank erosion into floodplain deposits.	Federal Way
33.1		0013 RM I.70	Geology	S	Channel dimensions: 3.0 m X 0.35 m. Very boggy.	Federal Way
33.2		0013 RM I.74-1.94	Habitat Geology	S	Runoff and chronic deposition of sediment from I-5 runoff via ditch along 12th Avenue S. has eliminated much of the former chum, coho, chinook, and steelhead spawning habitat and is reducing rearing habitat (pools) at this location. Steelhead have been absent since a fish kill in 1985.	Federal Way
33.3		0013 RM I.94-2.40	Habitat Geology Land Use	S	The only segment of the Hylebos system with both spawning and rearing habitat. Bank and canopy vegetation, and LOD are generally very good throughout and maintain varied instream and riparian habitat for fish and wildlife. Stream buffered by a large adjacent wetland fed by a number of small, perennial springs. A large wetland parcel between 359th Street, 364th Street, and the Lloyd fill on SR 99 is on the King County Open Space Program acquisitions list. Part of the wetland has been evaluated by the Corps, and was assigned a preliminary wetland inventory number by the County (Hylebos Wetland #46A). The Puyallup Tribe supports permanent protection of wetlands and possible future siting of a small hatchery and interpretive center.	Federal Way

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					Threats to instream habitat include scouring, sedimentation, and filling in of pools during storms. Past damage to the wetland from filling east of SR 99, and north and south of 359th Street by FWSWD to install a pump station (the pump station was excavated in active springs) and sewer lines; and the large Lloyd Enterprises fill on SR 99. Future threats to the wetland include proposed expansion of the Lloyd fill, increased sedimentation and frequency of innundation by stormwater, and a decline in groundwater recharge. Local residents report that flow in local springs seems to have dropped in recent years.	
33.4		0013 RM 2.00	Geology Habitat	S	Stream gravels heavily packed with fines.	Federal Way
33.5		0013 RM 2.05	Geology Habitat	S	Channel dimensions: 2.0 m X 0.30 m. Silt infiltrated into stream gravels.	Federal Way
33.6		0013 RM 2.10	Water Quality	S	Suds above 359th St. Observed 1/88.	Federal Way
33.7		0013 RM 2.25	Geology Habitat	S	Much silt in stream gravels.	Federal Way
34		0013 RM 2.30	Geology	R	Logging debris in stream channel. Channel appears stable.	Federal Way
35	No entry					
36		0013 RM 2.30-2.60	Habitat	R	Sudsy, gray, foul-smelling water, indicating pollution. Streambank experiencing slight erosion. Sources are SR 99 and probably truck stop nearby.	Federal Way
36.1		0013 RM 2.43	Hydrology Geology Habitat	S	Creek overtopped 359th St. undermining 10' of fill under street washing out 80% of the road during the 1/9/90 storm. 18" culvert became blocked	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					with debris. Riparian and instream habitat was badly damaged by blowout of road fill and collapse of large trees. Road construction will also reconstruct and revegetate riparian habitat 200 feet downstream of 359th St.	
37		0013 RM 2.70	Geology	R,S	Suds in stream indicate pollution. Stream drains SR 99. Channel appears stable.	Federal Way
37.1		0013 RM 2.80	Hydrology	S	New private R/D facility (Welters Pond) malfunctioned during the 1/9/90 storm. Outlet control structure was not yet anchored when the storm event occurred. Erosion control facilities for fill onsite failing. Stream is piped from pond inlet upstream along 351st to underground tank in Costco parking lot.	Federal Way
37.2		0013 RM 2.88 (QWH6)	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, Zn, and fecal densities during storm events. Potential sources include: truck wash, roadway runoff, construction activities associated with properties immediately upstream (e.g., Costco), automobiles, and sewerline leaks. Potential effects include: eutrophication, nuisance growths of algae, reduced spawning success, toxicity to freshwater aquatic species, and reduced recreational activities.	Federal Way
37.3		0013 RM 2.90 (QWH7)	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, Pb, Zn, and fecal densities during storm events. Potential sources include: truck wash, roadway runoff, construction activities associated with Costco and other properties upstream, automobiles, and sewerline leaks. Potential effects include: eutrophication, nuisance growths of algae, reduced spawning success downstream, toxicity to freshwater	Federal Way

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					aquatic species, and reduced recreational activities.	
37.4		0013 RM 2.96	Water Quality	S	Silt and other deleterious materials from a concrete company and other commercial land uses upstream are visible in the outfall of the culvert on the east side of SR 99.	Federal Way
37.5		0013 Undefined Channel	Hydrology Habitat	DI 88-0393	A 53 gallon drum with holes and overflow placed in stream, also in stream diversion piping water to a bird bath in vicinity of S.W. 374th St. & 2nd Ave. S.	Federal Way
37.6		0013B RM 0.00-0.81	Hydrology Geology Habitat	S	Peak flows during 1/9/90 storm caused severe downcutting, erosion, and streambed scouring. Two feet of sand and silt deposited at the mouth of the stream decreased local channel capacity. Large sediment accumulation in flume of culvert under Spring Valley Trailer Park on SR 99 & 377th St. clogged pipe and caused high volume overland flow accompanied by sediment deposition and flooding in trailer park and adjacent property to the north, and washed out portion of road bed on east lane of SR 99. Stream appears to be perennial in lower reaches; sculpin and crawfish found in trailer park one day after the storm.	Federal Way
37.7		0013B RM 1.77	Habitat	S	Headwaters originate within Hylebos Wetland #21.	Federal Way
37.8		Off Channel	Hydrology	DI 89-0728	Flooding at intersection of 5th Ave. S.W. & 371st St.	Federal Way
37.9	WH3	Off Channel	Hydrology	C	Localized flooding at S. 344th St. and 18th Pl. S. during the 1/9/90 storm.	Federal Way
37.10	WH3	Off Channel	Hydrology	C	Localized flooding in vicinity of S. 346th St. (extended) E. of SR 161 during the 1/9/90 storm.	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
37.11		0014 RM 0.00	Hydrology	S	Localized flooding at confluence with trib. 0013 during the 1/9/90 storm.	Federal Way
38		0014 RM 0.00-0.15	Geology	R	Bank erosion noted along much of the channel. Erosion is cutting into floodplain deposits approx. one foot high. Channel dimensions 2.5 m X 0.25 m.	Federal Way
39		0014 RM 0.00-0.20	Habitat	R	Good gravel for spawning from RM .00-.15. Five salmon observed. Lots of pools and riffles.	Federal Way
40		0014 RM 0.15-1.04	Hydrology	R	Lower reach is in good hydraulic condition due to natural R/D and water quality filtration provided by Hylebos Wetland 2418. Flooding due to increased peak flows from upper basin development has been reported in recent years.	Federal Way
40.1		0014 RM 0.19-0.25	Habitat Hydrology	S	Stream and natural floodplain area has been modified by land owner into trapezoidal channel with riprap banks to increase channel capacity. Instream and riparian habitat is limited by removal of bank vegetation (especially on the right bank) partial removal of canopy vegetation, and channel riprapping. Other adverse conditions include lack of LOD and pools, chronic deposition of unsuitably large sediment from upstream sources, and streambed scouring during peak flows. The landowner proposes additional channel excavation and widening to prevent future flooding of school buildings. Adjacent Hylebos Wetland #22 (1.8 acres) provides good wildlife habitat and a modest amount of flood storage. Channel overflowed onto school grounds and undercut channel armor during the 1/9/90 storm.	Federal Way
40.2		0014 RM 0.40	Geology	S	Channel dimensions: 3.0 m X 0.30 m.	Federal Way

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
40.3		0014 RM 0.47-0.57	Habitat Land Use	S	Inadequate bank and canopy vegetation, especially along the left bank; encroachment into riparian corridor by debris behind abandoned house.	Federal Way
40.4		0014 RM 0.57-0.76	Habitat Geology	S	Runs through a broad, secluded ravine flanked by 40-80% slopes lined with mature cedar, hemlock, big leaf maple and alder.Good to excellent bank and canopy vegetation and ample LOD maintains a series of small step pools that serve as rearing habitat, however sediment is generally too coarse to serve as spawning habitat. Habitat was damaged during the 1/9/90 storm by mass wasting from walls of ravine and severe downcutting which released large amounts of gravel and cobble, and contributed to extensive scouring and sediment deposition throughout the riparian corridor for at least a mile downstream. Good wildlife habitat.	Federal Way
40.5		0014 RM 0.95-1.71	Habitat Land Use	S	Bank trampling by livestock; pastures and yard are encroaching into riparian corridor; canopy and bank vegetation fair to poor; inadequate LOD.	Federal Way
40.6		0014 RM 1.04-1.06	Habitat	S	Encroachment into riparian corridor due to removal of left bank trees and deposition of slash in stream. The streambed consists almost entirely of silt with patches of small, cemented gravel.	Federal Way
41		0014 RM 1.09	Habitat	R,S	Some sand moving down system in bed load. Area has been clearcut, including stream sides.	Federal Way
41.1		0014 RM 1.09 (QWH8)	Water Quality	M	Dissolved oxygen concentrations were lower than other stations in the basin and other routinely monitored King County streams during baseflow conditions. Fecal densities exceeded DOE criteria 4	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					times (33%) during baseflow monitoring. No sample for temperature or pH exceeded DOE Water Quality Criteria - Class A (Excellent) for this baseflow monitoring period.	
41.2		0014 RM I.09	Hydrology	S	Severe flooding at 356th St. overtopping the road during the 12/5/89 and 1/9/90 storms.	Federal Way
42		0014 RM I.50	Hydrology	R	Existing R/D lakes servicing this portion of West Campus appear to be functioning quite adequately as is evidenced by lack of problems at outlet at S. 348th St. Substantial landscape buffers also contribute to lack of drainage problems.	Federal Way
42.1	WH4/WH7	Off Channel	Hydrology	DI 90-0087	Water nearly flooded a home at 11th Ave. SW & SW 356th St.	Federal Way
41.2	WH4	Off Channel	Hydrology Water Quality	DI 86-01F4	Drainage with animal wastes from barn flowing into drainage ditch on 6th S.W. at S.W. 363rd St.	Federal Way
41.3	WH4	Off Channel	Hydrology	C	Storm water 6-8' deep flooded ravine area in vicinity of 356th St. and 6th Ave. S. during the 1/9/90 storm. No roads flooded.	Federal Way
43		0014A RM 0.00-3.0	Hydrology	R,S	Reach contributed the greatest portion of increased flows to west Hylebos system. Improvements to Pacific Hwy. S. storm system have aggravated the erosion problems in the lower reach north of S. 348th St. RM 1.10 is severely impacted by clearing and grading; natural R/D in area has been eliminated due to removal of two small culverts which drained the wetland. In 1985, wetland had been logged, scraped, ditched, and drained. Severe erosion on site from upstream runoff. Some debris present. Loss of natural stormwater storage is creating erosion and sedimentation problems downstream. Severe siltation of downstream due to steep bank cuts.	Federal Way

HYLEBOS CREEK BASIN
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					Heavy deposition of gravel at and below below confluence with trib. 0014C. This is the site of the north and south pond of the 336th Street stormwater capital improvement project, and the reconnaissance proposal for regional R/D facility	
43.1		0014A RM 0.00-0.23	Habitat Geology	R,S	Encroachment into riparian corridor due to removal of left bank trees and deposition of slash in stream. The streambed consists almost entirely of silt with patches of small, cemented gravel.	
43.2		0014A RM 0.20	Habitat Water Quality Land Use	S	Trash in stream (barrels, tires, and other debris); encroachment into the riparian corridor due to filling of lot on SR 99 with illegal materials (woody debris); runoff of fertilizers and possibly pesticide residues enters stream through ditch draining dump behind Chem Lawn.	
43.3		0014A Lake	Hydrology Habitat	DI 88-0480	Brook Lake control removed, drying up the lake. Lake bottom filled with sediment that is level with the invert of 24-inch pipe at control structure.	
43.4		0014A Lake	Habitat Geology	S	Because of its relative seclusion and good water quality, Brook Lake and surrounding forest contains locally significant wildlife habitat. Coho formerly reared in the lake and in a short stretch of 0014A north of the lake; rainbow trout are still present. Littoral habitat is very good along the north and wes shoreline where the lake borders the future West Hylebos State Park. Bank and canopy vegetation are also good on the north and west sides of the lake, but habitat encroachment along the remainder of the shoreline has occurred due to past wetland filling and removal of shoreline vegetation. The fishway at the outlet may be impassable water may cause fish to jump out	

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					under certain flow conditions. Habitat value within the lake is by sediment deposition from upstream impervious services. The lake underwent uncontrolled drainage in 1986(?) due to failure of the outlet structure, followed by dredging. These activities resulted in siltation of the streambed for a considerable distance downstream in 0014.	
44		0014A RM 0.35	Geology	R,S	Heavy gravel deposition in streambed and moderate streambank erosion indicate high peak flows.	Federal Way
45		0014A RM 0.35-0.50	Habitat	R	Large amounts of debris and gravel in stream. At RM .50 stream is ditched with steep sideslopes and no vegetation (major erosion potential). Wetland found just south of S. 348th Street.	Federal Way
45.1		0014A RM 0.40	Habitat Land Use	S	Hung culvert under access road to FWSWD pump station. Pump station appears to have been built on fill placed several feet from the stream within Hylebos Wetland #18. This passage barrier defines the upper limit of anadromomous fish use on this tributary.	Federal Way
45.2		0014A RM 0.40-0.47	Habitat	S	Habitat within and above this reach and is limited by extreme streamflow variability.	Federal Way
45.3		0014A RM 0.48-0.57	Habitat Geology Land Use	S	Encroachment into riparian corridor by wetland filling during construction of the Metro Park-and-Ride lot south of 348th St. South, and construction of several small sedimentation ponds nearby, which appear to be ineffective in detaining flows or trapping sediment from nearby bare ground.	Federal Way
46		0014A RM 0.50	Geology	R,S	Stream flows through cleared area. Channel has been ditched. Unprotected	Federal Way

HYLEBOS CREEK BASIN
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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					fill sideslopes approx. 10 feet high at 45 degrees. Erosion occurs from sideslopes into stream channels.	
46.1		0014A RM 0.57	Hydrology Geology Habitat	DI 87-0887	Clearing activity pushed trees into stream channel and denuded stream bank. Channel and streambank not stabilized in vicinity of S. 348th St. & 11th Ave. S.	Federal Way
47		0014A RM 0.58	Geology	R,S	Evidence of abundant gravel discharge. Gravel deposition in small wetland south of 348th St. Two small gabion check dams upstream from 348th St. are completely filled with sediment and are failing. Evidence of high flows.	Federal Way
48	No entry					
48.1		0014A RM 0.57-0.68	Habitat Hydrology Water Quality Land Use	S	In 1989 reach appears to have been channelized during road construction and plat development north of 348th St. The corridor is less less than 25 feet wide on both banks in the lower segment, and the soil along the right bank appears to be fill. Riparian vegetation is absent along the northern segment, which has also been intensively armored with ripap and log check dams below the outfall of a culvert at RM 0.68. A deposit of oils and greases from parking lots in the vicinity of Sea Tac Mall is visible below this outfall. Flow volumes are extremely erratic and are largely runoff from impervious surfaces to the north.	Federal Way
49		0014A RM 0.60-0.73	Geology Habitat Hydrology Water Quality Land Use	R,S	Heavy bank and channel erosion in 1985. Downcutting on order of 3 to 5 feet, with local incision at culvert outfall of 12 feet. Undercutting and failure of banks. Possible destabilization of adjacent fill 20 feet above stream. Total depth of channel is approx. seven feet. Cut shows four feet of fill over three feet native gravel. Approximate inset channel dimensions 2.0 m X 0.20 m.	Federal Way
50	No entry					

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
51	No entry					
51.1		0014A RM 1.16	Water Quality	M	Hydrocarbon contamination has infiltrated stream sediments. At confluence of tribs. 0014A/0014C.	Federal Way
51.2		0014A RM 1.25 (QWKC)	Water Quality	S	Relatively low concentrations of TSS obtained at this site during storm events. Wetlands upstream of this location near Kitts Corner.	Federal Way
51.3		0014A RM 1.30-1.43	Geology Habitat Land Use	S,R	Extreme channel incision due to sudden drainage of Hylebos Wetland #10. Encroachment into riparian corridor due to filling of uninventoried wetland on SR 99.	Federal Way
52		0014A RM 1.30	Geology	R,S	Gravel discharge from culvert under 336th St. This is outfall of a long underground storm system under a commercial development. Recent downstream incision locally 3 feet deep.	Federal Way
52.1		0014A RM 1.39 (QWH13)	Water Quality	S	Relatively high concentrations of Cu and Zn, and fecal densities during storm events. Potential sources include roadway runoff and automobiles. Potential effects include reduced spawning success, toxicity to freshwater aquatic species, and reduced recreational activities.	Federal Way
53		0014A RM 1.65	Habitat	R	Ditched stream, steep sideslopes with little or no vegetation. Severe bank erosion occurring. Gray, sudsy, foul water (pollution) enters this channel through pipe from SR 99.	Federal Way
53.1		0014A RM 2.30	Hydrology	C	Intersection at S.W. 320th St. and SR 99 flooded during the 1/9/90 storm.	Federal Way
53.2	WH11	Off Channel	Hydrology Geology	DI 86-1094	Culvert in vicinity of 335th St. and 13th Pl. S. silted up and caused Kindercare to flood. Silt also in drainage ditch to creek. Kindercare filed a claim against King County.	Federal Way

HYLEBOS CREEK BASIN
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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
53.3	WH11	Off Channel	Hydrology	C	Flooding at intersection of SR 99 and S. 324th St. during 1986 storm.	Federal Way
53.4	WH11	Off Channel	Hydrology	C	Flooding at SR 99 and S. 324th St. during the 1/9/90 storm.	Federal Way
53.5	WH12	Off Channel	Hydrology	DI 87-0746	Flooding at 10th Ave. S. & 320th St. during 86 storm. Claim File F83819.	Federal Way
54		0014B RM 0.28-0.30	Habitat	R	Sand in bedload, probably from construction of new road system in the West Campus area.	Federal Way
55		0014B RM 0.30	Geology	R,S	Stream flows through wetland area. Minor low bank erosion noted, probably natural. Channel dimensions 1.5 m X 0.30 m.	Federal Way
55.1		0014B RM 0.30-0.50	Hydrology Water Quality Habitat Land Use	S	High flood flows from Panther Lake overtopped intersection of 1st Ave. South and driveway entrance of Emerald Forest Apts. during 1/9/90 storm. 1st Ave. also flooded 12/5/90. Stormwater surcharged through sewer manhole on 12/5/89, which was paved over thereafter. Odor of raw sewage and erosion of road shoulders and pavement undermined during both storms. Adjacent portion of Hylebos Wetland #18 is threatened by sedimentation and increased frequency of innundation by stormwater. Widening of 1st Avenue South and construction of FWWSD pump station were accompanied by channelization and extreme encroachment into riparian corridor and into Hylebos Wetland #18. Stream appears to have been routed through road fill a few feet from the sidewalk on the west side of the road. Extreme bank instability due to excessive and highly erosive peak flows and total lack of overhanging vegetation, especially on the left bank.	Federal Way
55.2		0014B RM 0.37-1.00	Hydrology Water Quality	C,S	Severe flooding on 1st Ave. S. and S.W. 336th St. from Panther Lake during	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
			Land Use		the 1/9/90 storm exceeded the design standards of the Panther Lake outlet. The resulting overland flow severely eroded a construction site and downstream forested area. Infiltration ability of Panther Lake has been drastically reduced.	
55.3		0014B RM 0.40-0.57	Geology Habitat Land Use	S	Channel ditched and rerouted across forest floor; heavily impacted from adjacent and upstream construction. One bank of the riparian corridor is somewhat buffered by relatively wide alder grove, one bank is grassed. High flows from Panther Lake during the 1/9/90 storm eroded channel and undermined sidewalk on 1st Ave. S.	Federal Way
56		0014B RM 0.57	Hydrology Geology	R	There is new regional detention facility constructed with recent improvements to S.W. 336th St. This appears well constructed, but property owner immediately downstream has complained of increased flows and local flooding. No flow in existing channel to facility.	Federal Way
56.1		0014B RM 0.57-0.67	Hydrology	S	Two culverts (30" + 36" cmps) drain Panther Lake outlet under S. 348th St. During the 1/9/90 storm, flooded S.W. 336th St. along west side of tributary. Peak flows are somewhat attenuated by the instream R/D pond within this reach.	Federal Way
57		0014B Lake	Hydrology	R	Panther Lake was performing very well as a regional R/D facility in 1985. The lake channel outlet was undefined, indicating good infiltration.	Federal Way
57.1		0014B Lake	Habitat Water Quality Hydrology Land Use	S	Panther Lake, a formally hydrologically isolated depressional wetland, was extensively altered in the mid-1980s to serve as an R/D facility for runoff from surrounding residential and commercial developments. Wetlands have been greatly reduced on all sides by past filling and removal of vegetation, resulting loss of habitat,	Federal Way

HYLEBOS CREEK BASIN
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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					flood storage, and biofiltration. Severe flooding currently occurs at the outlet because of the addition of 583 acres of drainage area that used to infiltrate within a large (now filled) wetland west of the lake typical flood debris, increased impervious surface in the subcatchments that drain to the lake, and loss of infiltration capacity in the bottom of the lake from development-related sedimentation. Groundwater recharge has declined sharply within the last 3-4 years due to siltation of the lakebed. Water quality is chronically impaired by turbidity, oils, and greases from upland construction sites and impervious surfaces. Siltation from the lake is visible downstream at least as far as RM 1.04 on 0014, even under summer low flow conditions.	
57.2		00014B Lake	Hydrology	S	Recent construction directs runoff to new channel that enters the west side of Panther Lake behind King County Aquatic Facility. Runoff is carrying large amounts of silts to the lake.	Federal Way
57.3	(formerly 60)	0014B RM 1.35	Geology	R	Artificial (excavated) channel between this point (a power line crossing) and 1st Ave. S. Channel is cut in till and flow seems stable.	Federal Way
57.4	(formerly 61)	0014B RM 1.40	Habitat	R	Stream is ditched and flows to Panther Lake.	Federal Way
58		0014B RM 1.60-1.70	Hydrology	R	Conveyance system upstream well maintained, with several landscaped ponds act as onsite detention and habitat for domestic waterfowl.	Federal Way
59		0014B RM 1.60	Habitat	R	Natural channel exists just north of new R/D facility.	Federal Way
59.1	WH7	Off Channel	Geology Habitat Hydrology	DI 87-0727	Fill violation above 18-inch culvert and unauthorized instream work on tributary to Hylebos Wetland 18 at site on S. 356th St., E. of 1st Ave.S.	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
59.2	WH13	Off Channel	Hydrology	C	Localized flooding in the vicinity of 4th Ave S.W. and 5th Pl. during the 1/9/90 storm.	Federal Way
59.3	WH14	Off Channel	Hydrology	C	Localized flooding in vicinity of S.W. 334th St. and 10th Ave. S.W. during the 1/9/90 storm.	Federal Way
59.4	WH14,L7	Off Channel	Hydrology	DI 86-1161 88-0001 88-0008 88-0268 88-0392 89-0485 87-0172	Flooding in vicinity of 10th - 16th Ave. S.W. & S.W. 321st - 330th Pl. Infiltration system filled in and park flooding. SWM DI has completed an engineering study of area.	Federal Way
60	See 57.6					
61	See 57.5					
62		0014C RM 0.00-0.30	Hydrology	R	Severe channel erosion has occurred on this reach from its start to the point where it emerges from a 36-inch pipe from Pacific Hwy. S. drainage system.	Federal Way
63		0014C RM 0.00-0.17	Geology	R,S	From RM 0.00 to 0.30, this stream was diverted from old channel down gravel road at same time Trib. 0014A, incised up to five feet into native ground. Lots of sediment being dumped onto 0014A. Headscarp of 7' knickpoint at RM 0.15 retreating at rates of a few feet per year.	Federal Way
64	No entry					
64.1	WH8	0014C RM 0.15	Hydrology	DI 90-0037	8 inches of water flooded SR 99 at S. 338th St.	Federal Way
64.2		0014C RM 0.15-0.34	Hydrology	S	S. 336th St. and SR 99 overtopped during 1/9/90 storm; one house near S. 336th St. had flooding. This is site of S. 336th St. CIP.	Federal Way
65		0014C RM 0.30	Geology	R	Evidence of recent overbank flows, but no serious erosion observed.	Federal Way

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
65.1		0014C RM 0.34 (QWH11)	Water Quality	S	Relatively high concentrations of Zn and fecal densities during storm events. Potential sources include: roadway runoff, automobiles, sewer line leaks, wildlife, and pet wastes. Potential effects include: reduced spawning success, toxicity to freshwater aquatic species, and reduced recreational activities.	Federal Way
66		0014C RM 0.30-0.80	Habitat	R	Debris and probably pollutants from impervious surfaces. Small wetland at RM .80.	Federal Way
67	No entry					
68		0014C RM 0.30-0.86	Hydrology Geology	R,S	Erosion of a foot or more appears to be recent and may be related to WSDOT improvements to SR 99 storm system. Upper reach has some localized minor flooding caused by backwaters from culvert road crossings.	Federal Way
69		0014C RM 0.60	Geology	R	Stream excavated under 20th Ave., upstream from culvert. Minor bank erosion on excavated slopes. Residence located close to top of sideslopes.	Federal Way
70		0014C RM 0.70	Geology	R	Evidence of minor erosion of channel banks and floodplain.	Federal Way
71		0014C RM 0.82	Geology	R	Evidence of minor erosion of channel banks and floodplain. Till exposed in channel bottom.	Federal Way
71.1	WH10	Off Channel	Hydrology	C	Flooding 3' deep across S. 320th St. between 20th and 23rd Ave. S. Water covered the sidewalk throughout the 1/9/90 storm. Ponds at Sea Tac Mall nearly empty during this period.	Federal Way
71.2		0015 RM 0.0-0.47	Habitat Geology Land Use	S	Encroachment into riparian corridor by FWSWD access road. Downcutting 4 to 5 feet near mouth; substrate is unsuitably large (cobble/rubble) for salmonid spawning habitat and has filled in	King County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					rearing habitat (pools). LOD is suspended 1 to 5 feet above streambed.	
72		0015 RM 0.10	Habitat Geology	R,S	Habitat in fair condition with large infinite slope failure at this river mile. Recent widening and incision suggested by bare bankcuts and notched channel. Incision up to 6 feet in small southern tributary to 0015.	King County
72.1		0015 RM 0.10-0.50	Habitat Geology Hydrology	S	FWSWD access road has been constructed on a berm along the right bank within a few feet of the stream. Stream is incising into the road bed in places. Excessive peak flows have caused severe downcutting (maximum depths = 6 to 7 feet; average depths = 1 to 3 feet), deposition of coarse sediment (cobble), cementing of gravels, filling in of pools, and scouring down to glacial till. Numerous small woody debris jams and tires are also present. In spite of the above problems, the stream still has good canopy and moderately good bank vegetation.	King County
73		0015 RM 0.20-0.95	Hydrology Geology	R,S	Accelerated channel erosion due to development above. Riprapped banks appear locally effective in stabilizing local bank failures, but channel and sidebank cut 2-3 feet high. Debris in streams facilities; local deflections of stream are undercutting sidebanks. Channel dimensions 2.5 m X 0.25 m.	Federal Way
73.1		0015 RM 0.50	Habitat Hydrology	S	Stream and adjacent wetland partially impounded by 28th Ave. S. road fill. West of 28th Ave. S., part of the wetland has been filled for construction of the FWSWD access road along 0015.	Federal Way
74	No entry					

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
74.1	H2	Off Channel	Hydrology Habitat Geology Water Quality	DI 88-0094	Drainage channel flowing south to a wetland at S. 368th St.. S. and 28th Ave. S. is seriously degraded from horses having full access to creek. Water flowing slowly through 2-12 inch concrete pipes along north side of S. 368th St. in the vicinity of 28th - 32nd Ave. S. and it appears there are capacity problems downstream. R/D pond and its new pipes probably not associated with problems, but roadside ditches on 368th St. partially full of debris and silt. Residence flooded during 86 storm.	Federal Way
74.2	H2	Off Channel	Habitat Water Quality Land Use	DI 88-0240	Scummy, odorous water in drainage channel flowing south from S. 374th Street, west of 34th Ave. S.	King County
75		0016 RM 0.00-0.38	Geology Habitat Land Use	R,S	Ten foot high bank cut exposes till over gravelly advance outwash at RM 0.02 Floodplain is 0-10 feet wide above RM .02-.38. Channel dimensions 3.0 m X 0.35 m. Deposition of coarse sediment is filling in pools and patches of streambed are scouring down to glacial till. Many tires in stream, along with trash from SR 161. Debris jam and five foot high impassable nick point at RM 0.30. Intermittent flows limit fish use much of the year.	King County
76		0016 RM 0.10-0.20	Habitat	R	In general, gravel and stream habitat in 1985 was good.	King County
77		0016 RM 0.20	Geology	S	Heavy recent deposition of sand in stream gravels. Numerous recent small-scale bank cuts and channel incision.	King County
77.1		0016 RM 0.30-0.50	Habitat	S	Excessive peak flows have caused severe downcutting, channel widening, deposition of coarse sediment, filling of pools, and patches of stream scouring to glacial till. Recent widening of SR 161 disturbed or eliminated riparian vegetation at upper end of channel. Intermittent flows limit fish use much of the year.	King County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
77.2		0016 RM 0.35	Geology	S	Bank cuts 1-2 feet; sewer pipe partly exposed crossing stream bed.	King County
77.3		0016 RM 0.50	Geology	S	Actively expanding 6'-high knick-point. 3' bank cuts typical downstream.	King County
77.4		0016 RM 0.55	Geology	S	Overly steep, unprotected fill slope at road crossing contributing much sediment to stream. Channel dimension: 1.5 m X 0.25 m.	King County King County
78		0016 RM 0.63	Geology	R	Large plunge pool and 10-foot undercut bank erosion present in 1985 at downstream end of culvert crossing SR 161 is no longer there. Embankment has been regraded, the culvert extended, and a manhole was installed as part of Regency Woods development.	King County
78.1		0016 Outflow from Regency Woods R/D Pond (QWR1)	Water Quality	S	Relatively high concentrations of TSS and Cu during storm events. Potential sources include: construction activities and roadway runoff associated with Regency Woods development. Potential effects could include: reduced spawning success (downstream) and toxicity to freshwater aquatic species.	King County
78.2		0016 Outflow from Regency Woods R/D Pond (QWR2)	Water Quality	S	Relatively high concentrations of TSS and Cu during storm events. Potential sources include: construction activities and roadway runoff associated with Regency Woods development. Potential effects could include: reduced spawning success downstream and toxicity to freshwater aquatic species.	King County
78.3		0016 RM 0.68 (QEH4)	Water Quality	S	Relatively high concentrations of $NO_3 + NO_2$, Cu, and fecal densities during storm events. Potential sources include: fertilizers from	King County

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					lawns and gardens, automobiles, Puyallup Kitts Corner retired sanitary landfill, failing on-site septic systems, sewerline leaks, and pet wastes. Potential effects include: eutrophication, toxicity to freshwater aquatic species, and reduced recreational activities.	
79		0016 RM 0.70	Habitat	R	Salmon blockage at culvert. Deeply incised bank from outfall of culvert in 1985. R/D pond not sized correctly on E. side of SR 161. Since 1985, the E. side of R/D was regraded to enlarge the channel and ponding area and culvert replaced. But culvert system is still a barrier to migration. Riser placed to carry flood overflows.	King County
79.1	H6	0016 RM 0.80	Hydrology	C	Localized flooding in vicinity of 25th Ave. S. and 367th Pl. during the 1/9/90 storm.	King County
79.2		0016 RM 0.82-0.95	Habitat Water Quality Hydrology Land Use	S	Release from Weyerhauser pond possibly caused high flow during 1986 storm. Significant erosion and sedimentation downstream of landfill. Stranded fish observed along streambank.	King County
79.3		0016 RM 0.82-0.92	Hydrology Land Use	S	Numerous driveway culverts and channel encroachments along 21st Place S. and S. 362nd Ct.	King County
80		0016 RM 0.83	Geology	R,S	Stream flows in open channel through housing development. Evidence of recent high flows. Sand infilling channel gravels.	King County
80.1		0016 RM 1.03	Habitat Hydrology Land Use	S	New in-stream R/D ponds for Evergreen Vale Apts. All LOD and native riparian vegetation has been replaced by mowed grass and landscaping. Trails cross the stream in two places and parallels the stream within 5 to 50 feet on both sides. A sprinkler system has been installed within 30 feet of the stream. Application of	King County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					fertilizers and pesticides within the riparian corridor is probable. R/D functioned properly during the 1/9/90 storm. R/D designed to handle the 100-year storm. Apt. Manager said he pumped stormwater downstream across S. 360th St. during 1/9/90 storm.	
81	No entry					
82		0016 RM 0.95	Habitat	R,S	Stream is sand-choked. Small amount of debris. Potential R/D site. Existing downstream culvert at/near capacity during high flows.	King County
82.1		0016 RM 1.20	Hydrology	S	Trash rack mounted on culvert outfall. Bank incision 1'-2' in trapezoidal channel.	King County
82.2	H8	0016 RM 1.30	Hydrology Geology	S	Existing 36" pipe at north end of old King County landfill overtopped in 1/9/90 storm. Culvert outlet near Evergreen Vale Apts. eroded by overland flow.	King County
83		0016 RM 1.60	Habitat Land Use	R	Stream channelized around old King County landfill. Good vegetative cover over stream. Riverine wetland at this river mile. A new plat is encroaching on the S. end of this wetland. Possible illegal filling.	King County
83.1		0016 RM 1.60	Geology	S	Channel dimension 3.0 m X 0.40 m in forested wetland.	King County
83.2		0016 RM 1.92 (QEH5)	Water Quality	S	Relatively high concentrations of Cu during storm events. Potential sources include: automobiles, roadway runoff (SR 18), and parking lot runoff from Weyerhauser Pond.	King County
84		0016 RM 2.39	Habitat Hydrology	S	No problems. Stream currently in good condition. Flow release from Weyerhauser Pond is controlled by adjustable weir within the Headquarters. Weir adjusted by maintenance man.	King County

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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
84.1		0016 Pond	Habitat Water Quality Land Use	S	Stream has been impounded to form Weyerhauser reflection pond that supports yellow perch, and possibly other warmwater fish and rainbow trout. Littoral habitat is limited by ongoing removal of emergent revegetation and lack of bank and canopy vegetation. Runoff from I-5 and nearby roads enters pond through a system of ditches which undergo severe erosion during peak flows. Excessive waterflowl use is promoted by daily feeding of hundreds of geese and ducks. Nutrients and avian feces enter the pond directly and in surface runoff from surrounding lawns and trails.	King County
85		0016 RM 2.10-2.60	Hydrology	R	No apparent drainage problems in 1985 due to R/D provided by North Lake and the Weyerhauser Pond and by current moderate levels of development.	King County
85.1		0016 RM 2.50-2.59	Habitat Geology	S	Canopy and bank vegetation provide wildlife habitat throughout most of this reach, except for a short segment just upstream from the Weyerhauser pond in which riparian vegetation is removed on an ongoing basis. Peak flows have caused moderate downcutting and scouring down to glacial till. Small (2 foot) knick point approximately 200 feet upstream from the pond.	King County
86		0016 RM 3.00	Habitat	R	No habitat observed in 1985.	King County
86.1		0016 Lake	Habitat Hydrology Geology	DI 88-0343	North Lake outlet control weir and concrete pipe extension broken, inability to control lake level and fish are escaping. Earthen berm detaining lake is eroding.	King County
86.2		0016 Lake	Habitat	S	North Lake is the largest lake in the Hylebos basin, and has the best littoral and lacustrine habi-	King County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					tat. It supports warmwater fish (yellow perch and largemouth bass) and rainbow trout; the latter are planted by WDW. The lake is largely surrounded by mature second growth forest, except for the east shoreline, which is bordered by single-family residences. A large forested parcel on the west side is on the King County Open Space Program acquisitions list.	
86.3	H10	Off Channel	Hydrology	C	Localized flooding on east side of Weyerhauser Pond and 30th Ave. S. during the 1/9/90 storm.	King County
86.4	H12	Off Channel	Hydrology Water Quality	DI 86-1176	Flooding at S. 330th St. and 38th Ave. S. is causing septic tanks to fail.	King County
86.5		0016A Undefined Ditch (QEBF) and (QEBF1)	Water Quality	S	Relatively high concentrations of $NO_3 + NO_2$, TP, TSS, Cu, and fecal densities during storm events. Potential sources include: bird farm associated with Enchanted Village, sewer and stormwater pump stations (i.e., at Enchanted Village outdoor restroom and residence) mixing during large runoff events, and roadway runoff. Potential effects could include: eutrophication, nuisance growths of algae, toxicity to freshwater species, and reduced spawning success downstream.	King County
86.6		0016A Undefined Ditch (QEBF2)	Water Quality	S	Potential sources include: sewer and stormwater pump stations (at Enchanted Village associated with outdoor restroom and residence) mixing during storm events. Potential effects include: eutrophication, nuisance growths of algae, reduced spawning success, toxicity to freshwater species and limited recreational activities. A fish kill on 12/13/89 below this site in the	King County

HYLEBOS CREEK BASIN
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					Regency Woods development site was observed by SWM Division staff.	
86.7		0016A RM 0.00-0.10	Habitat Land Use Hydrology Water Quality	S	Excessive peak flows have scoured the streambed down to glacial till. Upper end of reach flows through a diffuse channel within a palustrine, forested, seasonally innundated wetland mature black cottonwood, red alder, and willows. This wetland is subjected to excessive peak flows, and surface runoff and erosion of SR 161 road fill. On 11/14/89 the swale near the SR 161 culvert was relatively turbid, but water downstream in 0016A was clear. The wetland appears to perform carry out sediment trapping, biofiltration (nutrient uptake), flood storage, in addition to its wildlife habitat.	King County
87		0016A RM 0.10	Geology	R,S	Erosion is active at and above where channel crosses SR 161.	King County
87.1		0016A RM 0.19 (QEH2)	Water Quality	S	Relatively high concentrations of NO_3 + NO_2, TP, and Cu during storm events. Potential sources include: fertilizers from lawns and gardens immediately upstream, automobiles, and I-5 runoff. Potential effects could include: eutrophication and nuisance growths of algae, and toxicity to freshwater aquatic species.	King County
88		0016A RM 0.20	Geology	R	Stream in open channel through housing development. No erosion.	King County
88.1		0016A RM 0.20-0.30	Hydrology	S	Housing development encroaching on riparian corridor. Streets and one house flooded during the 1/9/90 storm. One house on south side of S. 363rd Pl. had lower floor flooded @ 3' deep. Stormwater ovetopped detention pond wall adjacent to the stream.	King County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
89		0016A RM 0.20-0.35	Habitat	R	Stream shows signs of high peak flows from large amount of impervious surfaces.	King County
90		0016A RM 0.35	Geology	R,S	Minor bank erosion is evidence of recent high flows. Several knickpoints 1 to 2 feet high. Gravel bed is cemented with fines. Channel dimension 2.0 m X 0.40 m.	King County
90.1		0016A RM 0.40	Hydrology	S	Culvert underneath access road is undersized; extreme backwatering on 1/9/90 jeopardized natural gas valve.	King County
90.2		0016A RM 0.40	Hydrology	S	Possible R/D site on north side of S. 360th St. extended, near I-5 and Milton Road.	King County
91		0016A RM 0.40-0.75	Hydrology Habitat Water Quality Land Use	R,S	Reach is conveying greater flows than anticipated in 1985 due to discovery of 48-inch culvert channeling flows from area five under I-5. Reach appears to be generating the most significant level of increased flows to this branch of Hylebos Creek. This segment consists of a shallow ditch excavated by DOT during construction of I-5, causing part of the flow that used to run into 0013 to now flow into 0016, and ultimately to 0006. ORV use of an access road at the lower end of this reach is a source of erosion into the stream. The streambed consists mainly of small river gravel, small crushed rock from I-5, and silt. The substrate is generally loose and unstable, although excessive peak flows have scoured down to glacial till in places. Both banks are extremely deficient in canopy and bank vegetation.	King County/ Federal Way
92		0016A RM 0.68 (QEH3)	Geology Water Quality	R,S	Channel runs along freeway, then passes under it at this point. Some scour and sidebank degradation to 3 feet high.	King County/ Federal Way

(EM8:3-14.38)

HYLEBOS CREEK BASIN
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
					Relatively high concentrations of $NO_3 + NO_2$, TP, and Cu during storm events. Potential sources include: fertilizers, automobiles, and street and highway (I-5) runoff. Potential effects could include: eutrophication, nuisance growths of algae, and toxicity to freshwater aquatic species.	
92.1		0016A RM 0.70	Water Quality	S	Deposition of dredge spoils on left bank.	Federal Way
93		0016A RM 0.75	Habitat	R	Stream shows signs of high peak flows from large amount of impervious surfaces. Channel was moved from subcatchment WH3 and new flows under I-5 to subcatchment H9.	Federal Way
93.1		0016A RM 0.80-0.12	Habitat Water Quality Land Use	S	DOT channelized stream into shallow ditch during I-5 construction. Moderate canopy and bank vegetation.	Federal Way
93.2		0016A RM 1.12	Hydrology Water Quality Land Use	S	Inadequate channel capacity coupled with local constriction at an inadequately sized culvert in the stream relocation channel behind Costco caused severe flooding on 1/9/90. The channel contains uniform-sized gravel; the riparian corridor was planted with inadequate amounts of vegetation and is especially deficient in conifers. Landowner wants to relocate the stream into a ditch DOT channelized stream into shallow ditch during I-5 construction. Moderate canopy and bank vegetation.	Federal Way
94		0016A RM 1.50	Hydrology	R	Flows from this area are tributary to to Recon. subcatchment area 8, not 9, as previously recorded. Flows are conveyed by ditch along west side of I-5 to 48-inch culvert that connected to trib. 0016A. This area is producing most significant increased flows to downstream system.	Federal Way
94.1		0016A	Geology	S	Channel dimension: 2.0 m X	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2/3]	Subject	Data Source	Existing Conditions Description	Entity
		RM 1.70			0.25 m.	
95		0016A RM 1.80	Habitat	R	Ditched stream. Sudsy water from freeway drainage.	Federal Way
96		0016A RM 2.20	Geology	R,DB 782a-88	Downstream from crossing with 336th, west of freeway. Channel ditched at time of freeway construction. Modest erosion in channel.	Federal Way

A P P E N D I X B

LOWER PUGET SOUND BASIN
OBSERVED CONDITIONS SUMMARY

LOWER PUGET SOUND BASIN
OBSERVED CONDITIONS SUMMARY

DATA SOURCE INDEX

P	1985 and 1988 aerial photos observation
R	Reconnaissance Program Observation
S	Basin Planning Staff Observation
M	Metro Observation Report
K	King County Conservation District Observation
DI	SWM Drainage Investigation Observation
C	Citizen Observation
O	Other Agency Observation

KEY TO WATER QUALITY CONDITIONS

* = sampling location identifier

NO_3 + NO_2 = Nitrate + Nitrite - Nitrogen

TP = Total Phosphorus

Cu = Copper

Pb = Lead

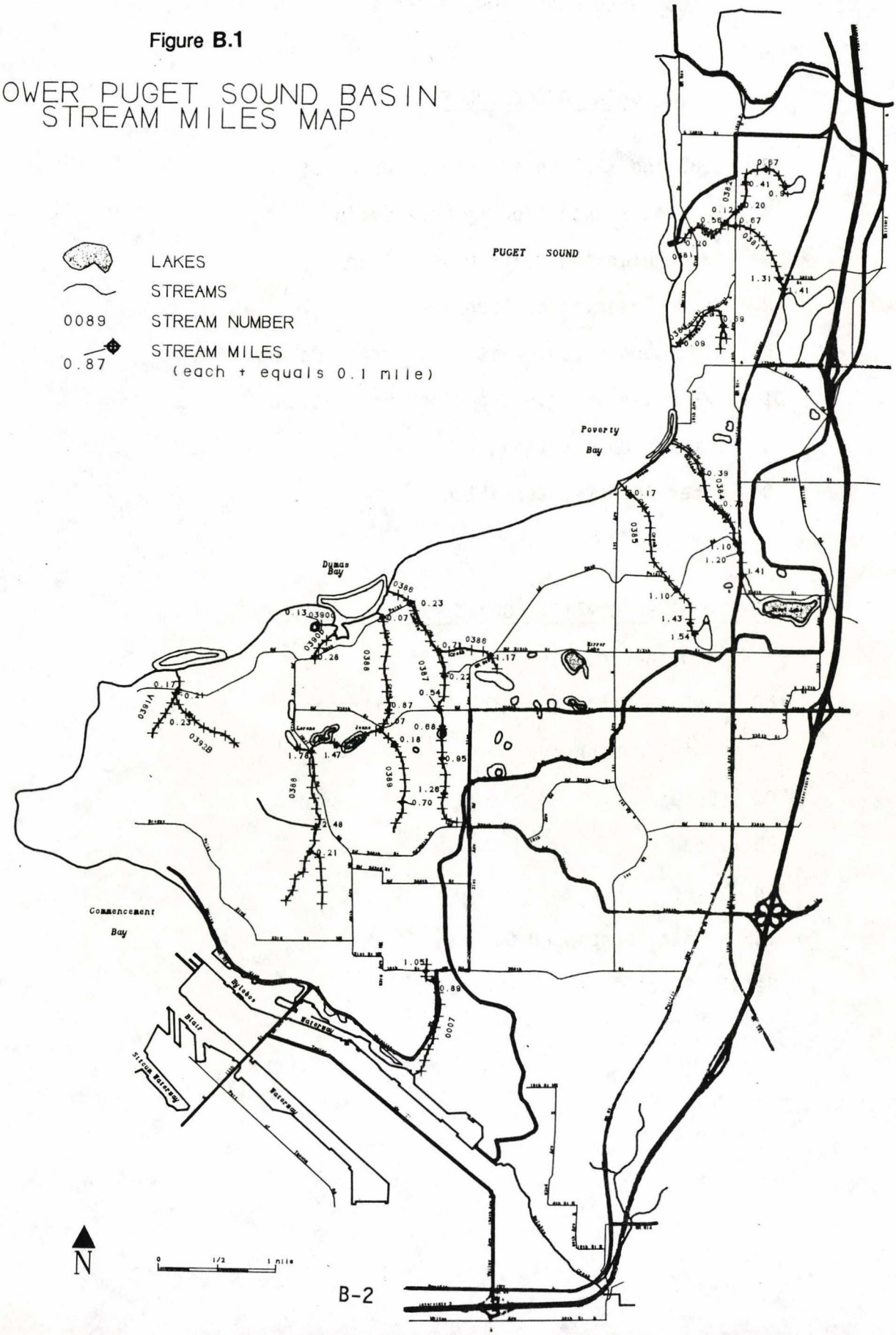
Zn = Zinc

TSS = Total Suspended Solids

Fecal = Fecal Coliform Bacteria

Figure **B.1**

LOWER PUGET SOUND BASIN STREAM MILES MAP



LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
1	Outside study area					
2-4	No entry					
5	Coastal		Geology	R	Mapped landslides. Steep headwall slopes and coastal bluffs. Surface erosion on steep slopes when soil is exposed.	Federal Way
6	Coastal		Geology	R	Landslide on coastal bluff has moved (probably since January 1986 storm).	Federal Way
6.1	NW of J1 Coastal		Geology Hydrology	DI 87-0362 86-0193	Potential for slide due to neighbor discharging water on top of steep bluff at 36th Ave. S.W. & SR 509.	Federal Way
6.2	S of W1 Coastal		Hydrology	DI 990-0035	Water coming from manhole on 8th Ave. S. near S. 273rd Crt. and one house, drive-way, and pool flooded during 1/9/90 storm.	Federal Way
6.3	NW of R4 Coastal		Hydrology Geology	DI 89-0480 89-0710 90-0219	Road drainage causing house to sink. Three-foot sink hole was rerouted in the vicinity of 7th Ave. S.W. & S.W. 294th St. Resident concerned house may slide into ravine on S.W. 294th St. & 6th Ave. S.W. Water from 1/9/90 storm flooding driveway and maybe garage. Complainant felt County project was cause of flooding.	Federal Way
6.4	S of S1 Coastal		Hydrology	DI 89-0739	6-8" of water filled crawl space under house at 9th Ave. S. and S. 261st Pl. during 12/89 storm.	King County
6.5	N of R1 Coastal		Hydrology	DI 88-0752 88-0032	Logging operation left trees in drainage channel blocking an 18" culvert in vicinity of S. 281st & 9th Ave. S. Drainage and mud flowing to property in vicinity of 282nd St. & 8th Ave. S.	King County

1 Item Numbers - whole item numbers refer to entries from the 1986-1987 King County Basin Reconnaissance Program. Entries designated with a decimal number supplement and update the Reconnaissance Program.
2 See Figure B.1 for river mile map.

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
6.6	N of R1 Coastal		Hydrology Geology	DI 88-0065 88-0012	Property on steep slope was cleared promoting a small slide in the vicinity of S. 272nd St. - S. 275th & 10th Ave. S.	King County
6.7	NW of J2 Coastal		Geology	DI 88-0559	Property owner cut into road right-of-way and removed two trees to build driveway down an almost 50% slope at SW 311th Place & 52nd Ave. SW. Undue disturbance could create a slide hazard.	Federal Way
6.8	NW of J2 Coastal		Hydrology Geology	DI 88-0779	Drainage from a culvert under SR-509 is sheet flowing onto a County road, 53rd Ave. SW via swaleflow. Roadside 12" pipe receiving water is plugged and its outlet is unknown. Overflow from pipe appears to flow to top of bluff. Possible erosion from runoff.	Federal Way
6.9	W of R4 Coastal		Hydrology	DI 87-1045	Property owner built railroad tie bulkhead that blocked an 8" CMP outlet at the west end of SW 292nd St. on the S. side, approximately 150' west of 3rd Ave. S.W.	Federal Way
6.10	W of R4 Coastal		Geology	DI 87-0222	Illegal fill moved onto site. Erosion running onto neighbor at 1st Ave. and S.W. 293rd St.	Federal Way
6.11	N of R4 Coastal		Geology Hydrology	DI 90-0335	Large slough occurred near 7th S. and S. 288th Ln. during 1/9/90 storm damaging property below. Area has history of slides.	Federal Way/King County
6.12	NW of R1 Coastal		Hydrology	DI 87-1121	Private concrete structure at S. 274th Pl. and 8th Ave. S. overflowed partially due to debris clogging pipe and possibly excess flows. Overflow flooded downstream pumphouse and pool.	King County
6.13	NW of R1 Coastal		Geology	DI 87-0838	Site cleared above step slope with no erosional/sedimentation controls. Runoff coming to one side of site. Earthwork may weaken bluff at S. 275th St. & 8th Ave. S.	King County
6.14	N of R1 Coastal		Hydrology	DI 86-0553	Flooding at several residences on 13th Ave. S. & S. 280th St. since new	King County

(EM8:1-18.4)

LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					developments built in hillside above and wetland was filled. Drainage channel relocated across complainant's property.	
6.15	NW of R4 Coastal		Geology Hydrology	C,DI 87-0269	Drainage from 2nd Adelaide Beach Estates flowing onto a ravine on 20th Pl. S.W. N. of S.W. 304th St. House with bulkhead built over channel and culvert through bulkhead backing-up water to house.	Federal Way
6.16	NE of M1 Coastal		Hydrology	DI 86-0610	Site at SE ¼ of 1st Ave. S. & S. 308th St., receiving flows from several directions. Fill from Fed. Way Medical Center encroaching on drainage surface flow. Also, culvert under 1st Ave. blocked.	Federal Way
6.17	NW of J2 Coastal		Hydrology Geology	DI 90-0497	Water drains off S.W. 311th Pl. and 53rd Ave. S.W. Eroding beach bank.	Federal Way
6.18	NW of J2 Coastal		Hydrology	DI 86-0824 90-0162	Large fill placed near outlet of 18" CP draining under SR 509 at 50th Ave. S.W. Other fill blocked CP outlet site east of King County property. Palasades Park flooding from stormwater diverted by fill.	Federal Way
6.19	Coastal	0390A	Hydrology Geology	DI 87-0948	Site cleared, potential for erosion into creek on 44th Ave. S.W. and SR 509. Also, state culvert under SR 509 needed cleaning.	Federal Way
7-19	Outside of Study Area					
20		0381 RM 0.15	Habitat	R,S	Good spawning gravels throughout, but diversity is lacking. Channel dimensions are 6.0 m X 0.30 m.	King County
20.1		0381 RM 0.05 (QM1)	Water Quality	M	$NO_3 + NO_2$, TSS, and turbidity concentrations (monitored during baseflow conditions) were generally good (low) and "better" in comparison to the 44 routine stream and river sites (median values) during the same period in Metro's Freshwater Assessment	King County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					Program. No sample for DO and temperature exceeded DOE Water Quality Criteria - Class A (Excellent) for this baseflow monitoring period. Fecal coliform densities exceeded DOE criteria 25% (3 times) during baseflow conditions.	
20.2		0381 RM 0.15 (QM1)	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, Pb, Zn, and fecal densities during storm events. Potential sources include: fertilizers, soil erosion, automobiles, failing on-site septic systems, and sewer line leaks. Potential effects of these pollutants include: eutrophication and nuisance growths of algae, toxicity to both freshwater and marine aquatic species, reduced spawning success of resident trout, and limited recreational activities (e.g., swimming, diving, and shellfish harvesting).	King County
21		0381 RM 0.25	Habitat	R	Excellent spawning riffles. Little diversity or overhanging vegetation.	King County
22		0381 RM 0.35	Hydrology	R	Culvert discharging across S. 251st St. and causing bank erosion in Saltwater State Park	King County
23		0381 RM 0.40	Habitat	R,S	Recently installed log weirs failing at low flows. Downstream weir is 2' barrier to fish. Heavy gully deposition in step-weir pools. Channel dimensions are 4.0 m X 0.30 m.	King County
24		0381 RM 0.60-0.80	Geology	R,S	Hillslope erosion under 16th Ave. S. bridges, below trails and campgrounds.	King County
24.1		0381 RM 0.60	Geology	S	Ravine incision up to 20' deep into right bank hillside from upland drainage.	King County
24.2		0381 RM 0.80	Geology	S	Large, old right-bank hillside failure. Smaller bank failure from lateral stream migration common downstream to bridge.	King County

LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
25		0381 RM I.00	Geology	R,S	Large slump blocks on north side of valley. Undercut sides on south side. Moderate channel erosion; irregular channel dimensions 3.0 m X 0.20 m.	King County
25.1		0381 RM I.04	Geology	DI 86-01E9	Seven acre site on McSorley Creek ravine cleared between S. 257th St. & S. 260th St. behind 20th Ave. S.	King County
26		0381 RM I.20	Habitat	R	Excellent habitat. Riffles free of silt. Pools contain many resident and anadromous fry. Approximate channel dimensions 1.50 m X 0.20 m.	King County
27		0381 RM I.20-1.45	Geology	R	Downcutting, bank and hillslope erosion in loose sandy-gravelly soils. Channel dimensions 3.0 m X 0.30 m.	King County
27.1		0381 RM I.37	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, and fecal densities (QM2) during storm events. Potential sources include: fertilizers, nutrient release from sediment/ aquatic plants in wetlands, roadway runoff from SR 99 and a park-and-ride lot, apartment parking lots, automobiles, failing on-site septic systems, sewer line leaks, and wildlife. Potential effects of these pollutants include: eutrophication and nuisance growths of algae, soil erosion, toxicity to both freshwater aquatic species, and limited recreational activities.	King County
28		0381 RM I.51	Hydrology	R	Collection point occurs at sensitive area (state park) and receives flow from largest drainage area.	King County
29		0381 RM 2.0	Geology	R	Downcutting and bank erosion.	King County
29.1	S9	0381 Headwaters	Hydrology	DI 87-0358 86-0158	R/D pond on S. Star Lk. Road near 24th Pl. S. is overtopping during storms because the catch basin is getting blocked with debris. The emergency spillway is not at the lowest point causing water to flood to adjacent residence.	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
29.2	S9	0381 Headwaters	Hydrology	DI 87-0373	The culvert under a private road at 26th Ave. S. & Star Lk. Road, drains a wetland. It is blocked and floods the road, but it appears the road would flood if culvert were open.	Federal Way
29.3	S9	0381 Headwaters	Hydrology	DI 88-0106	A 36" metal pipe under S. 272nd St. has 22" of standing water in it. Silt from the drainage channel on S. Star Lk. Road has built up in an 18" concrete culvert. This culvert had 9" of standing water in it. Redondo Beach condominium construction filled an outlet ditch. SWM DI study on 272nd/ Star Lake Road to be completed in 1990.	King County
29.4	S8	Off Channel	Hydrology	DI 87-0734	Natural channel was filled, sink holes formed in wet weather on S. 256th St. at 29th Ave. S.	King County
29.5	S8	Off Channel	Hydrology	DI 89-0060	Water flowing along 31st Ave. S. at S. 253rd St. Year around flooding and freezing on the street.	King County
29.6	S9	Off Channel	Hydrology	DI 89-0794	R/D pond at end of 20th Ave. S. & S. 279th Pl. near Redondo Crest Apts. is full. It appears there's too much drainage for the pond at the south end of 20th Ave. S. This pond is one of KC's olds/offs.	King County
30		0382 RM 0.10	Habitat	R,S	Heavy silt deposition in pools and riffles; debris encouraging channel migration and some bank failure. Channel dimensions 3.0 m X 0.30 m.	King County
30.1		0382 RM 0.12 (#11)	Water Quality	O	Relatively low dissolved oxygen concentrations observed during the summer months. Relatively high concentrations of TP, NO_3, Cu, Zn, and fecal densities during spring, summer, or winter periods from 1986-1989. Potential sources include: fertilizers, roadway runoff, automobiles, failing on-site septic systems, sewer line leaks, wildlife and pet wastes. Potential impacts could include:	King County

LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					eutrophication and nuisance growths of algae, toxicity to freshwater and marine aquatic species, and reduced recreational activities (e.g., swimming, diving, and shellfish harvesting).	
31		0382 RM 0.45	Hydrology Water Quality	R	Water quality adversely affected by grease and oils due to poor construction of R/D facility (i.e., invert of control structure above emergency spillway).	Des Moines
31.2		0383 RM 0.00	Geology	S	Active fan-building at beach; culvert outlet is 1/2-full.	King County
32		0383 RM 0.15	Geology	R	Loss of part of road in 1/86 storm. Road drainage directed over hill but outfall is buried.	King County
32.1		0383 RM 9.20	Hydrology	DI 86-0159	Ditch to tributary overflowing into yards on 14th Ave. S. and S. 270th St.	King County
32.2	W2	Off Channel	Hydrology	DI 90-0040 90-0253 90-0254 90-0365	One foot of standing water in basement and crawl spaces of home in vicinity of 18th - 20th Ave. S. at S. 263rd Pl. and 264th Pl. during 1/9/90 storm.	King County
32.3		0383 RM 0.17	Geology	S	Local 3'-5' bank scours; much sand in bed. Owner of streamside house reports no problems 1986-1988	King County
32.4		0383 RM 0.52	Geology	S	Relatively stable banks; Channel dimensions 1.0 m X 0.20 m.	King County
32.5	S of 0383 Coastal		Geology	S	Old, apparently inactive landslide bowl, between Marine View Dr. S. and 13th Ave. S. at about S. 277th St.	King County
32.6	S of 0383 Coastal		Geology	R,S	Mapped landslide; headscarp still steep and bare. Development on downslope slide debris.	King County
33		0384 RM 0.00-0.60	Hydrology	R,S	Moderate channel erosion in trib. 0384 from RM 0.00-0.60. Culvert flooding at RM 0.11 with associated gravel deposition. Channel dimensions 2.0 m X 0.40 m.	King County/ Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
33.1	W of R1	0384 RM 0.00	Hydrology Geology	DI 88-0080	Erosion at 4' cmp inlet in vicinity of Redondo Way & 4th Pl. S. inlet draining to a 3' system. Three-foot arched pipe inlet W. of Redondo Way does not have an inlet grate. Large rocks and debris could enter inlet. A 6' by 6' slump has formed possibly from underground drainage pipe. The County has asked homeowners to buy slump area.	King County
33.2		0384 RM 0.01 (QC1)	Water Quality	M	NO_3 + NO_2 and turbidity concentrations (monitored during baseflow conditions) were generally good (low) and "better" in comparison to the 44 routine stream and river sites (median values) during the same period in Metro's Freshwater Assessment Program. No sample for DO, temperature, and pH exceeded DOE Water Quality Criteria - Class A (Excellent) for this baseflow monitoring period.	King County
33.3		0384 RM 0.01 (QC1)	Water Quality	S	Relatively high concentrations of TP, TSS, Cu, Pb, Zn, and fecal densities during storm events. Potential sources include: fertilizers, soil erosion, automobiles, failing on-site septic systems, and sewer line leaks. Potential effects of these pollutants include: eutrophication and nuisance growths of algae, toxicity to both freshwater and marine aquatic species, reduced spawning success of resident trout, and limited recreational activities (e.g., shellfish harvesting and swimming).	King County
33.4	R1	Off Channel	Hydrology Geology	DI 89-0327	Erosion below old 24" culvert under SR 99 at S. 284th St.	Federal Way
33.5	R1	Off Channel	Hydrology Geology	DI 88-0165	Steep roadside bank is eroding bringing rock and debris onto sidewalk and private drain tiles are outletting to sidewalk on 15th Pl. S. and S. 290th Pl.	Federal Way

(EM8:1-18.10)

LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
33.6	R1	Off Channel	Geology	DI 86-1142	Two caves on roadside SW of Redondo Way S. between SR 509 and Redondo Way 40± feet across.	Federal Way
33.7	R1	Off Channel	Geology	DI 87-1015	Slope failure along pipeline at approx. S. 288th St. and SR 509 may be caused by excessive rain and drainage discharges on top of slope. Major mud flow came down on County road.	Federal Way
34		0384 RM 0.40-0.80	Geology	R,D DI 86-1136	Downcutting and bank erosion exist in previously unchanneled valley (upper) and along Redondo Way S. (lower). Incipient hillside failure along right bank at RM 0.40; January 1986 failure of hillslope above left bank blocked road. Further hillside failure during 1/9/90 storm. Past stabilization efforts unsuccessful.	Federal Way
34.1		0384 RM 0.89-0.95	Hydrology	DI 86-1061 86-0165 86-0190 86-1144	Fill site blocking the natural outlet of an 18" cross tile causing local flooding on 18th Ave S. between S. 296th St. & S. 293rd St.	Federal Way
34.2	R2	Off Channel	Hydrology	DI 90-0084	Two inches of standing water in basement on 18th Ave. S. at S. 293rd St.	Federal Way
34.3		0384 Lake	Hydrology Water Quality	DI 86-1267	Steel Lake outlet culvert filling with sediment and oils at 21st Ave. S. & S. 304th Street.	Federal Way
34.4		0384 RM 1.10 (QC2)	Water Quality	S	Relatively high concentrations of Cu, Zn, and fecal densities during storm events. Potential sources include road runoff associated with SR 99, a gasoline service station immediately upstream, failing on-site septic systems, and sewerline leaks. Potential effects of these pollutants include: toxicity to freshwater and marine species and limited recreational activities (e.g., swimming and shellfish harvesting).	Federal Way
34.5		0384 RM 1.60	Water Quality	S	Relatively high concentrations of Cu and fecal densities during	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2] (QC3)	Subject	Data Source	Existing Conditions Description	Entity
					storm events. Potential sources include: roadway runoff, an apartment complex parking lot, failing on-site septic systems, sewerline leaks, and wildlife. Potential effects of these pollutants include: toxicity to freshwater and marine species and limited recreational activities.	
35		0385 RM 0.05	Hydrology	R	Existing drainage not adequate to handle projected growth.	Federal Way
35.1	NW of R4 Coastal		Geology	DI 86-1282 86-0227	Large old mapped landslide with typical slide topography has been logged potentially accelerating slide movement at 10th Ave. S.W. & S.W. 294th St. Shoreline erosion at toe of slope.	Federal Way
36		0385 RM .05-0.15	Geology	R,S	Recent active slope failures, especially southwest of the creek.	Federal Way
36.1	R4	Off Channel	Hydrology	DI 90-0042	Water in basement crawlspace on S. 301st Pl. near 8th Ave. S.	Federal Way
36.2		0385 RM 0.17	Geology	S,DI 87-250 88-0474	Landslide above Del Ray Mobile Home Park on S. 290th St. & 1st Ave. S.	Federal Way
37		0385 RM 0.18	Habitat	R	6' by 200' concrete pipe (creates velocity barrier for upstream migrating salmonids).	Federal Way
38		0385 RM 0.32	Habitat Geology	R,S	Debris jam barrier; active channel erosion.	Federal Way
39		0385 RM 0.70-0.80	Geology	R,S	Channel downcutting and bank erosion, up to 10'deep.	Federal Way
39.1		0385 RM 1.00	Geology	S	Slot erosion, up to 6' deep. Channel dimensions 2.0 m X 0.25 m.	Federal Way
39.2		0385 RM 1.25	Hydrology	S,DI 86-1281	Channel downcutting and severe bank erosion causing bank failure and loss of property in vicinity of S. 304th St. & 10th Ave. S.	Federal Way

LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
40	No entry					
40.1		0385 RM I.31	Hydrology Geology	DI 88-0172	Drainage from Easter Lake is eroding the channel/ravine on 10th Ave S. near S. 306th St. Piped outfalls to ravine not stabilized. Streets in area are prone to flooding if not well maintained.	Federal Way
40.2		0385 Lake	Hydrology	S	Flooding around Easter Lake perimeter. During 1/9/90, Evergreen Retirement Manor had first floor flooded. Flooding has occurred three times in the last five years.	Federal Way
40.3	NW of R4 Coastal		Hydrology Geology	DI 88-0128	Slope eroding into roadside drainage system aggravated by animal burrowing on the slope. Eroded materials are clogging private drainage system in vicinity of 1st Ave S. & Del Ray Park Drive.	Federal Way
40.4	R4	Off Channel	Hydrology	DI 90-0036	R/D pond at 3rd Ave. S. and S. 308th St. full and not draining. This pond has filled before flooding a residence.	Federal Way
40.5	W of 0385 Coastal		Geology	S	Zone of unstable soils and past landslide activity, between 2nd and 7th Ave. S.W. north of S.W. 297th St.	Federal Way
40.6	W of 0385 Coastal		Geology	R,S	Large, old landslide is still active. Erosion around headscarp north of S.W. 295th and west of 7th Ave. S.W.	Federal Way
40.7	W of 0385 Coastal		Geology	R	Surface erosion and gullying in pasture above Adelaide.	Federal Way
40.8	W of 0385 Coastal		Geology	S	Gully erosion in rear yard at S.W. 295th St. and 11th Ave. S.W. has initiated headward-progressing	Federal Way
40.9	(formerly 41)	0386 RM 0.00-0.03	Geology	R	Gullying, bank erosion in sewage treatment plant construction area.	Federal Way
40.10		0386 RM 0.23 (QL1)	Water Quality	M	Dissolved oxygen (DO), turbidity, and TSS concentrations (monitored during baseflow conditions) were	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					generally good and "better" in comparison to the 44 routine stream and river sites (median values) during the same period in Metro's Freshwater Assessment Program. No sample for DO, temperature, and pH exceeded DOE Water Quality Criteria - Class A (Excellent) for this baseflow monitoring period. During baseflow conditions, NO_3 + NO_2 concentrations were high (only one other stream in King County routinely monitored by Metro had values as high).	
40.11		0386 RM 0.50	Geology	S	Active streamside landsliding; gullying down unmapped left-bank tributary.	Federal Way
40.12		0386 RM 0.23 (QL1)	Water Quality	S	NO_3 + NO_2 concentrations were relatively low during storm events (i.e., 3.5 times as low as measured during baseflow conditions). Relatively high concentrations of TP, TSS, Cu, Pb, Zn, and fecal densities during storm events. Potential sources include: ferlilizers, soil erosion, automobiles, failing on-site septic systems, and sewer line leaks. Potential effects of these pollutants on beneficial uses and other attributes include: eutrophication and nuisance growths of algae, toxicity to both freshwater and marine aquatic species, reduced spawning success of resident trout and anadromous salmon species, and limited recreational activities (e.g., shellfish harvesting).	Federal Way
40.13		0386 RM 0.33	Geology	DI 86-1280	In 1986 STP construction site was hydroseeded but insufficient vegetation to prevent gullying and sediment transport. Vegetation was reestablished by 1989.	Federal Way

LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
40.14		0386 RM 0.50	Geology	S	Active streamside landsliding; gullying down unmapped left-bank tributary.	
41		0386 RM 0.60	Habitat	R,S	Culvert outlet drops 24" to water level with no pool forming upstream migration barrier. Downstream bank failures common; channel dimensions 3.0 m X 0.40 m.	Federal Way
41.1	R6	Off Channel	Hydrology	C	Flooding at intersection of S.W. 323rd St. & 26th Ave. S.W. during 1/9/90 storm.	Federal Way
41.2	L2	Off Channel	Geology Hydrology	DI 88-0614	Stormwater flowing down the south side of SW 308th Pl. at 26th Ave. SW to a ravine that is starting to erode. Resident concerned about sewer line under private road eroding.	Federal Way
41.3		0387 RM 0.35 (QL2)	Water Quality	S	Relatively high concentrations of Cu and fecal densities during storm events. Potential sources include: roadway runoff and automobiles; Decatur High School parking lot; failing on-site septic systems, sewer line leaks. Potential effects include: toxicity to freshwater aquatic species and limited recreational activities.	Federal Way
41.4		0386 RM 0.75	Geology	S	2'-high knickpoint migrating upchannel; channel dimensions above 2.0 m X 0.20 m in relatively stable channel.	Federal Way
41.5		0386 RM 0.90	Geology	S	Active erosion down unmapped right-bank tributary.	Federal Way
41.6		0386 RM 1.10	Geology	S	Active incision along channel below culvert outlet. Channel dimensions 1.5 m X 0.25 m.	Federal Way
41.7		0386 RM 1.15	Geology	S	Upstream migrating knickpoint incising 1-2'; channel dimensions 1.0 m X 0.15 m.	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
42		0386 RM 1.25	Hydrology	R	Trib. 0386 degraded from increased development. Wetland 3309 acting as a natural detention point for tributary. Wetland is the site of the County Lakota Creek Stormwater Capital Improvement Project.	Federal Way
42.1		0386 Lake	Hydrology Habitat	S,DI 88-0452 87-0861 87-0883	Over 1,000 yards of fill 2'-4' thick placed in Mirror Lake outlet (wetland) blocking the channel at S.W. 316th St. and 4th Ave. S.W. Even without the outlet blocked, residents concerned about rapidly rising lake level during wet weather.	Federal Way
42.2	L6	Off Channel	Hydrology	DI 88-0162	Drainage ditch filled not able to handle runoff. Filling may encroach on County easement. Complainant experiencing flooding in yard in vicinity of S.W. 317th St. & 10th Pl. S.W.	Federal Way
42.3	L7,WH14	Off Channel	Hydrology	DI 87-0172 86-1161	Localized flooding in Alderbrook Area, Pond 1, S.W. 324th St. & 13th Ave. S.W.	Federal Way
42.4	M2	Off Channel	Hydrology	DI 90-0220	Four inches of water in residence on 7th Ave. S.W. and S.W. 326th St. during 1/9/90 storm.	Federal Way
42.5	M3	Off Channel	Hydrology	C	Flooding on 1st Ave. S. near S. 316th St. during 1/9/90 storm.	Federal Way
43	No entry					
44	See 41.9					
44.1		0387 RM 0.05	Geology	S	Channel dimensions 2.0 m X 0.25 m. Incision 1-2', fine sediments cementing stream gravels.	Federal Way
45		0387 RM 0.19	Habitat	R,S	Culvert outfall to rocks is a fish barrier. Downstream scour and lateral incision causing bank failures up to 10-12' high.	Federal Way
46		0387 RM 0.30-0.50	Geology	R,S	Channel erosion 1-2' deep downstream of Decatur H.S.; deposition at confluence with trib. 0386.	Federal Way

LOWER PUGET SOUND BASINS
OBSERVED CONDITIONS

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
46.1		0387 RM 0.35 (QL2)	Water Quality	S	Relatively high concentrations of Cu and fecal densities during storm events. Potential sources include: roadway runoff and automobiles; Decatur High School parking lot; failing onsite septic systems, and sewerline leaks. Potential effects include: toxicity to freshwater aquatic species and limited recreational activities.	Federal Way
47		0387 RM 0.80	Habitat Water Quality	R	Nutrient loading from fertilizers, herbicides, and pesticides is damaging Lake Ponce De Leon.	Federal Way
47.1 formerly Item 1, Hylebos Creek Basin Observed Conditions Summary)	L5	0387 RM 1.60	Hydrology	R	Apparent lack of problems in 1985 in vicinity of SW 336th and 21st Ave. SW (proposed project site 2422) due to high infiltrative gradients, and moderate development (evidenced by undefined surface drainage course).	Federal Way
47.2	L5	0387 Lake	Hydrology	DI 86-0567	Outlet pipe to Lake Ponce De Leon deteriorating behind 2526 S.W. 323rd St. on the lake.	Federal Way
47.3	L8	Off Channel	Hydrology	DI 89-0835	Cedardale and Parkway Apts. R/D ponds overtopped flooding dip in road on S.W. 336th St. at 22nd Pl. S.W. Road closed during 12/89 storm.	Federal Way
47.4	L8	Off Channel	Hydrology	DI 90-0029	Four-5' water on one stretch of road flooded S.W. 336th St. at 25th Ln. S.W. during 1/9/90 storm.	Federal Way
48	No entry					
48.1		0388 RM 0.00-0.06	Habitat	S	Six-8' wide X 3-4' deep stream through yard of home to the sand and gravel tideflats. The substrate is pebble-cobble-sand, and consists entirely of riffles, with no cover or LOD, and only fair spawning habitat.	Federal Way
49		0388 RM 0.03	Habitat	R	Heavy sedimentation.	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
49.1		0388 RM 0.06-0.18	Habitat	S	The stream enters second growth cedar with a cottonwood, alder, and vine maple overstory (≤20 = dbh), and ferns dominating the understory; 60-80% canopy cover; increasing LOD upstream; no bank cover. A 1.75' (max) deep 13 sq.ft. pool (the first pool) is formed by cedar logs. The first failure (left bank) is 2,000 cubic feet. Spawning gravels are good, and understory cover from salmon berry becomes thick upstream.	Federal Way
49.2		0388 RM 0.07 (QJ1)*	Water Quality	M	Dissolved oxygen (DO), turbidity, and TSS concentrations (monitored during baseflow conditions) were generally good and "better" in comparison to the 44 routine stream and river sites (median values) during the same period in Metro's Freshwater Assessment Program. No sample for DO, temperature, pH, and fecal exceeded Washington Department of Ecology (DOE) Water Quality Criteria - Class A (Excellent) for this baseflow monitoring period. NO_3 + NO_2, TP concentrations higher than other routinely monitored King County streams during baseflow conditions.	Federal Way
49.3		0388 RM 0.07 (QJ1)*	Water Quality	S	Relatively high concentrations of TP, Cu, TSS, and fecal densities during storm events. Potential sources of these nonpoint pollutants include: fertilizers, automobiles, soil erosion, failing on-site septic systems, and sewerline leaks. Potential effects of these pollutants on beneficial uses and other attributes include: eutrophication and nuisance growths of algae, toxicity to both freshwater and marine aquatic species, reduced, spawning success of resident trout, and	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					limited recreational activities (e.g., shellfish harvesting).	
49.4		0388 RM 0.15	Geology	S	Old mass movements on adjacent hillsides; moderate stream erosion. Channel dimensions 6.0 m X 0.25 m.	Federal Way
49.5		0388 RM 0.18-0.29	Habitat	S	The substrate consists mainly of pebble-cobble-sand with pockets of cobble-rubble. Thick understory cover (20-80%) salmon berry and thimbleberry overhanging channel. There are 4 or 5 medium sized jams of medium and large woody debris (all passable), but none with large pools; largest pool is 12 sq.ft. and 1.5 (max.) deep. Significant recent sand deposition has partially filled many pools.	Federal Way
49.6		0388 RM 0.30	Habitat Geology	S	About 12 alders (8-24" dbh) newly down due to a 4,500 cubic ft. failure on the right bank.	Federal Way
49.7		0388 RM 0.31-0.44	Habitat Geology	S	Understory thins to an average of 30%; alder canopy thins to 0-50% with 1-5" dbh (diameter at breast height) hemlock reproduction. A 1.25' falls with a 1.25' deep (max.) plunge may be a barrier during moderate and low flows. A 12 sq. ft. 1.5' deep (max.) pool due to LOD, along with a 2.0' deep (max.) 16 sq. ft. pool at the bottom of a section of cascades are the only pools. These cascades are probably barriers at low and moderate flows. A small tributary off right bank (0.05 cfs) is downcut 1-2'. Good spawning habitat in pebble-cobble channel. Heavy LOD with sand deposition.	Federal Way
49.8		0388 RM 0.45-0.65	Habitat	S	The stream braids through a 50-70' wide valley (stream is 4-9' wide, 2-4" deep) with 80-150' high,	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					40-50% slopes. Canopy is 6-20" alder with some cottonwood, hemlock, and Douglas fir. LOD is still heavy (mostly individual old cedars partly buried in channel or embedded in banks). Excellent wildlife corridor. A jam of medium-sized woody debris is probably impassable at low flows (could easily be made passable). A small 16 sq. ft. 1.25' deep (max.) pool occurs at RM 0.50, 0.05 miles downstream of a 2.0' deep (max.) 40 sq. ft. pool with no brush cover and a 50% tree canopy. Both pools are formed by LOD which provides some cover. One 4-6" (in length) salmonid was seen here. Several trickling tributaries drain the left and right slopes through devil's club with 40-80%, 120' high slopes above. A 2.0' deep (max.) 45 sq. ft. pool at RM .57 with good vine maple cover is due to two old cedars, with a 10 sq. ft. 1.25' deep (max.) pool 0.06 miles upstream.	
50		0388 RM 0.55	Habitat	R,SW	Debris jam exists. Directed flow has initiated a 20'-high failure on left bank. Local bank incision up to 2'; heavy sand sedimentation.	Federal Way
50.1		0388 RM 0.66-0.71	Habitat	S	A 1.75' tall (and 1.5' wide) falls is probably impassable; a 2.0' deep (max.) 42 sq. ft. pool is at the top of falls. Just downstream at RM 0.69 a small jam of medium and large wooody debris may be a barrier at low flows (there may be passage under debris). At RM 0.70 braiding begins under a relatively open canopy. The valley is 60-100' wide with 60-80' high slopes of 40-70%.	Federal Way
50.2		0388 RM 0.72	Habitat Hydrology	S	An 18' p.v.c. pipe drains a detention pond from a freshly cleared	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					housing development above the right slope; it outfalls in the channel into a gabion wall. The pipe (and possibly the pond) may be undersized, and that barrel velocities would be extreme during peak flows.	
50.3		0388 RM 0.73-0.88	Habitat Geology	S	A 300 sq. ft. 2-12' deep pool has partially filled with sand. Understory on slopes is much more open, dominated by sword fern. Douglas fir becomes numerous (18-24" dbh) with alder still dominant. Some LOD in channels is now new alder (vs. virtually all old cedar downstream). A 1,500 cubic foot failure on the right bank has deposited sands into a jam of medium and large woody debris at its base. Water flows over a 3' falls and winds under the jam; this is probably impassable at low flows and pools are absent. A 2,000 cubic foot 15' high X 25' wide bank failure in very sandy soils occurs at RM 0.82. Another jam at RM 0.84 has created a 4' falls that is definitely impassable at all but high flows when backwatering may allow passage. Spawning gravels are pebble-cobble or cobble-pebble with low fines in majority of riffles.	Federal Way
50.4		0388 RM 0.75	Geology	S	Minor, localized bank failures; abundant woody debris protecting channel from more severe erosion.	Federal Way
51		0388 RM 0.85	Habitat Water Quality	R	Leachate and debris from fill enters stream.	Federal Way
51.1		0388 RM 0.89-1.02	Habitat Geology	S	A 2 cfs 200' tributary seeps from right slope just downstream from the golf course driving range. The right bank of the main channel parallels the range until it	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					enters a 36" culvert and crosses under SW 320th St. A 2-5' fill along this stretch is caving in at many spots. The stream averages 6' wide and 2-4" deep with a pebble-cobble or cobble-pebble substrate, much of it choked with metal and wood debris and is impassable, although debris is easily cleared.	
51.2		0388 RM 1.00 (QJ2)	Water Quality	S	Relatively high concentrations of Cu during storm events. Potential sources include road runoff from automobiles (e.g., thrust bearings, bushing and brake linings). Addition of copper sulfate to lakes or clogged pipes. Potential effects could include toxicity to both freshwater and marine aquatic species.	Federal Way
51.3		0388 RM 2.27	Hydrology	DI 86-1091 86-1080	Soil put into channel is blocking stream channel at S.W. 333rd St. $ 43rd Ave. S.W. Up to 4-inch cuts near creek. Possible change made to streambed in response to flooding of trailer from golf course pumping water.	Federal Way
51.4		0388 approx. RM 3.25	Hydrology Water Quality	C	New housing developments have caused sediment from construction to enter stream and lakes. Approx. 120 acres were cleared in fall of 1989.	Tacoma
53		0388 RM 0.90-1.00	Geology	R,S	Erosion of channel banks in filled valley.	Federal Way
53.1		0388 RM 1.02-1.23	Habitat	S	The fork with 0389 currently provides no salmonid habitat.	Federal Way
53.2		0388 RM 1.23-1.50/ Lakes	Habitat Water Quality	S	The shoreline of Lake Jeane is residential to the lake edge--virtually no riparian habitat remains. Lake Jeane is used as a water source for golf course irrigation. The lakes are are connected by a 300' open channel (half of which is riprapped). The shoreline of Lake Lorene is residential except for the community	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					park (lawns with trees) or the south shore. There are stranded reaches of good salmonid habitat just upstream of Lorene. Resident fish in Jeane and Lorene Lakes could pass upstream into 0388, reaching up to SW 335th St. where the stream is 1' wide and 2-3" deep. There is a several hundred feet long and 150'-200' wide wetland of high habitat value starting at SW 329th St. and paralleling Hoyt Road. This is a barrier at low flows and may be at all flows.	
53.3		0388 Lakes	Hydrology	C	During 1/9/90 storm, Jeane and Lorene Lake levels rose flooding 5-7 residences.	Federal Way
53.4	J1	Off Channel	Hydrology Habitat	C	During 1/9/90 storm Twin Lakes Golf Course's duck pond flooded.	Federal Way
53.5	N of 0388 Coastal		Geology	R,S	Severe erosion of coastal bluff by ill-controlled upland runoff on west-central Dumas Bay.	Federal Way
53.6	(formerly 52)	0388A RM 0.10	Hydrology Water Quality	R	Poor installation of new culvert, exposing 8" sanitary sewer line in drain flow path (4th & SW 293rd). Iron sewer pipe is corroding, contributing significant amounts of iron oxide into swale below.	Federal Way
54		0389 RM 0.19-0.90	Hydrology Geology	C,R,S DI 86-1201 86-0204 86-1033	New development has increased tributary flows, resulting in severe channel incision, channel erosion, and bank instability. Gabion dams have been placed upstream to attenuate flows, but erosion is still active on slopes with residences above. Channel dimensions 2.0 m X 0.30 m. Incision of swale in Olympic View Park (Woodridge Park Ravine) due to increase in surface runoff. Erosion of sand and gravel, particularly severe at RM 0.25.	
55	No entry					
56	W of 0392B Coastal		Geology	R,S	Recent rotational landslide on bluff in state park.	Federal Way

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
56.1		0390 RM 0.00-0.25	Habitat	S	All three branches of this system pass through the wildlife sanctuary at Dumas Bay. Each of the branches is 2-3' wide and 2-3" deep at most (av. 2' X 1.5") and none have any pools. All have good canopy and fair to good understory cover. There is little to LOD (with a few exceptions). The lower 0.05 miles of the middle and eastern forks is a cattail and skunk cabbage wetland with no distinct channel and no fish passage at low flows, and possibly none at any stage. There is an 18" drop at the outfall of a 24" culvert 100' upstream from the mouth of the western fork which makes it impassable at low (and probably high) flows. There is a 3-5' downcut at RM 0.15.	Federal Way
57	No entry					
58		0391A RM 0.00	Habitat Geology	R	Heavy sedimentation; gravels silted.	Federal Way
58.1		0391A RM 0.00-0.18	Habitat Geology	R,S	This tributary enters 0392B at RM 0.18. Incision of alluvium at confluence of tributary and stream, probably due to increased runoff from development on plateau. At the confluence it is 3-4'wide and 1-2.5" deep, with maximum depths of 7" and no pools. There is heavy sand deposition with pockets of pebble-cobble. Chunks of old LOD help stabilize the channel, which is downcut as deep as 4-5' where it is 7-8' wide. Salmonberry, thimbleberry, and nettles are heavy, with 6-24" dbh alder and big leaf maples on 5-20% slopes.	Federal Way
58.2		0391A RM 0.07	Habitat Geology	S	A 10,000 cubic foot rotational failure on the left slope starts at a slope break 20' away from a	Federal Way

LOWER PUGET SOUND BASINS
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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					new home; the toe of the failure runs to within 20' of the stream.	
58.3		0391A RM 0.08-0.17	Habitat	S	The valley narrows to 40-60' with 80-100' high slopes of 60-80%. The channel is 3-5' wide and 1-2' deep. Medium and large woody debris is plentiful, but the gradient increases to 4% and there are no pools. Cut banks 4-8' high and 3-5' downcutting begins at RM 0.12 and continues upstream where it worsens.	Federal Way/ Pierce County
58.4		0391A RM 0.18	Habitat	S	The first major debris jam is impassable at most or all flows (5' drop over and through medium and large woody debris). The slopes are still very sandy: existing chunks of LOD have prevented much worse downcutting. The gradient steepens to 75% above this, which is the upper limit of salmonid habitat.	Pierce County
58.5		0391A RM 0.50	Geology	S	Many ravine-wall landslides in this area of creek, from both incision and upland runoff.	Pierce County
59		0391A RM 0.65	Habitat	R	Debris jam restricts passage.	Pierce County
60	No entry					
60.1		0392B RM 0.00-0.04	Habitat Geology	S	The 4-5' wide and 2-3' deep stream passes from the sand tideflats through 0.02 miles of riprapped channel and 0.02 miles of natural channel through a group picnic area; neither stretch has fish habitat due to lack of cover and pools.	Pierce County
60.2		0392B RM 0.04-0.17	Habitat Water Quality	S	Canopy of big lead maple and alder increases to an average of 70%; understory channel cover averages flows 30% (0-70%). Substrate is pebble-cobble-sand, or sand-pebble;	Pierce County

Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
					spawning habitat is poor due to 1st high sand content. A drainage ditch encircling the picnic area parking lot enters the stream at RM 0.03 and 0.04; the lot is big enough to produce heavy pulses of runoff contaminants. There are no pools and no LOD below RM 0.07. There are several new alders down at RM 0.07. There are several new alders down at RM 0.07, but otherwise most LOD is old cedar.	
60.3		0392B RM 0.18	Habitat	S	0391A (a tributary) meets the stream, increasing total discharge by about 30%.	Pierce County
60.4		0392B RM 0.19-0.39	Habitat	S	The stream is 5-7' wide and 2-3" deep in a 150' wide valley. Substrate is very sandy with pockets of good pebble-cobble. There are cut banks 0-2' high and medium to very heavy salmonberry and red elder (and skunk cabbage near the channel in the lower section) that thin out to an open understory of salmonberry and swordfern upstream. 40-60%, 100' high slopes have 6-24" dbh alder, big leaf maples, hemlock, and Douglas firs; conifers dominate upstream. Very good LOD loading upstream of RM 0.24, but pools average less than 8" deep. The first boulders occur at RM 0.22 where the gradient increases to 4% or more. Most LOD is old cedar but some is newer alder and big leaf maple. Two tributaries drain the left slope near RM 0.24; the larger is 2' wide and 2" deep, the smaller is 1' wide and 2" deep.	Pierce County
60.5		0392B RM 0.40	Habitat	S	A 4' falls (lacking a plunge pool) may be passable at very high flows when water passes around the falls.	Pierce County

LOWER PUGET SOUND BASINS
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Item[1]	Modeled Subcatch.# & Reach #	Trib. & River Mile[2]	Subject	Data Source	Existing Conditions Description	Entity
60.6		0392B RM 0.42	Habitat	S	The stream forks into equal sized cascading channels of 75% gradient. The substrate is rubble-cobble with frequent boulders. Canopy cover is 50-100% (mostly Douglas fir and alder) and understory cover over the channel averages 15% (mostly salmonberry). There are 3-4' falls at the bottom of each fork: this is the top of potential salmonid habitat.	Pierce County
60.7	(formerly 60)	0392B RM 0.09	Hydrology	R	R/D construction to mitigate peak flows for new housing development not receiving any flow. R/D installed at wrong location to receive flows (51st Place SW & SW 325th Place).	King County

A P P E N D I X C

MODELED HSPF FLOW FREQUENCIES AND DURATIONS BY SUBCATCHMENT

Table C.1

17-May-90 MODELED FLOW FREQUENCIES UNDER VARIOUS LAND USE SCENARIOS

FOREST= Pre-developed Land Use
1987= 1987 Land Use
FH= Future High Land Use Without Detention

Sub-Basin	Land Use	Peak Annual Flow Frequency (CFS) 1.01-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr	Mean of 2-100 Yr Flows
H KITT	1987	23.1	40.5	46.8	50.0	53.2	55.2	56.9	60.1	50.4
H1	1987	52.0	119.0	163.0	193.0	231.0	260.0	290.0	361.0	209.3
H10	1987	2.1	4.7	7.1	9.0	11.9	14.5	17.4	25.8	10.8
H11	1987	2.3	6.5	9.3	11.1	13.5	15.3	17.2	21.5	12.1
H12	1987	0.8	1.9	3.0	4.0	5.6	7.1	8.9	14.7	5.1
H1+WH1	1987	111.0	236.0	318.0	374.0	446.0	500.0	556.0	692.0	405.0
H2	1987	4.8	11.9	16.7	19.9	24.0	27.2	30.4	38.1	21.7
H3	1987	9.2	22.2	29.8	34.5	40.2	44.3	48.2	57.1	36.5
H4	1987	43.4	87.3	111.0	125.0	142.0	153.0	165.0	190.0	130.6
H5	1987	8.1	17.1	22.8	26.6	31.4	35.0	38.7	47.4	28.6
H6	1987	35.6	71.2	89.0	99.4	111.0	120.0	127.0	144.0	102.9
H7	1987	0.7	3.7	5.4	6.3	7.2	7.7	8.2	9.0	6.4
H8	1987	13.6	31.3	42.1	49.1	57.8	64.2	70.5	85.2	52.5
H9	1987	23.6	44.4	56.5	64.2	73.8	80.8	87.7	104.0	67.9
J1	1987	45.8	93.8	119.0	134.0	151.0	163.0	175.0	200.0	139.3
J2	1987	6.4	11.9	16.3	19.7	24.4	28.3	32.5	44.0	22.2
J3	1987	8.5	17.0	22.5	26.2	31.0	34.5	38.2	47.0	28.2
J4	1987	27.6	56.5	70.6	78.8	88.1	94.5	100.0	113.0	81.4
J5	1987	27.1	55.9	70.3	78.6	88.1	94.6	101.0	114.0	81.4
J6	1987	6.7	13.3	18.1	21.6	26.3	30.1	34.1	44.4	23.9
J7	1987	0.03	0.04	0.07	0.10	0.18	0.28	0.44	1.25	0.2
J8	1987	3.4	7.5	11.2	14.3	19.0	23.1	27.8	41.7	17.1
L PONCE	1987	7.2	17.0	23.1	27.2	32.3	36.0	39.8	48.6	29.2
L1	1987	30.8	57.7	72.1	81.0	91.6	99.2	106.0	123.0	84.6
L2	1987	30.8	57.8	72.5	81.5	92.4	100.0	108.0	125.0	85.4
L3	1987	18.1	33.0	40.8	45.5	51.2	55.2	59.1	67.7	47.5
L4	1987	11.1	23.2	30.4	35.1	40.9	45.2	49.4	59.4	37.4
L5	1987	12.7	24.2	30.3	34.1	38.7	41.9	45.0	52.0	35.7
L6	1987	4.1	9.6	11.2	11.9	12.5	12.7	13.0	13.3	11.8
L7	1987	17.4	33.0	42.4	48.6	56.2	61.9	67.6	81.1	51.6
M1	1987	0.4	0.7	1.0	1.2	1.4	1.6	1.8	2.3	1.3
M3	1987	CLOSED BASIN								
R1	1987	29.0	60.1	77.1	87.4	99.8	109.0	117.0	136.0	91.7
R2	1987	9.4	21.6	28.4	32.7	37.7	41.3	44.8	52.5	34.4
R3	1987	0.2	2.1	4.5	6.3	8.9	11.0	13.1	18.3	7.6
R4	1987	17.2	37.6	48.0	54.0	60.9	65.6	70.0	79.3	56.0
R5	1987	10.5	19.7	24.3	27.0	30.1	32.2	34.2	38.4	27.9
R6	1987	2.1	4.3	5.9	7.2	8.9	10.3	11.8	15.7	8.1
S1	1987	51.3	107.0	136.0	153.0	173.0	186.0	199.0	228.0	159.0
S2	1987	50.2	107.0	137.0	154.0	174.0	187.0	200.0	228.0	159.8
S3	1987	18.9	41.1	53.2	60.5	69.2	75.3	81.1	94.0	63.4
S4	1987	22.4	47.2	60.5	68.5	78.0	84.7	91.1	105.0	71.7
S5	1987	17.4	36.9	47.5	54.0	61.7	67.2	72.5	84.2	56.6
S6	1987	2.3	4.8	6.6	7.9	9.7	11.1	12.5	16.3	8.7

Table C.1

17-May-90 MODELED FLOW FREQUENCIES UNDER VARIOUS LAND USE SCENARIOS

FOREST= Pre-developed Land Use
1987= 1987 Land Use
FH= Future High Land Use Without Detention

Sub-Basin	Land Use	Peak Annual Flow Frequency (CFS) 1.01-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr	Mean of 2-100 Yr Flows
S7	1987	CLOSED BASIN								
S8	1987	10.7	23.8	32.0	37.4	44.3	49.4	54.6	66.8	40.3
S9	1987	17.7	33.0	40.9	45.7	51.4	55.3	59.1	67.6	47.6
W1	1987	24.0	47.7	60.9	69.1	78.9	86.0	92.8	108.0	72.6
W2	1987	14.0	27.4	34.8	39.3	44.7	48.6	52.4	60.8	41.2
WH UW	1987	38.8	71.5	93.5	109.0	129.0	145.0	161.0	201.0	118.2
WH1	1987	62.9	121.0	161.0	189.0	227.0	257.0	287.0	365.0	207.0
WH10	1987	22.6	39.0	47.0	51.6	57.0	60.7	64.1	71.6	53.2
WH11	1987	48.1	76.7	93.2	104.0	117.0	127.0	137.0	160.0	109.2
WH13	1987	CLOSED BASIN								
WH2	1987	60.6	115.0	154.0	181.0	217.0	245.0	275.0	351.0	197.8
WH3	1987	27.5	48.5	59.5	66.2	74.2	79.9	85.3	97.5	68.9
WH4	1987	42.7	79.0	106.0	125.0	151.0	172.0	194.0	251.0	137.8
WH5	1987	33.7	61.6	80.1	92.8	109.0	122.0	135.0	168.0	100.1
WH6	1987	1.6	3.1	4.1	4.7	5.5	6.1	6.7	8.2	5.0
WH7	1987	4.6	8.3	11.6	14.2	18.0	21.3	25.0	35.5	16.4
WH8	1987	44.7	83.9	108.0	123.0	143.0	158.0	172.0	208.0	131.3
WH9	1987	0.9	1.5	2.1	2.6	3.3	3.9	4.5	6.4	3.0
H KITT	FOREST	4.9	16.2	25.5	32.4	42.0	49.7	57.8	79.0	37.3
H1	FOREST	25.2	58.2	85.8	107.0	138.0	164.0	192.0	270.0	124.2
H10	FOREST	1.7	4.2	6.3	7.9	10.2	12.1	14.3	20.2	9.2
H11	FOREST	1.1	3.9	6.2	7.8	9.9	11.6	13.4	17.7	8.8
H12	FOREST	0.6	2.1	3.4	4.6	6.3	7.8	9.5	14.6	5.6
H1+WH1	FOREST	47.7	113.0	165.0	204.0	260.0	306.0	356.0	489.0	234.0
H2	FOREST	3.1	6.7	9.6	11.8	14.9	17.3	20.0	27.3	13.4
H3	FOREST	4.2	10.3	15.0	18.5	23.2	27.0	31.1	41.7	20.9
H4	FOREST	13.6	40.0	60.9	76.4	97.7	115.0	133.0	180.0	87.2
H5	FOREST	3.1	8.8	12.7	15.4	18.8	21.4	24.1	30.5	16.9
H6	FOREST	10.3	32.2	49.7	62.8	80.8	95.2	111.0	150.0	72.0
H7	FOREST	0.6	3.2	4.5	5.2	5.8	6.2	6.4	6.9	5.2
H8	FOREST	4.9	15.2	23.2	29.1	37.1	43.5	50.2	67.4	33.1
H9	FOREST	4.9	16.4	26.4	34.1	45.0	54.0	63.9	90.2	40.0
J1	FOREST	8.7	24.1	35.6	44.0	55.4	64.5	74.0	98.2	49.6
J2	FOREST	3.2	6.7	9.2	11.0	13.5	15.4	17.5	22.7	12.2
J3	FOREST	3.6	7.5	10.3	12.3	15.0	17.1	19.4	25.1	13.6
J4	FOREST	3.7	14.5	23.6	30.4	39.6	47.0	54.7	74.5	35.0
J5	FOREST	3.8	14.9	24.2	31.1	40.7	48.4	56.4	77.1	36.0
J6	FOREST	1.1	2.7	4.4	6.0	8.4	10.6	13.2	21.4	7.5
J7	FOREST	0.031	0.041	0.068	0.103	0.183	0.283	0.441	1.250	0.2
J8	FOREST	0.4	1.3	2.4	3.6	5.6	7.7	10.4	20.1	5.2
L PONCE	FOREST	1.4	3.5	5.3	6.6	8.6	10.2	12.0	17.0	7.7
L1	FOREST	4.9	9.9	14.3	17.8	22.9	27.2	32.1	45.9	20.7
L2	FOREST	4.6	9.7	14.0	17.5	22.5	26.7	31.4	44.6	20.3
L3	FOREST	1.8	5.4	8.5	10.8	14.1	16.8	19.7	27.5	12.5

Table C.1

17-May-90 MODELED FLOW FREQUENCIES UNDER VARIOUS LAND USE SCENARIOS

FOREST= Pre-developed Land Use
1987= 1987 Land Use
FH= Future High Land Use Without Detention

Sub-Basin	Land Use	Peak Annual Flow Frequency (CFS) 1.01-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr	Mean of 2-100 Yr Flows
L4	FOREST	1.8	4.0	5.8	7.2	9.3	11.0	12.8	18.0	8.4
L5	FOREST	1.4	3.5	5.3	6.6	8.6	10.2	12.0	17.0	7.7
L6	FOREST	0.9	3.2	5.3	7.0	9.6	11.8	14.2	21.0	8.5
L7	FOREST	2.3	6.2	9.6	12.3	16.2	19.6	23.3	33.6	14.5
M1	FOREST	0.2	0.4	0.6	0.7	0.8	0.9	1.0	1.3	0.8
M3	FOREST	CLOSED BASIN								
R1	FOREST	2.8	8.9	15.9	22.2	32.6	42.5	54.5	93.0	29.4
R2	FOREST	1.7	4.3	7.0	9.3	13.0	16.4	20.3	32.5	11.7
R3	FOREST	0.2	0.5	1.1	2.1	5.0	9.4	17.6	75.1	5.9
R4	FOREST	2.6	8.8	14.3	18.7	24.9	30.0	35.7	50.9	22.1
R5	FOREST	1.2	4.0	6.5	8.4	11.4	13.8	16.6	24.2	10.1
R6	FOREST	0.7	1.4	1.9	2.3	2.9	3.4	3.9	5.2	2.6
S1	FOREST	12.1	35.3	51.8	63.3	78.3	89.7	101.0	130.0	69.9
S2	FOREST	11.5	34.6	51.1	62.5	77.3	88.7	100.0	128.0	69.0
S3	FOREST	5.8	17.2	24.4	29.0	34.7	38.7	42.7	51.7	31.1
S4	FOREST	4.6	13.7	21.0	26.5	34.1	40.3	46.9	64.2	30.4
S5	FOREST	3.5	10.6	16.5	20.8	26.9	31.8	37.1	51.0	24.0
S6	FOREST	0.9	1.8	2.6	3.1	3.9	4.6	5.3	7.2	3.6
S7	FOREST	CLOSED BASIN								
S8	FOREST	4.5	12.9	18.2	21.6	25.7	28.7	31.6	38.2	23.1
S9	FOREST	4.3	10.0	14.2	17.2	21.3	24.5	27.9	36.6	19.2
W1	FOREST	4.2	14.1	21.9	27.7	35.5	41.7	48.3	64.9	31.5
W2	FOREST	2.2	6.9	11.0	14.1	18.5	22.1	26.1	36.8	16.5
WH UW	FOREST	9.8	25.2	36.4	44.4	55.2	63.6	72.4	94.7	49.5
WH1	FOREST	23.1	55.1	80.1	98.8	125.0	146.0	168.0	228.0	112.2
WH10	FOREST	3.1	9.4	13.8	16.9	20.8	23.8	26.8	34.0	18.6
WH11	FOREST	3.6	13.9	23.5	31.2	42.4	51.8	62.3	90.8	37.5
WH13	FOREST	CLOSED BASIN								
WH2	FOREST	21.0	51.0	74.5	92.1	117.0	137.0	158.0	215.0	104.9
WH3	FOREST	5.1	18.1	28.8	36.9	48.1	57.1	66.7	91.6	42.6
WH4	FOREST	12.1	31.0	45.0	55.1	68.6	79.2	90.4	119.0	61.6
WH5	FOREST	6.0	17.3	25.3	30.9	38.2	43.7	49.4	63.3	34.1
WH6	FOREST	0.5	1.9	2.9	3.5	4.3	4.8	5.4	6.6	3.8
WH7	FOREST	3.6	6.8	9.4	11.4	14.4	16.8	19.5	27.0	13.0
WH8	FOREST	7.0	18.6	28.5	36.1	47.0	56.1	66.2	93.4	42.1
WH9	FOREST	0.3	0.8	1.1	1.3	1.6	1.8	2.1	2.7	1.4
H KITT	FH	38.5	57.5	73.3	85.2	102.0	116.0	131.0	171.0	94.2
H1	FH	136.0	259.0	329.0	375.0	430.0	471.0	511.0	604.0	395.8
H10	FH	5.4	13.3	18.3	21.6	25.7	28.8	31.9	39.1	23.3
H11	FH	9.0	17.4	21.5	23.9	26.7	28.6	30.3	34.1	24.7
H12	FH	1.1	6.2	9.0	10.5	11.9	12.8	13.4	14.6	10.6
H1+WH1	FH	239.0	479.0	617.0	705.0	814.0	892.0	970.0	1150.0	746.2
H2	FH	17.3	35.5	46.2	53.1	61.6	67.9	74.0	88.4	56.4
H3	FH	25.7	55.4	70.7	79.8	90.3	97.6	104.0	119.0	83.0

Table C.1

17-May-90 MODELED FLOW FREQUENCIES UNDER VARIOUS LAND USE SCENARIOS

FOREST= Pre-developed Land Use
1987= 1987 Land Use
FH= Future High Land Use Without Detention

Sub-Basin	Land Use	Peak Annual Flow Frequency (CFS) 1.01-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr	Mean of 2-100 Yr Flows
H4	FH	91.2	153.0	192.0	218.0	252.0	277.0	303.0	366.0	232.5
H5	FH	13.5	29.9	38.2	43.0	48.5	52.2	55.6	62.9	44.6
H6	FH	78.3	124.0	156.0	177.0	205.0	227.0	249.0	305.0	189.7
H7	FH	1.1	6.4	8.9	10.0	10.9	11.4	11.7	12.2	9.9
H8	FH	32.3	64.3	80.6	90.3	102.0	110.0	117.0	133.0	94.0
H9	FH	46.9	81.0	98.1	108.0	120.0	128.0	136.0	153.0	111.9
J1	FH	54.8	115.0	147.0	167.0	190.0	206.0	222.0	256.0	174.5
J2	FH	10.6	25.5	37.3	46.1	58.4	68.4	79.3	108.0	52.5
J3	FH	12.2	28.2	40.6	49.8	62.7	73.1	84.3	114.0	56.4
J4	FH	32.1	65.5	81.3	90.2	100.0	107.0	113.0	126.0	92.8
J5	FH	31.1	65.3	81.4	90.6	101.0	107.0	114.0	126.0	93.2
J6	FH	29.1	45.7	58.3	67.6	80.2	90.4	101.0	130.0	73.9
J7	FH	3.4	5.3	6.8	8.0	9.8	11.2	12.8	17.1	9.0
J8	FH	17.8	28.2	36.4	42.4	50.8	57.7	65.1	84.6	46.8
L PONCE	FH	6.6	16.9	23.1	27.1	31.9	35.5	38.9	46.7	28.9
L1	FH	40.0	71.3	88.0	98.2	110.0	119.0	128.0	146.0	102.4
L2	FH	37.3	68.0	84.6	94.9	107.0	116.0	124.0	144.0	99.1
L3	FH	20.8	38.0	47.0	52.5	58.9	63.5	67.9	77.6	54.6
L4	FH	12.0	24.8	32.4	37.2	43.1	47.5	51.7	61.6	39.5
L5	FH	12.2	23.9	30.2	34.0	38.6	41.8	45.0	51.9	35.6
L6	FH	7.7	9.8	12.6	15.0	18.7	22.1	26.1	38.0	17.4
L7	FH	18.1	35.6	46.0	52.7	60.9	67.0	73.0	87.1	55.9
M1	FH	0.4	0.9	1.1	1.3	1.6	1.8	2.0	2.5	1.5
M3	FH	CLOSED BASIN								
R1	FH	40.2	79.8	102.0	116.0	132.0	144.0	156.0	183.0	121.6
R2	FH	14.2	27.7	35.7	40.9	47.3	52.0	56.6	67.5	43.4
R3	FH	0.6	6.4	8.5	9.2	9.5	9.7	9.7	9.8	8.8
R4	FH	16.5	40.6	52.6	59.3	66.9	71.8	76.4	85.6	61.3
R5	FH	11.8	21.4	26.2	29.1	32.5	34.8	37.0	41.8	30.2
R6	FH	2.2	4.9	6.8	8.1	9.8	11.1	12.5	15.8	8.9
S1	FH	84.9	163.0	199.0	220.0	243.0	258.0	273.0	303.0	226.0
S2	FH	81.9	162.0	200.0	222.0	246.0	263.0	278.0	311.0	228.5
S3	FH	30.7	59.3	73.6	82.1	91.8	98.6	105.0	119.0	85.1
S4	FH	44.6	82.3	101.0	111.0	124.0	132.0	140.0	157.0	115.1
S5	FH	20.6	46.0	59.0	66.6	75.4	81.5	87.1	99.2	69.3
S6	FH	3.1	6.3	8.8	10.6	13.2	15.3	17.5	23.4	12.0
S7	FH	20.2	23.5	25.6	27.0	28.7	30.0	31.3	34.2	27.7
S8	FH	15.1	31.5	40.7	46.4	53.4	58.3	63.2	74.2	48.9
S9	FH	28.1	51.1	64.4	72.9	83.4	91.2	98.8	117.0	77.0
W1	FH	32.3	66.7	84.6	95.3	108.0	117.0	125.0	143.0	99.4
W2	FH	18.0	35.6	44.2	49.2	54.8	58.6	62.2	69.7	50.8
WH UW	FH	75.5	155.0	212.0	252.0	306.0	348.0	393.0	506.0	277.7
WH1	FH	121.0	235.0	311.0	363.0	431.0	484.0	538.0	671.0	393.7
WH10	FH	35.4	55.9	66.3	72.5	79.9	85.1	90.1	101.0	75.0

Table C.1

17-May-90 MODELED FLOW FREQUENCIES UNDER VARIOUS LAND USE SCENARIOS

FOREST= Pre-developed Land Use
1987= 1987 Land Use
FH= Future High Land Use Without Detention

Sub-Basin	Land Use	Peak Annual Flow Frequency (CFS) 1.01-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr	Mean of 2-100 Yr Flows
WH11	FH	69.1	103.0	126.0	141.0	161.0	177.0	193.0	232.0	150.2
WH13	FH	20.7	77.9	114.0	136.0	162.0	180.0	197.0	233.0	144.5
WH2	FH	117.0	233.0	309.0	360.0	427.0	477.0	529.0	655.0	389.2
WH3	FH	54.1	88.8	106.0	117.0	130.0	138.0	147.0	166.0	121.1
WH4	FH	85.3	172.0	234.0	280.0	341.0	389.0	441.0	573.0	309.5
WH5	FH	53.9	98.5	125.0	143.0	164.0	180.0	197.0	235.0	151.3
WH6	FH	2.6	4.3	5.8	7.0	8.7	10.1	11.7	16.2	7.9
WH7	FH	21.4	72.8	106.0	127.0	153.0	171.0	189.0	228.0	136.5
WH8	FH	78.6	141.0	172.0	191.0	214.0	229.0	244.0	277.0	198.5
WH9	FH	1.2	2.6	4.0	5.0	6.7	8.1	9.7	14.3	6.0

17-May-90

TABLE C.2
HSPF DURATION DATA

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FH= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	10	20	50	75	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	MAX	MIN	MEAN	SDEV
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																							
WH7	5	1987	1	1	0.08262	0.00147	0.00011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24.87	0	0.5389	1.238
WH7	5	1987	2	1367000	113000	2020	152	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	1987	3	1	1982	21	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	1987	4	1367000	57	96.19	76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	1987	5	1E+30	109.4	74.12	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	1987	1	1	0.00051	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.463	0	0.0965	0.1928
WH9	6	1987	2	1367000	706	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	1987	3	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	1987	4	1367000	47.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	1987	5	1E+30	31.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	1987	1	1	0.00326	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.601	0	0.1454	0.3033
WH6	7	1987	2	1367000	4458	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	1987	3	1	215	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	1987	4	1367000	20.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	1987	5	1E+30	35.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	1987	1	1	0.09122	0.01307	0.00167	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55.63	0	0.7248	2.167
WH10	8	1987	2	1367000	124700	17880	2287	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	1987	3	1	3881	1693	276	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	1987	4	1367000	32.14	10.56	8.286	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	1987	5	1E+30	52.8	11.49	9.308	1.166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	1987	1	1	0.103	0.02349	0.00636	0.00038	0.00004	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	123.7	0	0.9727	3.319
WH11	9	1987	2	1367000	140900	32130	8704	529	60	6	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	1987	3	1	4066	2988	1336	157	32	3	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	1987	4	1367000	34.64	10.75	6.515	3.369	1.875	2	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	1987	5	1E+30	47.22	10.98	6.59	2.416	0.9601	0.8165	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	1987	1	1	0.2062	0.05948	0.02255	0.00197	0.00043	0.00010	0	0	0	0	0	0	0	0	0	0	0	0	0	142.8	0	2.12	5.859
WH8	10	1987	2	1367000	281900	81330	30840	2698	592	138	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	1987	3	1	2618	2416	1351	171	49	18	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	1987	4	1367000	107.7	33.66	22.83	15.78	12.08	7.667	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	1987	5	1E+30	183.4	34.12	20.36	15.26	8.824	5.715	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	1987	1	1	0.2878	0.05055	0.01775	0.0013	0.00030	0.00004	0	0	0	0	0	0	0	0	0	0	0	0	0	107.9	0	2.24	5.163
WH5	11	1987	2	1367000	393500	69120	24270	1777	417	56	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	1987	3	1	1147	1140	589	63	19	4	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	1987	4	1367000	343.1	60.63	41.2	28.21	21.95	14	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	1987	5	1E+30	444	57.15	32.56	22.32	17.05	5.148	0	0	0	0	0	0	0	0	0	0	0	0	0				
12102920	12	1987	1	1	0.322	0.07321	0.02837	0.00253	0.00066	0.00014	0	0	0	0	0	0	0	0	0	0	0	0	0	132.5	0	2.925	6.498
12102920	12	1987	2	1367000	440300	100100	38790	3460	903	205	0	0	0	0	0	0	0	0	0	0	0	0	0				
12102920	12	1987	3	1	1115	1176	720	101	28	7	0	0	0	0	0	0	0	0	0	0	0	0	0				
12102920	12	1987	4	1367000	394.9	85.13	53.87	34.26	32.25	29.29	0	0	0	0	0	0	0	0	0	0	0	0	0				
12102920	12	1987	5	1E+30	546.7	97.23	53.11	26.24	24.39	23.09	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH4	13	1987	1	1	0.3422	0.09098	0.03698	0.00398	0.00099	0.00036	0.00002	0	0	0	0	0	0	0	0	0	0	0	0	158.9	0	3.445	7.571
WH4	13	1987	2	1367000	467900	124400	50570	5450	1357	497	33	0	0	0	0	0	0	0	0	0	0	0	0				
WH4	13	1987	3	1	1171	1121	731	127	34	18	2	0	0	0	0	0	0	0	0	0	0	0	0				
WH4	13	1987	4	1367000	399.6	111	69.18	42.91	39.91	27.61	16.5	0	0	0	0	0	0	0	0	0	0	0	0				

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TABLE C.2
HSPF DURATION DATA

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FH= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	10	20	50	75	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	MAX	MIN	MEAN	SDEV
WH4	13	1987	5	1E+30	587	123.6	70.95	33.99	26.98	19.31	5.5	0	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	1987	1	1	0.1208	0.01349	0.00245	0.00008	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79.22	0	0.9077	2.461
WH3	14	1987	2	1367000	165100	18450	3363	122	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	1987	3	1	3018	1748	498	30	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	1987	4	1367000	54.71	10.55	6.753	4.067	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	1987	5	1E+30	111.5	14.78	8.712	3.66	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH2	15	1987	1	1	0.8177	0.2322	0.0889	0.01287	0.00345	0.00125	0.00024	0.00006	0	0	0	0	0	0	0	0	0	0	0	232.6	0	8.135	11.04
WH2	15	1987	2	1367000	1118000	317500	121600	17600	4718	1719	337	85	0	0	0	0	0	0	0	0	0	0	0				
WH2	15	1987	3	1	286	1494	1238	350	125	51	18	3	0	0	0	0	0	0	0	0	0	0	0				
WH2	15	1987	4	1367000	3909	212.5	98.19	50.3	37.74	33.71	18.72	28.33	0	0	0	0	0	0	0	0	0	0	0				
WH2	15	1987	5	1E+30	8907	518.6	142.6	52.16	37.88	29.8	20.2	30.21	0	0	0	0	0	0	0	0	0	0	0				
WH1	16	1987	1	1	0.8322	0.2448	0.09814	0.01556	0.00433	0.00159	0.00037	0.00009	0	0	0	0	0	0	0	0	0	0	0	245.5	0.05773	8.586	11.85
WH1	16	1987	2	1367000	1138000	334800	134200	21280	5929	2178	515	126	0	0	0	0	0	0	0	0	0	0	0				
WH1	16	1987	3	1	271	1406	1204	378	140	53	19	5	0	0	0	0	0	0	0	0	0	0	0				
WH1	16	1987	4	1367000	4199	238.1	111.5	56.29	42.35	41.09	27.11	25.2	0	0	0	0	0	0	0	0	0	0	0				
WH1	16	1987	5	1E+30	8769	553.8	165.1	57.31	40.31	32.12	20.28	27.01	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	FH	1	1	0.3356	0.1444	0.05103	0.00531	0.00146	0.00057	0.00005	0	0	0	0	0	0	0	0	0	0	0	0	186.7	0	4.152	8.783
WH7	5	FH	2	1367000	458900	197400	69780	7274	2000	793	72	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	FH	3	1	1598	577	330	78	24	11	1	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	FH	4	1367000	287.2	342.2	211.4	93.26	83.33	72.09	72	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	FH	5	1E+30	552.2	308.7	153.9	56.68	44.62	30.34	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FH	1	1	0.00195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.597	0	0.1381	0.2794
WH9	6	FH	2	1367000	2666	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FH	3	1	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FH	4	1367000	44.43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FH	5	1E+30	35.86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FH	1	1	0.01075	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.29	0	0.2122	0.4465
WH6	7	FH	2	1367000	14700	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FH	3	1	716	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FH	4	1367000	20.53	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FH	5	1E+30	32.39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	FH	1	1	0.09884	0.02484	0.00506	0.00018	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83.52	0	0.9288	3.08
WH10	8	FH	2	1367000	135200	33970	6922	256	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	FH	3	1	4197	2556	740	50	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	FH	4	1367000	32.2	13.29	9.354	5.12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	FH	5	1E+30	38.51	13.18	9.034	3.664	1.414	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FH	1	1	0.1083	0.03425	0.01235	0.00124	0.00025	0.00004	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	176.2	0	1.222	4.538
WH11	9	FH	2	1367000	148100	46840	16890	1701	355	68	3	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FH	3	1	4262	3623	2155	430	119	37	2	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FH	4	1367000	34.74	12.93	7.838	3.956	2.983	1.838	1.5	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FH	5	1E+30	33.48	12.69	7.991	3.805	2.169	1.103	0.5	0	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	FH	1	1	0.1976	0.08137	0.04228	0.00735	0.00219	0.00089	0.00013	0.00000	0	0	0	0	0	0	0	0	0	0	0	203.9	0	2.907	9.008
WH8	10	FH	2	1367000	270200	111300	57810	10060	2997	1230	185	3	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	FH	3	1	2808	2972	2117	557	212	107	22	2	0	0	0	0	0	0	0	0	0	0	0				

17-May-90

TABLE C.2
HSPF DURATION DATA

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FU= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	10	20	50	75	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	MAX	MIN	MEAN	SDEV
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																							
WH8	10	FH	4	1367000	96.23	37.44	27.31	18.07	14.14	11.5	8.409	1.5	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	FH	5	1E+30	116.6	32.4	23.22	14.62	12.42	9.379	4.397	0.5	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FH	1	1	0.31	0.07582	0.03697	0.00543	0.00153	0.00056	0.00003	0	0	0	0	0	0	0	0	0	0	0	0	162.7	0	3.085	7.952
WH5	11	FH	2	1367000	424000	103700	50550	7429	2101	769	42	0	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FH	3	1	1275	1664	1104	246	81	33	4	0	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FH	4	1367000	332.5	62.31	45.79	30.2	25.94	23.3	10.5	0	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FH	5	1E+30	369.3	50.64	34.55	22.3	20.06	16.5	8.201	0	0	0	0	0	0	0	0	0	0	0	0				
12102920	12	FH	1	1	0.4023	0.2204	0.1176	0.02592	0.00937	0.00407	0.00106	0.00043	0.00013	0.00001	0	0	0	0	0	0	0	0	0	320.8	0	7.449	15.84
12102920	12	FH	2	1367000	550100	301400	160900	35440	12820	5565	1451	597	190	27	0	0	0	0	0	0	0	0	0				
12102920	12	FH	3	1	1232	1085	1230	576	247	125	32	17	6	1	0	0	0	0	0	0	0	0	0				
12102920	12	FH	4	1367000	446.5	277.8	130.8	61.53	51.92	44.52	45.34	35.12	31.67	27	0	0	0	0	0	0	0	0	0				
12102920	12	FH	5	1E+30	723.9	359.4	166.2	65.19	48.29	39.66	32.68	27.01	23.7	0	0	0	0	0	0	0	0	0	0				
WH4	13	FH	1	1	0.414	0.2413	0.1345	0.03291	0.0131	0.00552	0.00153	0.00062	0.00024	0.00009	0.00001	0	0	0	0	0	0	0	0	360.3	0	8.388	17.73
WH4	13	FH	2	1367000	566000	330000	183900	45000	17920	7561	2098	848	337	125	20	0	0	0	0	0	0	0	0				
WH4	13	FH	3	1	1178	1171	1197	620	316	150	47	19	10	5	1	0	0	0	0	0	0	0	0				
WH4	13	FH	4	1367000	480.5	281.8	153.6	72.58	56.7	50.41	44.64	44.63	33.7	25	20	0	0	0	0	0	0	0	0				
WH4	13	FH	5	1E+30	762.1	376.9	189.7	72.67	53.55	41.94	34.45	31.77	28.13	24.78	0	0	0	0	0	0	0	0	0				
WH3	14	FH	1	1	0.1537	0.03746	0.01292	0.00121	0.00024	0.00003	0	0	0	0	0	0	0	0	0	0	0	0	0	136	0	1.503	4.638
WH3	14	FH	2	1367000	210100	51220	17670	1666	332	50	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	FH	3	1	3364	3442	1946	263	65	18	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	FH	4	1367000	62.47	14.88	9.08	6.335	5.108	2.778	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	FH	5	1E+30	105.8	16.52	9.81	6.346	4.008	1.812	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH2	15	FH	1	1	0.8272	0.3356	0.2069	0.05889	0.0258	0.01242	0.00353	0.00136	0.00062	0.00030	0.00012	0.00004	0	0	0	0	0	0	0	452	0	13.82	22.58
WH2	15	FH	2	1367000	1131000	458900	282900	80520	35290	16990	4839	1864	860	421	175	66	0	0	0	0	0	0	0				
WH2	15	FH	3	1	273	1388	1641	1108	642	402	144	57	26	17	7	5	0	0	0	0	0	0	0				
WH2	15	FH	4	1367000	4143	330.6	172.4	72.67	54.96	42.25	33.6	32.7	33.08	24.76	25	13.2	0	0	0	0	0	0	0				
WH2	15	FH	5	1E+30	9079	641.7	293.8	90.24	62.7	50	37.52	33.73	29.49	25.26	24.87	15.59	0	0	0	0	0	0	0				
WH1	16	FH	1	1	0.8634	0.3448	0.2168	0.06462	0.02879	0.01434	0.00411	0.00163	0.00074	0.00038	0.00016	0.00007	0	0	0	0	0	0	0	465.5	0.1192	14.58	23.72
WH1	16	FH	2	1367000	1181000	471500	296400	88360	39370	19600	5633	2235	1023	528	220	100	0	0	0	0	0	0	0				
WH1	16	FH	3	1	230	1333	1550	1096	626	403	135	59	22	16	8	3	0	0	0	0	0	0	0				
WH1	16	FH	4	1367000	5133	353.7	191.2	80.62	62.89	48.65	41.73	37.88	46.5	33	27.5	33.33	0	0	0	0	0	0	0				
WH1	16	FH	5	1E+30	9303	676.9	316.9	99.36	67.44	51.7	39.9	34.43	31.8	25.82	24.43	24.64	0	0	0	0	0	0	0				
H12	17	1987	1	1	0.00783	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.555	0	0.4006	0.5258
H12	17	1987	2	1367000	10710	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	1987	3	1	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	1987	4	1367000	510.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	1987	5	1E+30	355.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	1987	1	1	0.0342	0.00013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.78	0	0.4855	0.6734
H11	18	1987	2	1367000	46770	191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	1987	3	1	523	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	1987	4	1367000	89.43	14.69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	1987	5	1E+30	265.9	22.43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	1987	1	1	0.08516	0.00032	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.54	0	0.6427	0.928
H10	19	1987	2	1367000	116400	448	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				

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TABLE C.2
HSPF DURATION DATA

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FH= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	10	20	50	75	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	MAX	MIN	MEAN	SDEV
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																							
H10	19	1987	3	1	263	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	1987	4	1367000	442.7	149.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	1987	5	1E+30	583	131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	1987	1	1	0.191	0.00937	0.00111	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60.74	0	1.225	2.175
H8	20	1987	2	1367000	261200	12820	1530	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	1987	3	1	1341	640	130	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	1987	4	1367000	194.7	20.04	11.77	6.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	1987	5	1E+30	502.2	42.89	25.33	1.118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	1987	1	1	0.1291	0.0134	0.00234	0.00007	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77.59	0	0.9035	2.41
H9	21	1987	2	1367000	176600	18330	3201	99	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	1987	3	1	2433	1280	324	21	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	1987	4	1367000	72.57	14.32	9.88	4.714	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	1987	5	1E+30	122.2	16.84	11.2	3.369	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	1987	1	1	0.1291	0.0134	0.00235	0.00002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52.92	0	0.9035	2.402
H KITT	29	1987	2	1367000	176600	18320	3218	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	1987	3	1	2430	1277	321	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	1987	4	1367000	72.66	14.35	10.02	9.667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	1987	5	1E+30	122.2	16.92	11.27	2.867	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H6	22	1987	1	1	0.2769	0.04844	0.01153	0.00087	0.00022	0.00002	0	0	0	0	0	0	0	0	0	0	0	0	0	115.7	0	2.182	4.573
H6	22	1987	2	1367000	378700	66240	15760	1190	311	29	0	0	0	0	0	0	0	0	0	0	0	0	0				
H6	22	1987	3	1	1595	1923	922	106	36	5	0	0	0	0	0	0	0	0	0	0	0	0	0				
H6	22	1987	4	1367000	237.4	34.45	17.1	11.23	8.639	5.8	0	0	0	0	0	0	0	0	0	0	0	0	0				
H6	22	1987	5	1E+30	575.2	71.54	26.75	13.29	7.952	2.561	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	1987	1	1	0.01465	0.00002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.58	0	0.2682	0.49
H7	23	1987	2	1367000	20040	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	1987	3	1	146	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	1987	4	1367000	137.3	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	1987	5	1E+30	132.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	1987	1	1	0.09678	0.00292	0.00025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32.68	0	0.6862	1.397
H5	24	1987	2	1367000	132300	4000	342	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	1987	3	1	1834	185	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	1987	4	1367000	72.16	21.62	14.87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	1987	5	1E+30	143.8	35.15	19.18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H4	25	1987	1	1	0.3283	0.07468	0.02153	0.00181	0.00051	0.00017	0	0	0	0	0	0	0	0	0	0	0	0	0	147.1	0	2.87	5.942
H4	25	1987	2	1367000	448900	102100	29440	2483	709	233	0	0	0	0	0	0	0	0	0	0	0	0	0				
H4	25	1987	3	1	1440	1963	1163	186	53	23	0	0	0	0	0	0	0	0	0	0	0	0	0				
H4	25	1987	4	1367000	311.7	52.02	25.31	13.35	13.38	10.13	0	0	0	0	0	0	0	0	0	0	0	0	0				
H4	25	1987	5	1E+30	843.8	104.1	47.51	20.51	13.83	8.669	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	1987	1	1	0.04763	0.00099	0.00007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.41	0	0.3964	0.9453
H2	26	1987	2	1367000	65130	1364	106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	1987	3	1	878	46	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	1987	4	1367000	74.18	29.65	13.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	1987	5	1E+30	97.63	27.97	7.838	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	1987	1	1	0.07676	0.00290	0.00035	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40.03	0	0.5726	1.369

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TABLE C.2
HSPF DURATION DATA

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FH= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	10	20	50	75	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	MAX	MIN	MEAN	SDEV
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																							
H3	27	1987	2	1367000	105000	3970	482	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	1987	3	1	1423	305	59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	1987	4	1367000	73.76	13.02	8.169	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	1987	5	1E+30	108.7	23.13	13.47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H1	28	1987	1	1	0.4277	0.1336	0.05346	0.00690	0.00200	0.00076	0.00020	0.00002	0	0	0	0	0	0	0	0	0	0	0	240.9	0.1373	4.83	9.304
H1	28	1987	2	1367000	584800	182700	73100	9446	2741	1049	284	39	0	0	0	0	0	0	0	0	0	0	0				
H1	28	1987	3	1	1047	1321	1243	336	112	47	19	4	0	0	0	0	0	0	0	0	0	0	0				
H1	28	1987	4	1367000	558.5	138.3	58.81	28.11	24.47	22.32	14.95	9.75	0	0	0	0	0	0	0	0	0	0	0				
H1	28	1987	5	1E+30	1499	239.7	93.99	34.66	28.17	21.08	16.88	4.603	0	0	0	0	0	0	0	0	0	0	0				
H1+WH1	33	1987	1	1	0.8996	0.3468	0.1909	0.05149	0.02226	0.0105	0.00289	0.00109	0.00053	0.00024	0.00013	0.00005	0	0	0	0	0	0	0	458.2	1.219	13.42	21.01
H1+WH1	33	1987	2	1367000	1230000	474200	261100	70410	30440	14350	3952	1501	733	337	182	74	0	0	0	0	0	0	0				
H1+WH1	33	1987	3	1	182	1179	1326	974	586	356	117	48	32	19	9	5	0	0	0	0	0	0	0				
H1+WH1	33	1987	4	1367000	6759	402.2	196.9	72.29	51.94	40.31	33.78	31.27	22.91	17.74	20.22	14.8	0	0	0	0	0	0	0				
H1+WH1	33	1987	5	1E+30	4659	1007	364.3	99.85	65.61	47.05	37.18	28.52	19.67	19.04	22.08	9.325	0	0	0	0	0	0	0				
H12	17	FH	1	1	0.05892	0.00043	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.22	0	0.7961	0.9623
H12	17	FH	2	1367000	80570	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	FH	3	1	178	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	FH	4	1367000	452.6	85.71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	FH	5	1E+30	404.8	82.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FH	1	1	0.1287	0.00223	0.00010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27.18	0.00003	0.9905	1.331
H11	18	FH	2	1367000	176000	3061	146	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FH	3	1	2570	257	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FH	4	1367000	68.47	11.91	6.952	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FH	5	1E+30	228.5	29.1	9.945	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FH	1	1	0.2138	0.00498	0.00027	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	1.27	1.716
H10	19	FH	2	1367000	292300	6810	380	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FH	3	1	827	84	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FH	4	1367000	353.5	81.07	47.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FH	5	1E+30	623	91.2	52.69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FH	1	1	0.2962	0.042	0.00900	0.00054	0.00007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97.66	0	2.216	4.062
H8	20	FH	2	1367000	405100	57430	12320	752	106	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FH	3	1	1573	2167	852	87	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FH	4	1367000	257.5	26.5	14.46	8.644	5.579	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FH	5	1E+30	604.8	50.84	21.79	11	3.217	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FH	1	1	0.1484	0.03455	0.01117	0.00097	0.00017	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	115.1	0	1.377	4.308
H9	21	FH	2	1367000	202900	47250	15280	1327	241	27	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FH	3	1	2916	2598	1301	176	44	9	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FH	4	1367000	69.6	18.19	11.74	7.54	5.477	3	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FH	5	1E+30	93.54	16.71	11.27	7.32	4.181	1.333	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FH	1	1	0.1484	0.03457	0.01137	0.00070	0.00005	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	106.7	0	1.377	4.241
H KITT	29	FH	2	1367000	202900	47280	15550	969	81	4	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FH	3	1	2914	2592	1298	53	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FH	4	1367000	69.65	18.24	11.98	18.28	7.364	4	0	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FH	5	1E+30	93.59	16.72	11.61	14.06	4.829	0	0	0	0	0	0	0	0	0	0	0	0	0	0				

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TABLE C.2
HSPF DURATION DATA

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FH= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	10	20	50	75	100	150	200	250	300	350	400	500	600	700	800	900	1000	1100	MAX	MIN	MEAN	SDEV
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																							
H6	22	FH	1	1	0.3574	0.09132	0.03916	0.00655	0.00229	0.00071	0.00007	0.00000	0	0	0	0	0	0	0	0	0	0	0	212.1	0	3.736	8.54
H6	22	FH	2	1367000	488800	124900	53550	8958	3136	977	109	3	0	0	0	0	0	0	0	0	0	0	0				
H6	22	FH	3	1	1442	3041	2471	721	269	85	13	1	0	0	0	0	0	0	0	0	0	0	0				
H6	22	FH	4	1367000	338.9	41.06	21.67	12.42	11.66	11.49	8.385	3	0	0	0	0	0	0	0	0	0	0	0				
H6	22	FH	5	1E+30	746.4	69.67	28.14	12.89	13.54	12.24	4.764	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	FH	1	1	0.03022	0.00019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.57	0	0.3859	0.6898
H7	23	FH	2	1367000	41330	266	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	FH	3	1	321	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	FH	4	1367000	128.7	44.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	FH	5	1E+30	121.7	31.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	FH	1	1	0.1379	0.01113	0.00144	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44.71	0	1.011	2.175
H5	24	FH	2	1367000	188600	15220	1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	FH	3	1	2606	696	110	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	FH	4	1367000	72.38	21.87	17.95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	FH	5	1E+30	133.3	30.09	20.69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H4	25	FH	1	1	0.4112	0.1228	0.05497	0.01089	0.00389	0.00172	0.00032	0.00005	0.00000	0	0	0	0	0	0	0	0	0	0	255.3	0	4.754	10.67
H4	25	FH	2	1367000	562300	167900	75170	14890	5321	2363	445	71	2	0	0	0	0	0	0	0	0	0	0				
H4	25	FH	3	1	1230	2848	2597	1049	416	183	37	10	1	0	0	0	0	0	0	0	0	0	0				
H4	25	FH	4	1367000	457.2	58.94	28.95	14.19	12.79	12.91	12.03	7.1	2	0	0	0	0	0	0	0	0	0	0				
H4	25	FH	5	1E+30	1165	106.3	44.38	16.31	13.85	15.34	13.6	5.029	0	0	0	0	0	0	0	0	0	0	0				
H2	26	FH	1	1	0.1193	0.01479	0.00249	0.00005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61.49	0	0.9253	2.49
H2	26	FH	2	1367000	163200	20230	3414	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	FH	3	1	2508	804	165	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	FH	4	1367000	65.06	25.16	20.69	11.29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	FH	5	1E+30	70.4	22.72	18.22	9.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FH	1	1	0.1414	0.02435	0.00514	0.00031	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	87.25	0	1.195	3.223
H3	27	FH	2	1367000	193400	33290	7038	433	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FH	3	1	2465	1528	523	58	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FH	4	1367000	78.46	21.79	13.46	7.466	2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FH	5	1E+30	97.34	24.23	16.5	8.028	1.077	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H1	28	FH	1	1	0.5006	0.1927	0.1024	0.03091	0.01347	0.00631	0.00225	0.00093	0.00040	0.00015	0.00004	0.00000	0	0	0	0	0	0	0	435.6	0.1333	8.019	17.81
H1	28	FH	2	1367000	684500	263600	140000	42270	18410	8630	3082	1272	559	211	67	8	0	0	0	0	0	0	0				
H1	28	FH	3	1	891	2002	2355	1401	791	441	188	79	40	19	8	2	0	0	0	0	0	0	0				
H1	28	FH	4	1367000	768.2	131.7	59.43	30.17	23.28	19.57	16.39	16.1	13.98	11.11	8.375	4	0	0	0	0	0	0	0				
H1	28	FH	5	1E+30	1935	219.2	81.91	32.24	21.83	17.46	15.98	16.25	13.32	8.902	5.611	2	0	0	0	0	0	0	0				
H1+WH1	33	FH	1	1	0.9301	0.4169	0.2906	0.1246	0.07188	0.04477	0.01951	0.00917	0.00475	0.00275	0.00168	0.00106	0.00049	0.00020	0.00008	0	0	0	0	799.5	1.321	22.59	40.61
H1+WH1	33	FH	2	1367000	1272000	570000	397400	170400	98290	61220	26680	12550	6507	3765	2303	1457	673	282	119	0	0	0	0				
H1+WH1	33	FH	3	1	110	1142	1433	1903	1616	1265	718	423	254	154	98	61	28	18	8	0	0	0	0				
H1+WH1	33	FH	4	1367000	11560	499.2	277.3	89.57	60.82	48.4	37.15	29.66	25.62	24.45	23.5	23.89	24.04	15.67	14.87	0	0	0	0				
H1+WH1	33	FH	5	1E+30	1E+30	1156	484.1	136.5	82.94	61.84	42.67	33.04	29.76	25.81	25.71	24.69	22.81	18.71	8.724	0	0	0	0				

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TABLE C.2

HSPF DURATION DATA

BASIN: HYLEBOS

SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987

TIMESTEP: 15 MINUTES

NUMBER OF TIMESTEPS IN ANALYSIS: 1367424

NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO

1987= 1987 (Calibration land use).

FH= Future land use without on-site detention.

FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN	SDEV
H12	17	FRST	1	1	0.01173	0.00090	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.343	0	0.364	0.588
H12	17	FRST	2	1367000	16030	1235	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	FRST	3	1	26	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	FRST	4	1367000	616.7	308.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H12	17	FRST	5	1E+30	358.2	166.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FRST	1	1	0.04278	0.00217	0.00021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.91	0	0.448	0.7393
H11	18	FRST	2	1367000	58490	2967	292	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FRST	3	1	224	27	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FRST	4	1367000	261.1	109.9	97.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H11	18	FRST	5	1E+30	492.1	180.8	134.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FRST	1	1	0.08852	0.00499	0.00044	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15.55	0	0.578	0.9846
H10	19	FRST	2	1367000	121000	6830	604	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FRST	3	1	180	20	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FRST	4	1367000	672.5	341.5	302	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H10	19	FRST	5	1E+30	763.7	253.4	127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FRST	1	1	0.1729	0.05196	0.00802	0.00046	0.00023	0.00013	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	41.88	0	1.045	2.031
H8	20	FRST	2	1367000	236400	71040	10980	638	326	187	5	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FRST	3	1	340	319	103	22	7	7	1	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FRST	4	1367000	695.3	222.7	106.6	29	46.57	26.71	5	0	0	0	0	0	0	0	0	0	0	0	0				
H8	20	FRST	5	1E+30	946.5	261.2	144.5	74.05	85.93	33.2	0	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FRST	1	1	0.1062	0.02681	0.00400	0.00029	0.00012	0.00005	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	48.41	0	0.6444	1.576
H9	21	FRST	2	1367000	145200	36660	5481	399	168	81	15	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FRST	3	1	454	293	114	28	16	9	4	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FRST	4	1367000	319.9	125.1	48.08	14.25	10.5	9	3.75	0	0	0	0	0	0	0	0	0	0	0	0				
H9	21	FRST	5	1E+30	325.4	143.4	70.16	32.38	15.52	6.944	1.92	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FRST	1	1	0.1062	0.02681	0.00400	0.00029	0.00012	0.00005	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	44.8	0	0.6444	1.576
H KITT	29	FRST	2	1367000	145200	36660	5482	399	174	82	15	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FRST	3	1	454	291	113	27	16	8	3	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FRST	4	1367000	319.9	126	48.51	14.78	10.87	10.25	5	0	0	0	0	0	0	0	0	0	0	0	0				
H KITT	29	FRST	5	1E+30	325.4	143.6	70.35	32.9	15.64	6.851	1.633	0	0	0	0	0	0	0	0	0	0	0	0				
H6	22	FRST	1	1	0.2297	0.1148	0.04058	0.00652	0.00291	0.00146	0.00042	0.00019	0.00009	0.00003	0.00001	0	0	0	0	0	0	0	0	87.24	0	1.753	3.729
H6	22	FRST	2	1367000	314100	157000	55490	8919	3986	1998	585	272	128	51	17	0	0	0	0	0	0	0	0				
H6	22	FRST	3	1	357	414	320	117	82	47	28	14	8	6	4	0	0	0	0	0	0	0	0				
H6	22	FRST	4	1367000	879.8	379.2	173.4	76.23	48.61	42.51	20.89	19.43	16	8.5	4.25	0	0	0	0	0	0	0	0				
H6	22	FRST	5	1E+30	1185	416.9	189.9	107.1	76.87	65.72	48.91	46.85	15.82	7.112	1.299	0	0	0	0	0	0	0	0				
H7	23	FRST	1	1	0.01429	0.00039	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.422	0	0.2358	0.4722
H7	23	FRST	2	1367000	19530	545	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	FRST	3	1	116	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	FRST	4	1367000	168.4	181.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H7	23	FRST	5	1E+30	159.8	79.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	FRST	1	1	0.08175	0.01502	0.00162	0.00007	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.71	0	0.551	1.211
H5	24	FRST	2	1367000	111800	20540	2221	108	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	FRST	3	1	402	143	23	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H5	24	FRST	4	1367000	278.1	143.6	96.57	54	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0				

17-May-90

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE C.2
HSPF DURATION DATA

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FH= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN	SDEV
H5	24	FRST	5	1E+30	306.4	147.1	86.89	39	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H4	25	FRST	1	1	0.2661	0.1489	0.0657	0.01541	0.00804	0.00435	0.00148	0.00055	0.00025	0.00017	0.00009	0.00004	0.00001	0	0	0	0	0	0	110.8	0	2.306	4.938
H4	25	FRST	2	1367000	363900	203600	89840	21080	10990	5953	2033	756	355	233	129	59	19	0	0	0	0	0	0				
H4	25	FRST	3	1	357	420	376	179	113	79	37	27	16	7	6	6	4	0	0	0	0	0	0				
H4	25	FRST	4	1367000	1019	484.8	238.9	117.7	97.3	75.35	54.95	28	22.19	33.29	21.5	9.833	4.75	0	0	0	0	0	0				
H4	25	FRST	5	1E+30	1497	623.6	264	148	117.6	95.41	75.77	56.72	53.92	58.49	24.77	10.32	3.112	0	0	0	0	0	0				
H2	26	FRST	1	1	0.04135	0.00495	0.00047	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18.85	0	0.3238	0.8168
H2	26	FRST	2	1367000	56540	6770	655	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	FRST	3	1	360	76	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	FRST	4	1367000	157	89.08	50.38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H2	26	FRST	5	1E+30	140.3	69.69	43.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FRST	1	1	0.06721	0.0128	0.00157	0.00007	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	30.42	0	0.4529	1.146
H3	27	FRST	2	1367000	91900	17510	2158	108	19	1	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FRST	3	1	460	186	35	6	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FRST	4	1367000	199.8	94.13	61.66	18	6.333	1	0	0	0	0	0	0	0	0	0	0	0	0	0				
H3	27	FRST	5	1E+30	177.3	97.21	58.97	35.36	4.989	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
H1	28	FRST	1	1	0.3422	0.2122	0.118	0.04518	0.02886	0.01902	0.00839	0.00404	0.00211	0.00122	0.00066	0.00040	0.00022	0.00010	0.00003	0.00000	0	0	0	176.8	0.1101	3.939	7.934
H1	28	FRST	2	1367000	467900	290100	161300	61780	39470	26010	11480	5527	2891	1675	906	560	304	144	44	3	0	0	0				
H1	28	FRST	3	1	313	369	411	321	239	176	94	53	31	22	15	11	6	5	4	1	0	0	0				
H1	28	FRST	4	1367000	1495	786.2	392.4	192.5	165.1	147.8	122.1	104.3	93.26	76.14	60.4	50.91	50.67	28.8	11	3	0	0	0				
H1	28	FRST	5	1E+30	2484	942	402.5	181.3	162.9	141.4	113.8	84.61	78.12	70.74	62.91	62.47	65.34	41.7	12.86	0	0	0	0				
H1+WH1	33	FRST	1	1	0.8502	0.4262	0.2718	0.1502	0.114	0.08808	0.05325	0.03373	0.02124	0.01382	0.00899	0.00633	0.00434	0.00183	0.00090	0.00041	0.00022	0.00010	0.00003	349.3	1.2	10.5	16.1
H1+WH1	33	FRST	2	1367000	1163000	582800	371700	205400	155900	120400	72810	46130	29050	18890	12310	8667	5935	2514	1236	566	301	137	42				
H1+WH1	33	FRST	3	1	87	209	343	377	395	376	322	253	174	133	91	73	55	29	18	10	6	4	3				
H1+WH1	33	FRST	4	1367000	13360	2788	1084	544.7	394.7	320.3	226.1	182.3	166.9	142	135.2	118.7	107.9	86.69	68.67	56.6	50.17	34.25	14				
H1+WH1	33	FRST	5	1E+30	5471	5043	1678	643.6	424.5	349.6	208.3	175.4	152.6	140.3	122.9	104.1	89.88	78.48	67.33	68.47	67.07	44.95	15.64				
WH7	5	FRST	1	1	0.0644	0.00979	0.00077	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.48	0	0.4285	1.051
WH7	5	FRST	2	1367000	88060	13390	1060	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	FRST	3	1	605	68	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	FRST	4	1367000	145.6	196.9	117.8	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH7	5	FRST	5	1E+30	166.6	113.4	80.37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FRST	1	1	0.00008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.28	0	0.05387	0.125
WH9	6	FRST	2	1367000	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FRST	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FRST	4	1367000	114	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH9	6	FRST	5	1E+30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FRST	1	1	0.00081	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.226	0	0.09089	0.2138
WH6	7	FRST	2	1367000	1113	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FRST	3	1	53	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FRST	4	1367000	21	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH6	7	FRST	5	1E+30	46.73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	FRST	1	1	0.04564	0.00516	0.00042	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22.63	0	0.3372	0.8404
WH10	8	FRST	2	1367000	62410	7057	580	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	FRST	3	1	473	171	39	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				

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TABLE C.2
HSPF DURATION DATA

BASIN: HYLEBOS
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.
5	Standard deviation of duration in table 4. Expressed in timesteps.

MODEL SCENARIO
1987= 1987 (Calibration land use).
FH= Future land use without on-site detention.
FRST= Pre-Developed Land Use.

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN	SDEV
WH10	8	FRST	4	1367000	132	41.27	14.87	2.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH10	8	FRST	5	1E+30	154	68.87	31.62	1.299	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FRST	1	1	0.05899	0.00718	0.00051	0.00006	0.00003	0.00001	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	54.22	0	0.3952	0.9579
WH11	9	FRST	2	1367000	80670	9831	704	83	42	15	4	1	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FRST	3	1	464	272	76	22	12	7	2	1	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FRST	4	1367000	173.9	36.14	9.263	3.773	3.5	2.143	2	1	0	0	0	0	0	0	0	0	0	0	0				
WH11	9	FRST	5	1E+30	214.8	77.92	27.76	3.218	2.63	1.245	1	0	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	FRST	1	1	0.1488	0.05689	0.01326	0.00133	0.00053	0.00025	0.00007	0.00001	0	0	0	0	0	0	0	0	0	0	0	54.87	0	0.9676	2.337
WH8	10	FRST	2	1367000	203400	77790	18130	1821	725	353	106	16	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	FRST	3	1	467	361	149	32	19	12	7	3	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	FRST	4	1367000	435.6	215.5	121.7	56.91	38.16	29.42	15.14	5.333	0	0	0	0	0	0	0	0	0	0	0				
WH8	10	FRST	5	1E+30	488.3	201	129.1	60.75	50.56	46.72	12.17	1.247	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FRST	1	1	0.1644	0.05271	0.01514	0.00160	0.00064	0.00026	0.00007	0.00001	0	0	0	0	0	0	0	0	0	0	0	52.38	0	1.044	2.432
WH5	11	FRST	2	1367000	224800	72070	20710	2197	881	366	105	23	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FRST	3	1	272	231	128	23	12	6	1	1	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FRST	4	1367000	826.6	312	161.8	95.52	73.42	61	105	23	0	0	0	0	0	0	0	0	0	0	0				
WH5	11	FRST	5	1E+30	737.2	240.9	142	70.81	63.77	65.67	0	0	0	0	0	0	0	0	0	0	0	0	0				
12102920	12	FRST	1	1	0.2063	0.1048	0.03514	0.00701	0.00317	0.00164	0.00046	0.00018	0.00008	0.00002	0	0	0	0	0	0	0	0	0	77.88	0	1.564	3.653
12102920	12	FRST	2	1367000	282100	143200	48060	9587	4346	2250	642	254	110	41	0	0	0	0	0	0	0	0	0				
12102920	12	FRST	3	1	361	342	237	61	36	21	10	4	1	1	0	0	0	0	0	0	0	0	0				
12102920	12	FRST	4	1367000	781.4	418.9	202.8	157.2	120.7	107.1	64.2	63.5	110	41	0	0	0	0	0	0	0	0	0				
12102920	12	FRST	5	1E+30	861	391.3	163.4	104.9	90.46	71.75	68.47	70.59	0	0	0	0	0	0	0	0	0	0	0				
WH4	13	FRST	1	1	0.2239	0.1281	0.04977	0.01201	0.00667	0.00352	0.00121	0.00043	0.00019	0.00009	0.00006	0.00002	0	0	0	0	0	0	0	97.56	0	1.919	4.504
WH4	13	FRST	2	1367000	306200	175200	68050	16420	9124	4818	1656	595	270	135	90	35	0	0	0	0	0	0	0				
WH4	13	FRST	3	1	346	359	276	100	63	41	19	9	4	2	1	1	0	0	0	0	0	0	0				
WH4	13	FRST	4	1367000	885	488	246.6	164.2	144.8	117.5	87.16	66.11	67.5	67.5	90	35	0	0	0	0	0	0	0				
WH4	13	FRST	5	1E+30	932.9	465.8	200	137.7	103.7	88.08	74.27	69.25	72.97	57.5	0	0	0	0	0	0	0	0	0				
WH3	14	FRST	1	1	0.08377	0.01777	0.00233	0.00023	0.00012	0.00007	0.00002	0.00000	0	0	0	0	0	0	0	0	0	0	0	50.54	0	0.5338	1.35
WH3	14	FRST	2	1367000	114500	24300	3194	318	169	101	30	2	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	FRST	3	1	559	427	157	37	19	17	6	2	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	FRST	4	1367000	204.9	56.91	20.34	8.595	8.895	5.941	5	1	0	0	0	0	0	0	0	0	0	0	0				
WH3	14	FRST	5	1E+30	240.8	98.45	41.48	16.07	10.37	4.359	2.769	0	0	0	0	0	0	0	0	0	0	0	0				
WH2	15	FRST	1	1	0.7553	0.3451	0.1755	0.05539	0.03375	0.01987	0.00803	0.00339	0.00156	0.00083	0.00041	0.00024	0.00017	0.00007	0.00001	0	0	0	0	160.1	0	6.216	7.659
WH2	15	FRST	2	1367000	1033000	471900	240000	75740	46140	27180	10980	4646	2133	1146	569	332	239	97	22	0	0	0	0				
WH2	15	FRST	3	1	114	261	365	301	244	166	77	49	25	19	10	7	4	2	1	0	0	0	0				
WH2	15	FRST	4	1367000	9060	1808	657.5	251.6	189.1	163.7	142.6	94.82	85.32	60.32	56.9	47.43	59.75	48.5	22	0	0	0	0				
WH2	15	FRST	5	1E+30	12120	3371	931.5	257	179.7	161.1	125.7	89.65	79.27	69.54	72.03	67.79	70.47	45.5	0	0	0	0	0				
WH1	16	FRST	1	1	0.7724	0.3553	0.1854	0.06349	0.0397	0.02429	0.00992	0.00474	0.00225	0.00120	0.00068	0.00036	0.00022	0.00009	0.00002	0	0	0	0	172.3	0.05729	6.546	8.252
WH1	16	FRST	2	1367000	1056000	485900	253500	86810	54280	33210	13570	6494	3085	1649	931	493	302	124	41	0	0	0	0				
WH1	16	FRST	3	1	101	257	372	314	252	177	90	55	31	19	17	8	5	2	2	0	0	0	0				
WH1	16	FRST	4	1367000	10460	1891	681.5	276.5	215.4	187.6	150.8	118.1	99.52	86.79	54.76	61.62	60.4	62	20.5	0	0	0	0				
WH1	16	FRST	5	1E+30	11760	3592	965	295.3	186.6	171	131.9	98.37	81.35	74.9	66.37	71.82	70.55	51	16.5	0	0	0	0				

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TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																						
L5	10	FH	2	1367000	61030	11100	2073	187	52	9	0	0	0	0	0	0	0	0	0	0	0	0	0			
L5	10	FH	3	1	2679	1415	397	57	27	5	0	0	0	0	0	0	0	0	0	0	0	0	0			
L5	10	FH	4	1367000	22.78	7.847	5.222	3.281	1.926	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	FH	1	1	0.04047	0.00579	0.00107	0.00007	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	30.93	0	0.37
PNC D LEON	1	FH	2	1367000	55350	7918	1466	105	22	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	FH	3	1	1248	446	116	23	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	FH	4	1367000	44.35	17.75	12.64	4.565	2.444	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	FH	1	1	0.07979	0.01586	0.00324	0.00037	0.00014	0.00005	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	43.11	0.1462	0.7014
L4	2	FH	2	1367000	109100	21690	4434	508	199	75	4	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	FH	3	1	2344	1110	374	72	32	16	2	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	FH	4	1367000	46.55	19.54	11.86	7.056	6.219	4.687	2	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	FH	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.906	0	0.07349
M1	7	FH	2	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	FH	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	FH	4	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	FH	1	1	0.02021	0.00410	0.00046	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19.94	0	0.1145
M3	8	FH	2	1367000	27630	5618	638	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	FH	3	1	202	77	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	FH	4	1367000	136.8	72.96	53.17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L7	9	FH	1	1	0.08409	0.02891	0.00751	0.00101	0.00045	0.00021	0.00004	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	63.27	0	0.6007
L7	9	FH	2	1367000	115000	39530	10280	1393	620	292	68	7	2	0	0	0	0	0	0	0	0	0	0			
L7	9	FH	3	1	3131	2481	1114	240	132	61	26	5	1	0	0	0	0	0	0	0	0	0	0			
L7	9	FH	4	1367000	36.73	15.93	9.226	5.804	4.697	4.787	2.615	1.4	2	0	0	0	0	0	0	0	0	0	0			
L6	3	FH	1	1	0.1322	0.03883	0.00817	0.00001	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	32.99	0	0.9984
L6	3	FH	2	1367000	180800	53100	11180	24	16	8	0	0	0	0	0	0	0	0	0	0	0	0	0			
L6	3	FH	3	1	472	299	46	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
L6	3	FH	4	1367000	383	177.6	243	24	16	8	0	0	0	0	0	0	0	0	0	0	0	0	0			
L3	4	FH	1	1	0.2237	0.07137	0.02604	0.00160	0.00069	0.00028	0.00004	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	62.55	0.2841	1.747
L3	4	FH	2	1367000	305900	97590	35600	2192	948	394	63	4	2	0	0	0	0	0	0	0	0	0	0			
L3	4	FH	3	1	2390	2417	1461	376	195	100	33	3	1	0	0	0	0	0	0	0	0	0	0			
L3	4	FH	4	1367000	128	40.38	24.37	5.83	4.862	3.94	1.909	1.333	2	0	0	0	0	0	0	0	0	0	0			
L2	5	FH	1	1	0.4979	0.1578	0.05692	0.01029	0.00511	0.00284	0.00110	0.00047	0.00019	0.00007	0.00002	0.00000	0.00000	0	0	0	0	0	0	116.6	1.128	3.442
L2	5	FH	2	1367000	680900	215700	77840	14070	6988	3890	1516	647	273	109	38	12	3	0	0	0	0	0	0			
L2	5	FH	3	1	1064	2619	2301	1186	777	478	224	113	59	29	16	5	2	0	0	0	0	0	0			
L2	5	FH	4	1367000	639.9	82.37	33.83	11.86	8.994	8.138	6.768	5.726	4.627	3.759	2.375	2.4	1.5	0	0	0	0	0	0			
L1	6	FH	1	1	0.563	0.1683	0.0622	0.01216	0.00623	0.00350	0.00141	0.00062	0.00027	0.00011	0.00004	0.00001	0.00000	0	0	0	0	0	0	121.1	1.247	3.671
L1	6	FH	2	1367000	769900	230100	85050	16620	8530	4790	1932	860	371	160	64	23	8	0	0	0	0	0	0			
L1	6	FH	3	1	823	2532	2321	1254	859	548	259	135	67	42	17	7	4	0	0	0	0	0	0			
L1	6	FH	4	1367000	935.5	90.88	36.64	13.26	9.93	8.741	7.459	6.37	5.537	3.81	3.765	3.286	2	0	0	0	0	0	0			
L5	10	1987	1	1	0.04428	0.00771	0.00146	0.00013	0.00003	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	40.19	0	0.3669
L5	10	1987	2	1367000	60550	10540	1996	190	52	10	1	0	0	0	0	0	0	0	0	0	0	0	0			
L5	10	1987	3	1	2611	1355	381	58	26	5	1	0	0	0	0	0	0	0	0	0	0	0	0			
L5	10	1987	4	1367000	23.19	7.782	5.239	3.276	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	1987	1	1	0.04017	0.00557	0.00104	0.00007	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	31.11	0	0.3706

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TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																						
PNC D LEON	1	1987	2	1367000	54930	7618	1428	104	23	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	1987	3	1	1202	425	116	24	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	1987	4	1367000	45.7	17.92	12.31	4.333	2.556	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	1987	1	1	0.07645	0.01355	0.00265	0.00028	0.00010	0.00004	0	0	0	0	0	0	0	0	0	0	0	0	0	39.88	0.1569	0.6926
L4	2	1987	2	1367000	104500	18530	3628	391	146	58	0	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	1987	3	1	2112	928	302	50	27	12	0	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	1987	4	1367000	49.5	19.97	12.01	7.82	5.407	4.833	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	1987	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.715	0	0.06584
M1	7	1987	2	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	1987	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	1987	4	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	1987	1	1	0.00987	0.00169	0.00017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16.25	0	0.05863
M3	8	1987	2	1367000	13510	2315	241	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	1987	3	1	84	23	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	1987	4	1367000	160.8	100.7	80.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L7	9	1987	1	1	0.07467	0.0218	0.00492	0.00066	0.00028	0.00013	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	58.68	0	0.5312
L7	9	1987	2	1367000	102100	29810	6731	904	390	181	27	4	0	0	0	0	0	0	0	0	0	0	0			
L7	9	1987	3	1	3101	2292	848	171	90	45	13	3	0	0	0	0	0	0	0	0	0	0	0			
L7	9	1987	4	1367000	32.93	13.01	7.937	5.287	4.333	4.022	2.077	1.333	0	0	0	0	0	0	0	0	0	0	0			
L6	3	1987	1	1	0.1035	0.02246	0.00329	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15.06	0	0.8038
L6	3	1987	2	1367000	141500	30710	4508	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L6	3	1987	3	1	382	183	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L6	3	1987	4	1367000	370.4	167.8	237.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L3	4	1987	1	1	0.1994	0.05131	0.01479	0.00093	0.00038	0.00013	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	55.56	0.2821	1.517
L3	4	1987	2	1367000	272700	70170	20220	1284	521	189	17	2	0	0	0	0	0	0	0	0	0	0	0			
L3	4	1987	3	1	2542	2225	1179	234	111	59	9	1	0	0	0	0	0	0	0	0	0	0	0			
L3	4	1987	4	1367000	107.3	31.54	17.15	5.487	4.694	3.203	1.889	2	0	0	0	0	0	0	0	0	0	0	0			
L2	5	1987	1	1	0.4888	0.1392	0.04105	0.00641	0.00307	0.00172	0.00064	0.00024	0.00008	0.00002	0.00000	0.00000	0.00000	0	0	0	0	0	0	100.9	1.164	3.192
L2	5	1987	2	1367000	668500	190400	56130	8768	4204	2361	881	339	120	41	11	1	1	0	0	0	0	0	0			
L2	5	1987	3	1	1113	2537	1967	787	462	280	130	65	33	15	4	1	1	0	0	0	0	0	0			
L2	5	1987	4	1367000	600.6	75.05	28.54	11.14	9.1	8.432	6.777	5.215	3.636	2.733	2.75	1	1	0	0	0	0	0	0			
L1	6	1987	1	1	0.5754	0.1497	0.04434	0.00713	0.00342	0.00191	0.00071	0.00029	0.00009	0.00003	0.00001	0.00000	0	0	0	0	0	0	0	98.8	1.298	3.404
L1	6	1987	2	1367000	786800	204700	60630	9756	4679	2615	984	399	133	48	14	2	0	0	0	0	0	0	0			
L1	6	1987	3	1	798	2422	1898	805	453	294	132	61	31	16	4	1	0	0	0	0	0	0	0			
L1	6	1987	4	1367000	986	84.52	31.95	12.12	10.33	8.895	7.455	6.541	4.29	3	3.5	2	0	0	0	0	0	0	0			
J8	1	1987	1	1	0.00259	0.00031	0.00002	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.07	0	0.1044
J8	1	1987	2	1367000	3552	425	33	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J8	1	1987	3	1	439	116	13	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J8	1	1987	4	1367000	8.091	3.664	2.538	1.5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	1987	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2933	0	0.00025
J7	2	1987	2	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	1987	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	1987	4	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J6	3	1987	1	1	0.01761	0.00192	0.00027	0.00000	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	34.23	0	0.2083

17-May-90

TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
J6	3	1987	2	1367000	24080	2636	370	12	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
J6	3	1987	3	1	1581	386	86	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
J6	3	1987	4	1367000	15.23	6.829	4.302	4	2.5	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
J2	4	1987	1	1	0.4675	0.08739	0.00586	0.00009	0.00006	0.00002	0	0	0	0	0	0	0	0	0	0	0	0	0	33.34	0.00291	2.471
J2	4	1987	2	1367000	639200	119500	8024	134	88	28	0	0	0	0	0	0	0	0	0	0	0	0	0			
J2	4	1987	3	1	507	426	83	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
J2	4	1987	4	1367000	1261	280.5	96.67	44.67	44	14	0	0	0	0	0	0	0	0	0	0	0	0	0			
J3	5	1987	1	1	0.4895	0.114	0.00939	0.00027	0.00008	0.00005	0	0	0	0	0	0	0	0	0	0	0	0	0	38.15	0.05541	2.633
J3	5	1987	2	1367000	669400	155800	12840	374	116	75	0	0	0	0	0	0	0	0	0	0	0	0	0			
J3	5	1987	3	1	912	1130	349	34	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
J3	5	1987	4	1367000	734	137.9	36.79	11	11.6	37.5	0	0	0	0	0	0	0	0	0	0	0	0	0			
J5	6	1987	1	1	0.1218	0.03425	0.00891	0.00192	0.00113	0.00072	0.00029	0.00012	0.00004	0.00001	0.00000	0.00000	0	0	0	0	0	0	0	98.47	0	0.8394
J5	6	1987	2	1367000	166500	46840	12190	2629	1549	997	404	166	61	15	3	1	0	0	0	0	0	0	0			
J5	6	1987	3	1	3231	2639	1445	443	275	184	96	49	25	7	1	1	0	0	0	0	0	0	0			
J5	6	1987	4	1367000	51.55	17.75	8.433	5.935	5.633	5.418	4.208	3.388	2.44	2.143	3	1	0	0	0	0	0	0	0			
J4	7	1987	1	1	0.1275	0.03762	0.01014	0.00215	0.00124	0.00080	0.00033	0.00014	0.00005	0.00001	0.00000	0.00000	0	0	0	0	0	0	0	99.67	0	0.881
J4	7	1987	2	1367000	174400	51440	13870	2944	1707	1096	462	195	76	19	4	1	0	0	0	0	0	0	0			
J4	7	1987	3	1	3071	2530	1466	454	291	190	94	52	22	7	2	1	0	0	0	0	0	0	0			
J4	7	1987	4	1367000	56.79	20.33	9.458	6.485	5.866	5.768	4.915	3.75	3.455	2.714	2	1	0	0	0	0	0	0	0			
J1	8	1987	1	1	0.7087	0.3228	0.1074	0.01987	0.01068	0.0062	0.00254	0.00130	0.00074	0.00044	0.00025	0.00015	0.00008	0.00001	0.00000	0	0	0	0	169.6	0.5237	4.952
J1	8	1987	2	1367000	969100	441400	146900	27170	14610	8478	3474	1785	1025	609	352	215	113	17	2	0	0	0	0			
J1	8	1987	3	1	584	1771	2370	1581	1140	777	389	229	144	85	61	51	26	5	1	0	0	0	0			
J1	8	1987	4	1367000	1659	249.3	61.98	17.19	12.81	10.91	8.931	7.795	7.118	7.165	5.77	4.216	4.346	3.4	2	0	0	0	0			
J8	1	FH	1	1	0.03936	0.01298	0.00285	0.00028	0.00010	0.00003	0.00000	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	61.6	0	0.3258
J8	1	FH	2	1367000	53830	17750	3903	390	144	54	6	3	1	0	0	0	0	0	0	0	0	0	0			
J8	1	FH	3	1	3329	2253	782	121	54	28	3	2	1	0	0	0	0	0	0	0	0	0	0			
J8	1	FH	4	1367000	16.17	7.881	4.991	3.223	2.667	1.929	2	1.5	1	0	0	0	0	0	0	0	0	0	0			
J7	2	FH	1	1	0.00347	0.00007	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.22	0	0.06505
J7	2	FH	2	1367000	4748	101	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	FH	3	1	751	39	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	FH	4	1367000	6.322	2.59	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J6	3	FH	1	1	0.07348	0.03057	0.01074	0.00194	0.00094	0.00046	0.00012	0.00003	0.00000	0.00000	0.00000	0.00000	0	0	0	0	0	0	0	96.59	0	0.5954
J6	3	FH	2	1367000	100500	41800	14680	2664	1288	636	173	46	13	5	3	1	0	0	0	0	0	0	0			
J6	3	FH	3	1	3692	3188	1815	490	266	159	52	22	6	3	2	1	0	0	0	0	0	0	0			
J6	3	FH	4	1367000	27.22	13.11	8.088	5.437	4.842	4	3.327	2.091	2.167	1.667	1.5	1	0	0	0	0	0	0	0			
J2	4	FH	1	1	0.503	0.1277	0.02453	0.00131	0.00079	0.00052	0.00019	0.00003	0	0	0	0	0	0	0	0	0	0	0	56.62	0.00286	2.857
J2	4	FH	2	1367000	687800	174600	33550	1798	1088	724	270	43	0	0	0	0	0	0	0	0	0	0	0			
J2	4	FH	3	1	626	909	453	53	34	24	18	4	0	0	0	0	0	0	0	0	0	0	0			
J2	4	FH	4	1367000	1099	192.1	74.05	33.92	32	30.17	15	10.75	0	0	0	0	0	0	0	0	0	0	0			
J3	5	FH	1	1	0.5197	0.1515	0.03022	0.00212	0.00096	0.00062	0.00027	0.00009	0.00000	0	0	0	0	0	0	0	0	0	0	60.98	0.05666	3.02
J3	5	FH	2	1367000	710700	207200	41320	2903	1318	857	376	125	5	0	0	0	0	0	0	0	0	0	0			
J3	5	FH	3	1	664	1174	589	101	42	28	19	7	3	0	0	0	0	0	0	0	0	0	0			
J3	5	FH	4	1367000	1070	176.5	70.15	28.74	31.38	30.61	19.79	17.86	1.667	0	0	0	0	0	0	0	0	0	0			
J5	6	FH	1	1	0.1352	0.04642	0.01489	0.00325	0.00189	0.00117	0.00052	0.00023	0.00010	0.00003	0.00001	0.00000	0.00000	0	0	0	0	0	0	106.7	0	0.9852

17-May-90

TABLE C.3

HSPF DURATION DATA

BASIN: LOWER PUGET SOUND

SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987

TIMESTEP: 15 MINUTES

NUMBER OF TIMESTEPS IN ANALYSIS: 1367424

NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO

FRST= Pre-developed land use (forested)

1987= 1987 (Calibration land use).

FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
J5	6	FH	2	1367000	184900	63480	20360	4454	2593	1612	714	322	145	53	16	4	2	0	0	0	0	0	0			
J5	6	FH	3	1	3333	3077	2009	706	448	290	150	77	40	25	8	2	2	0	0	0	0	0	0			
J5	6	FH	4	1367000	55.47	20.63	10.14	6.309	5.788	5.559	4.76	4.182	3.625	2.12	2	2	1	0	0	0	0	0	0			
J4	7	FH	1	1	0.1396	0.04907	0.01631	0.00361	0.00209	0.00130	0.00059	0.00026	0.00011	0.00005	0.00001	0.00000	0.00000	0	0	0	0	0	0	108.2	0	1.025
J4	7	FH	2	1367000	190900	67100	22300	4946	2868	1787	812	363	162	70	21	5	2	0	0	0	0	0	0			
J4	7	FH	3	1	3197	2937	2029	724	449	294	151	76	46	29	9	2	2	0	0	0	0	0	0			
J4	7	FH	4	1367000	59.73	22.85	10.99	6.831	6.388	6.078	5.377	4.776	3.522	2.414	2.333	2.5	1	0	0	0	0	0	0			
J1	8	FH	1	1	0.7089	0.3369	0.1284	0.03472	0.02047	0.01281	0.00558	0.00284	0.00163	0.00101	0.00066	0.00044	0.00032	0.00010	0.00002	0.00000	0	0	0	195	0.5069	5.463
J1	8	FH	2	1367000	969300	460700	175600	47470	27980	17520	7632	3883	2238	1394	904	606	440	144	35	5	0	0	0			
J1	8	FH	3	1	496	1617	2511	2006	1577	1216	683	396	248	167	115	76	57	29	10	2	0	0	0			
J1	8	FH	4	1367000	1954	284.9	69.94	23.67	17.75	14.41	11.17	9.806	9.024	8.347	7.861	7.974	7.719	4.966	3.5	2.5	0	0	0			
R6	4	1987	1	1	0.00703	0.00040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.149	0	0.1537
R6	4	1987	2	1367000	9614	551	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R6	4	1987	3	1	263	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R6	4	1987	4	1367000	36.56	22.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	1987	1	1	0.04345	0.00655	0.00107	0.00005	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28.16	0	0.3505
R5	5	1987	2	1367000	59420	8959	1471	77	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	1987	3	1	2646	1109	267	32	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	1987	4	1367000	22.46	8.078	5.509	2.406	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R4	6	1987	1	1	0.1369	0.02296	0.00425	0.00082	0.00045	0.00024	0.00005	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	67.62	0.4916	1.259
R4	6	1987	2	1367000	187100	31390	5815	1130	619	336	77	9	2	0	0	0	0	0	0	0	0	0	0			
R4	6	1987	3	1	2300	1305	713	186	119	74	25	3	1	0	0	0	0	0	0	0	0	0	0			
R4	6	1987	4	1367000	81.37	24.06	8.156	6.075	5.202	4.541	3.08	3	2	0	0	0	0	0	0	0	0	0	0			
R6	4	FH	1	1	0.01048	0.00060	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.849	0	0.1715
R6	4	FH	2	1367000	14320	831	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R6	4	FH	3	1	369	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R6	4	FH	4	1367000	38.82	27.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	FH	1	1	0.05177	0.00976	0.0016	0.00010	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	31.29	0	0.3853
R5	5	FH	2	1367000	70790	13360	2188	150	26	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	FH	3	1	2936	1540	385	47	14	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	FH	4	1367000	24.11	8.673	5.683	3.191	1.857	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
R4	6	FH	1	1	0.1485	0.03459	0.00708	0.00116	0.00063	0.00035	0.00009	0.00001	0.00000	0.00000	0	0	0	0	0	0	0	0	0	72.15	0.4406	1.303
R4	6	FH	2	1367000	203100	47300	9688	1594	864	479	128	25	3	1	0	0	0	0	0	0	0	0	0			
R4	6	FH	3	1	2338	1576	903	235	143	85	43	13	2	1	0	0	0	0	0	0	0	0	0			
R4	6	FH	4	1367000	86.86	30.01	10.73	6.783	6.042	5.635	2.977	1.923	1.5	1	0	0	0	0	0	0	0	0	0			
R3	1	1987	1	1	0.02239	0.00103	0.00009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.48	0.277	0.5202
R3	1	1987	2	1367000	30610	1414	128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R3	1	1987	3	1	72	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R3	1	1987	4	1367000	425.1	176.7	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	1987	1	1	0.05333	0.00557	0.00071	0.00004	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	31.89	0.277	0.6835
R2	2	1987	2	1367000	72920	7625	979	55	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	1987	3	1	3296	1048	216	32	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	1987	4	1367000	22.12	7.276	4.532	1.719	1.25	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
R1	3	1987	1	1	0.1078	0.02886	0.00573	0.00116	0.00061	0.00033	0.00010	0.00003	0.00001	0.00000	0.00000	0	0	0	0	0	0	0	0	88.36	0.277	0.9934

17-May-90

TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
R1	3	1987	2	1367000	147300	39470	7838	1587	836	459	143	45	15	3	2	0	0	0	0	0	0	0	0			
R1	3	1987	3	1	3628	2618	1262	444	270	175	77	31	11	3	2	0	0	0	0	0	0	0	0			
R1	3	1987	4	1367000	40.61	15.08	6.211	3.574	3.096	2.623	1.857	1.452	1.364	1	1	0	0	0	0	0	0	0	0			
R3	1	FH	1	1	0.08419	0.00734	0.00029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19.66	0.3195	0.7591
R3	1	FH	2	1367000	115100	10040	408	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R3	1	FH	3	1	191	57	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R3	1	FH	4	1367000	602.8	176.1	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	FH	1	1	0.1331	0.02333	0.00238	0.00016	0.00005	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	37.84	0.3195	1.004
R2	2	FH	2	1367000	182000	31900	3260	228	70	14	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	FH	3	1	3410	2075	576	74	30	11	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	FH	4	1367000	53.38	15.37	5.66	3.081	2.333	1.273	0	0	0	0	0	0	0	0	0	0	0	0	0			
R1	3	FH	1	1	0.1858	0.06315	0.01697	0.00356	0.00187	0.00111	0.00041	0.00015	0.00005	0.00002	0.00001	0.00000	0.00000	0	0	0	0	0	0	109.4	0.3195	1.47
R1	3	FH	2	1367000	254100	86350	23200	4876	2565	1524	563	214	79	30	17	7	3	0	0	0	0	0	0			
R1	3	FH	3	1	3137	3308	2385	1208	719	485	216	112	51	22	12	6	3	0	0	0	0	0	0			
R1	3	FH	4	1367000	80.99	26.1	9.728	4.036	3.567	3.142	2.606	1.911	1.549	1.364	1.417	1.167	1	0	0	0	0	0	0			
W2	1	1987	1	1	0.03888	0.00577	0.00128	0.00015	0.00005	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	43.87	0.0391	0.4368
W2	1	1987	2	1367000	53160	7895	1755	217	72	17	2	0	0	0	0	0	0	0	0	0	0	0	0			
W2	1	1987	3	1	3503	1457	440	87	38	11	1	0	0	0	0	0	0	0	0	0	0	0	0			
W2	1	1987	4	1367000	15.18	5.419	3.989	2.494	1.895	1.545	2	0	0	0	0	0	0	0	0	0	0	0	0			
W1	2	1987	1	1	0.1118	0.02648	0.00595	0.00119	0.00067	0.00037	0.00011	0.00003	0.00000	0.00000	0	0	0	0	0	0	0	0	0	79.93	0.08605	0.8994
W1	2	1987	2	1367000	152800	36210	8146	1638	926	510	161	49	6	3	0	0	0	0	0	0	0	0	0			
W1	2	1987	3	1	3341	2510	1274	359	217	140	55	28	4	2	0	0	0	0	0	0	0	0	0			
W1	2	1987	4	1367000	45.74	14.43	6.394	4.563	4.267	3.643	2.927	1.75	1.5	1.5	0	0	0	0	0	0	0	0	0			
W2	1	FH	1	1	0.05249	0.01332	0.00304	0.00042	0.00018	0.00007	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	52.33	0.02752	0.4805
W2	1	FH	2	1367000	71780	18210	4167	581	253	98	14	2	0	0	0	0	0	0	0	0	0	0	0			
W2	1	FH	3	1	4523	2654	1011	187	105	48	11	1	0	0	0	0	0	0	0	0	0	0	0			
W2	1	FH	4	1367000	15.87	6.862	4.122	3.107	2.41	2.042	1.273	2	0	0	0	0	0	0	0	0	0	0	0			
W1	2	FH	1	1	0.1161	0.03953	0.01284	0.00281	0.00159	0.00098	0.00038	0.00015	0.00006	0.00001	0.00000	0.00000	0.00000	0	0	0	0	0	0	102.1	0.06468	0.9908
W1	2	FH	2	1367000	158700	54050	17560	3852	2176	1344	527	214	84	26	9	4	1	0	0	0	0	0	0			
W1	2	FH	3	1	3859	3583	2347	838	505	335	161	80	40	17	7	2	1	0	0	0	0	0	0			
W1	2	FH	4	1367000	41.13	15.08	7.481	4.597	4.309	4.012	3.273	2.675	2.1	1.529	1.286	2	1	0	0	0	0	0	0			
S9	1	1987	1	1	0.1323	0.0405	0.00943	0.00126	0.00058	0.00029	0.00003	0.00000	0	0	0	0	0	0	0	0	0	0	0	52.01	0.1017	1.059
S9	1	1987	2	1367000	180900	55380	12890	1732	800	405	52	2	0	0	0	0	0	0	0	0	0	0	0			
S9	1	1987	3	1	3057	2205	906	175	85	52	12	1	0	0	0	0	0	0	0	0	0	0	0			
S9	1	1987	4	1367000	59.18	25.11	14.23	9.897	9.412	7.788	4.333	2	0	0	0	0	0	0	0	0	0	0	0			
S8	2	1987	1	1	0.352	0.08943	0.02667	0.00331	0.00143	0.00073	0.00018	0.00000	0	0	0	0	0	0	0	0	0	0	0	50.41	0.00220	2.258
S8	2	1987	2	1367000	481400	122300	36470	4531	1958	1004	250	12	0	0	0	0	0	0	0	0	0	0	0			
S8	2	1987	3	1	525	462	282	57	26	14	6	1	0	0	0	0	0	0	0	0	0	0	0			
S8	2	1987	4	1367000	916.9	264.7	129.3	79.49	75.31	71.71	41.67	12	0	0	0	0	0	0	0	0	0	0	0			
S3	3	1987	1	1	0.4059	0.1504	0.04306	0.00722	0.00337	0.00175	0.00059	0.00018	0.00003	0.00000	0	0	0	0	0	0	0	0	0	70.38	0.07587	2.767
S3	3	1987	2	1367000	555100	205700	58880	9873	4614	2396	809	248	52	2	0	0	0	0	0	0	0	0	0			
S3	3	1987	3	1	1164	2102	1206	356	206	118	49	25	8	1	0	0	0	0	0	0	0	0	0			
S3	3	1987	4	1367000	476.9	97.84	48.82	27.73	22.4	20.31	16.51	9.92	6.5	2	0	0	0	0	0	0	0	0	0			
S6	5	1987	1	1	0.01195	0.00078	0.00002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.18	0.02178	0.3045

17-May-90

TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
S6	5	1987	2	1367000	16340	1075	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S6	5	1987	3	1	255	27	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S6	5	1987	4	1367000	64.09	39.81	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S5	6	1987	1	1	0.1072	0.01867	0.00325	0.00057	0.00028	0.00013	0.00002	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	62.71	0.0664	0.8205
S5	6	1987	2	1367000	146600	25530	4456	783	392	181	32	3	1	0	0	0	0	0	0	0	0	0	0			
S5	6	1987	3	1	2626	2180	831	195	114	65	19	2	1	0	0	0	0	0	0	0	0	0	0			
S5	6	1987	4	1367000	55.83	11.71	5.362	4.015	3.439	2.785	1.684	1.5	1	0	0	0	0	0	0	0	0	0	0			
S7 CLSD DP	4	1987	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
S7 CLSD DP	4	1987	2	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx			
S7 CLSD DP	4	1987	3	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx			
S7 CLSD DP	4	1987	4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx			
S4	7	1987	1	1	0.1397	0.0312	0.00593	0.00108	0.00062	0.00034	0.00010	0.00002	0.00000	0.00000	0	0	0	0	0	0	0	0	0	78.69	0.08492	1.012
S4	7	1987	2	1367000	191100	42660	8114	1486	855	473	149	41	5	3	0	0	0	0	0	0	0	0	0			
S4	7	1987	3	1	2603	2715	1236	338	208	133	57	23	3	2	0	0	0	0	0	0	0	0	0			
S4	7	1987	4	1367000	73.4	15.71	6.565	4.396	4.111	3.556	2.614	1.783	1.667	1.5	0	0	0	0	0	0	0	0	0			
S2	8	1987	1	1	0.5027	0.2541	0.1023	0.02902	0.01703	0.01044	0.00433	0.00217	0.00122	0.00071	0.00042	0.00026	0.00017	0.00003	0.00000	0	0	0	0	174.7	0.2999	4.308
S2	8	1987	2	1367000	687400	347500	139800	39680	23280	14280	5923	2977	1681	978	583	361	236	48	4	0	0	0	0			
S2	8	1987	3	1	1008	1797	2394	1560	1258	987	563	344	209	153	102	69	53	20	3	0	0	0	0			
S2	8	1987	4	1367000	681.9	193.4	58.41	25.44	18.51	14.47	10.52	8.654	8.043	6.392	5.716	5.232	4.453	2.4	1.333	0	0	0	0			
S1	9	1987	1	1	0.5082	0.2574	0.1047	0.03028	0.01782	0.011	0.00460	0.00232	0.00129	0.00075	0.00045	0.00028	0.00018	0.00004	0.00000	0.00000	0	0	0	179.7	0.3128	4.382
S1	9	1987	2	1367000	695000	352000	143200	41400	24370	15040	6297	3174	1772	1037	621	385	251	56	4	1	0	0	0			
S1	9	1987	3	1	968	1766	2328	1504	1235	964	560	343	205	147	99	66	56	24	3	1	0	0	0			
S1	9	1987	4	1367000	717.9	199.3	61.5	27.53	19.73	15.6	11.24	9.254	8.644	7.054	6.273	5.833	4.482	2.333	1.333	1	0	0	0			
S9	1	FH	1	1	0.132	0.05524	0.02058	0.00414	0.00215	0.00120	0.00039	0.00011	0.00004	0.00000	0	0	0	0	0	0	0	0	0	78.45	0.07431	1.183
S9	1	FH	2	1367000	180600	75540	28140	5674	2948	1647	537	157	64	12	0	0	0	0	0	0	0	0	0			
S9	1	FH	3	1	3483	3036	1813	529	312	193	68	30	16	5	0	0	0	0	0	0	0	0	0			
S9	1	FH	4	1367000	51.84	24.88	15.52	10.73	9.449	8.534	7.897	5.233	4	2.4	0	0	0	0	0	0	0	0	0			
S8	2	FH	1	1	0.3705	0.1067	0.0394	0.00670	0.00318	0.00161	0.00063	0.00005	0	0	0	0	0	0	0	0	0	0	0	58.35	0.00214	2.48
S8	2	FH	2	1367000	506600	145800	53880	9174	4354	2210	869	79	0	0	0	0	0	0	0	0	0	0	0			
S8	2	FH	3	1	675	670	498	132	70	37	15	1	0	0	0	0	0	0	0	0	0	0	0			
S8	2	FH	4	1367000	750.5	217.7	108.2	69.5	62.2	59.73	57.93	79	0	0	0	0	0	0	0	0	0	0	0			
S3	3	FH	1	1	0.4103	0.1679	0.06079	0.01448	0.00758	0.00421	0.00158	0.00064	0.00025	0.00008	0.00001	0.00000	0	0	0	0	0	0	0	92.27	0.05461	3.052
S3	3	FH	2	1367000	561000	229500	83120	19810	10370	5757	2170	883	346	111	17	1	0	0	0	0	0	0	0			
S3	3	FH	3	1	1217	2656	2101	845	577	354	147	82	40	27	7	1	0	0	0	0	0	0	0			
S3	3	FH	4	1367000	461	86.42	39.56	23.44	17.98	16.26	14.76	10.77	8.65	4.111	2.429	1	0	0	0	0	0	0	0			
S6	5	FH	1	1	0.02101	0.00160	0.00012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13.14	0.01565	0.3335
S6	5	FH	2	1367000	28720	2190	174	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S6	5	FH	3	1	458	63	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S6	5	FH	4	1367000	62.71	34.76	19.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S5	6	FH	1	1	0.1178	0.02821	0.00595	0.00109	0.00060	0.00033	0.00009	0.00002	0.00000	0.00000	0	0	0	0	0	0	0	0	0	72.7	0.05303	0.8857
S5	6	FH	2	1367000	161100	38570	8147	1500	827	453	131	30	6	1	0	0	0	0	0	0	0	0	0			
S5	6	FH	3	1	3117	2981	1355	343	211	130	56	18	4	1	0	0	0	0	0	0	0	0	0			
S5	6	FH	4	1367000	51.69	12.94	6.013	4.373	3.919	3.485	2.339	1.667	1.5	1	0	0	0	0	0	0	0	0	0			
S7	4	FH	1	1	0.05965	0.02471	0.00980	0.00336	0.00026	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29.35	0	0.7634

17-May-90

TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
S7	4	FH	2	1367000	81570	33790	13410	4601	367	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S7	4	FH	3	1	2008	1918	1143	359	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S7	4	FH	4	1367000	40.62	17.62	11.73	12.82	22.94	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S4	7	FH	1	1	0.2236	0.07781	0.03011	0.00952	0.00642	0.00467	0.00196	0.00082	0.00037	0.00016	0.00005	0.00001	0.00000	0	0	0	0	0	0	119	0.06911	1.859
S4	7	FH	2	1367000	305800	106400	41170	13030	8790	6390	2690	1124	510	221	77	24	6	0	0	0	0	0	0			
S4	7	FH	3	1	2267	3225	2526	1249	936	698	467	235	127	68	38	14	5	0	0	0	0	0	0			
S4	7	FH	4	1367000	134.9	32.99	16.3	10.43	9.391	9.155	5.76	4.783	4.016	3.25	2.026	1.714	1.2	0	0	0	0	0	0			
S2	8	FH	1	1	0.5454	0.2976	0.1326	0.05253	0.03628	0.02572	0.014	0.00825	0.00521	0.00344	0.00231	0.00157	0.00106	0.00041	0.00018	0.00005	0.00000	0	0	236.1	0.2625	5.449
S2	8	FH	2	1367000	745800	407000	181400	71830	49610	35160	19140	11290	7137	4716	3165	2157	1450	569	247	71	10	0	0			
S2	8	FH	3	1	808	1726	2736	2369	2123	1882	1307	967	688	518	384	279	204	99	60	30	8	0	0			
S2	8	FH	4	1367000	923	235.8	66.29	30.32	23.37	18.68	14.64	11.67	10.37	9.104	8.242	7.731	7.108	5.747	4.117	2.367	1.25	0	0			
S1	9	FH	1	1	0.5495	0.3009	0.1348	0.05396	0.03714	0.02643	0.01444	0.00850	0.00539	0.00355	0.00238	0.00164	0.00110	0.00043	0.00019	0.00005	0.00001	0	0	243	0.2745	5.527
S1	9	FH	2	1367000	751500	411400	184300	73780	50790	36140	19750	11630	7383	4856	3255	2244	1512	597	262	82	14	0	0			
S1	9	FH	3	1	779	1699	2715	2324	2080	1841	1282	958	703	513	390	280	208	103	60	28	8	0	0			
S1	9	FH	4	1367000	964.6	242.2	67.88	31.75	24.42	19.63	15.4	12.14	10.5	9.466	8.346	8.014	7.269	5.796	4.367	2.929	1.75	0	0			
L5	10	FRST	1	1	0.00964	0.00040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.985	0	0.1674
L5	10	FRST	2	1367000	13180	556	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L5	10	FRST	3	1	110	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L5	10	FRST	4	1367000	119.8	34.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	FRST	1	1	0.00964	0.00040	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.985	0	0.1674
PNC D LEON	1	FRST	2	1367000	13180	556	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	FRST	3	1	110	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
PNC D LEON	1	FRST	4	1367000	119.8	34.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	FRST	1	1	0.01867	0.00074	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.01	0.2096	0.4577
L4	2	FRST	2	1367000	25540	1016	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	FRST	3	1	184	18	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L4	2	FRST	4	1367000	138.8	56.44	4.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	FRST	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.122	0	0.03891
M1	7	FRST	2	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	FRST	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M1	7	FRST	4	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	FRST	1	1	0.00170	0.00032	0.00007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.53	0	0.00943
M3	8	FRST	2	1367000	2331	441	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	FRST	3	1	9	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
M3	8	FRST	4	1367000	259	220.5	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L7	9	FRST	1	1	0.01793	0.00225	0.00030	0.00003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23.15	0	0.1984
L7	9	FRST	2	1367000	24510	3080	414	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L7	9	FRST	3	1	301	67	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L7	9	FRST	4	1367000	81.44	45.97	41.4	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L6	3	FRST	1	1	0.0214	0.00238	0.00044	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.79	0	0.2966
L6	3	FRST	2	1367000	29270	3259	615	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L6	3	FRST	3	1	86	14	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L6	3	FRST	4	1367000	340.3	232.8	307.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L3	4	FRST	1	1	0.07475	0.00493	0.00097	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17.09	0.3774	0.8856

17-May-90

TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
				DISCHARGE LEVELS (CUBIC FEET PER SECOND)																						
L3	4	FRST	2	1367000	102200	6746	1329	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L3	4	FRST	3	1	275	55	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L3	4	FRST	4	1367000	371.7	122.7	110.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L2	5	FRST	1	1	0.3778	0.03992	0.00358	0.00023	0.00004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29.09	1.323	2.317
L2	5	FRST	2	1367000	516600	54590	4906	323	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L2	5	FRST	3	1	325	232	35	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L2	5	FRST	4	1367000	1590	235.3	140.2	64.6	13.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L1	6	FRST	1	1	0.6032	0.04734	0.00396	0.00026	0.00006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29.94	1.469	2.526
L1	6	FRST	2	1367000	824900	64730	5419	363	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L1	6	FRST	3	1	233	247	34	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
L1	6	FRST	4	1367000	3540	262.1	159.4	60.5	14.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J8	1	FRST	1	1	0.00008	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.211	0	0.04932
J8	1	FRST	2	1367000	120	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J8	1	FRST	3	1	18	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J8	1	FRST	4	1367000	6.667	2.667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	FRST	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2933	0	0.00025
J7	2	FRST	2	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	FRST	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J7	2	FRST	4	1367000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J6	3	FRST	1	1	0.00227	0.00007	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.16	0	0.1028
J6	3	FRST	2	1367000	3108	96	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J6	3	FRST	3	1	79	13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J6	3	FRST	4	1367000	39.34	7.385	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J2	4	FRST	1	1	0.4057	0.06031	0.00190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18.01	0.00285	2.166
J2	4	FRST	2	1367000	554700	82470	2602	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J2	4	FRST	3	1	128	132	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J2	4	FRST	4	1367000	4334	624.8	236.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J3	5	FRST	1	1	0.4265	0.079	0.00294	0.00001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.17	0.05899	2.289
J3	5	FRST	2	1367000	583200	108000	4032	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J3	5	FRST	3	1	142	163	15	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J3	5	FRST	4	1367000	4107	662.7	268.8	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
J5	6	FRST	1	1	0.06909	0.01025	0.00094	0.00008	0.00003	0.00001	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	50.02	0	0.442
J5	6	FRST	2	1367000	94470	14020	1287	114	50	21	3	1	0	0	0	0	0	0	0	0	0	0	0			
J5	6	FRST	3	1	558	277	104	28	10	5	1	1	0	0	0	0	0	0	0	0	0	0	0			
J5	6	FRST	4	1367000	169.3	50.62	12.37	4.071	5	4.2	3	1	0	0	0	0	0	0	0	0	0	0	0			
J4	7	FRST	1	1	0.07196	0.01143	0.00115	0.00009	0.00003	0.00001	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	48.11	0	0.4562
J4	7	FRST	2	1367000	98390	15640	1575	128	54	20	2	0	0	0	0	0	0	0	0	0	0	0	0			
J4	7	FRST	3	1	515	245	99	25	11	5	1	0	0	0	0	0	0	0	0	0	0	0	0			
J4	7	FRST	4	1367000	191.1	63.82	15.91	5.12	4.909	4	2	0	0	0	0	0	0	0	0	0	0	0	0			
J1	8	FRST	1	1	0.6614	0.2769	0.07147	0.00442	0.00136	0.00050	0.00016	0.00003	0.00000	0	0	0	0	0	0	0	0	0	0	62.3	0.5762	4.143
J1	8	FRST	2	1367000	904400	378600	97730	6045	1862	686	229	49	2	0	0	0	0	0	0	0	0	0	0			
J1	8	FRST	3	1	172	283	300	82	45	28	9	6	1	0	0	0	0	0	0	0	0	0	0			
J1	8	FRST	4	1367000	5258	1338	325.8	73.72	41.38	24.5	25.44	8.167	2	0	0	0	0	0	0	0	0	0	0			
R6	4	FRST	1	1	0.00036	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8	0	0.07095

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TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
R6	4	FRST	2	1367000	505	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R6	4	FRST	3	1	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R6	4	FRST	4	1367000	42.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	FRST	1	1	0.00636	0.00017	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.95	0	0.1519
R5	5	FRST	2	1367000	8707	246	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	FRST	3	1	178	33	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R5	5	FRST	4	1367000	48.92	7.455	1.333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R4	6	FRST	1	1	0.07294	0.00495	0.00027	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29.17	0.4981	0.9609
R4	6	FRST	2	1367000	99740	6770	379	13	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R4	6	FRST	3	1	496	118	36	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R4	6	FRST	4	1367000	201.1	57.37	10.53	2.6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R3	1	FRST	1	1	0.00626	0.00056	0.00008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10.57	0.1706	0.3748
R3	1	FRST	2	1367000	8572	772	111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R3	1	FRST	3	1	15	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R3	1	FRST	4	1367000	571.5	386	111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	FRST	1	1	0.01161	0.00108	0.00022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.75	0.1711	0.4695
R2	2	FRST	2	1367000	15870	1482	305	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	FRST	3	1	241	40	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R2	2	FRST	4	1367000	65.85	37.05	38.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
R1	3	FRST	1	1	0.0463	0.00517	0.00053	0.00006	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	33.96	0.1711	0.6255
R1	3	FRST	2	1367000	63310	7073	726	88	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
R1	3	FRST	3	1	522	135	34	17	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
R1	3	FRST	4	1367000	121.3	52.39	21.35	5.176	1.6	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
W2	1	FRST	1	1	0.01616	0.00056	0.00004	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.01	0.05008	0.3462
W2	1	FRST	2	1367000	22100	767	55	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
W2	1	FRST	3	1	446	89	24	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
W2	1	FRST	4	1367000	49.55	8.618	2.292	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
W1	2	FRST	1	1	0.08533	0.01039	0.00090	0.00005	0.00001	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	41.08	0.1052	0.7377
W1	2	FRST	2	1367000	116700	14200	1240	76	17	3	1	0	0	0	0	0	0	0	0	0	0	0	0			
W1	2	FRST	3	1	628	294	100	25	10	2	1	0	0	0	0	0	0	0	0	0	0	0	0			
W1	2	FRST	4	1367000	185.8	48.31	12.4	3.04	1.7	1.5	1	0	0	0	0	0	0	0	0	0	0	0	0			
S9	1	FRST	1	1	0.09931	0.0139	0.00129	0.00004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24.26	0.1123	0.8511
S9	1	FRST	2	1367000	135800	19010	1768	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S9	1	FRST	3	1	602	216	35	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S9	1	FRST	4	1367000	225.6	88.02	50.51	9.167	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S8	2	FRST	1	1	0.2964	0.06202	0.01058	0.00047	0.00026	0.00011	0	0	0	0	0	0	0	0	0	0	0	0	0	37.92	0.00229	1.846
S8	2	FRST	2	1367000	405300	84810	14470	649	364	154	0	0	0	0	0	0	0	0	0	0	0	0	0			
S8	2	FRST	3	1	171	195	67	5	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0			
S8	2	FRST	4	1367000	2370	434.9	216	129.8	121.3	154	0	0	0	0	0	0	0	0	0	0	0	0	0			
S3	3	FRST	1	1	0.3478	0.1113	0.02094	0.00171	0.00046	0.00030	0.00008	0	0	0	0	0	0	0	0	0	0	0	0	47.88	0.09443	2.257
S3	3	FRST	2	1367000	475600	152200	28640	2349	639	412	115	0	0	0	0	0	0	0	0	0	0	0	0			
S3	3	FRST	3	1	170	352	180	28	13	5	2	0	0	0	0	0	0	0	0	0	0	0	0			
S3	3	FRST	4	1367000	2797	432.5	159.1	83.89	49.15	82.4	57.5	0	0	0	0	0	0	0	0	0	0	0	0			
S6	5	FRST	1	1	0.00291	0.00004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.776	0.03366	0.2374

17-May-90

TABLE C.3
HSPF DURATION DATA

BASIN: LOWER PUGET SOUND
SIMULATION LENGTH: 39 YEARS, WATER YEARS 1949-1987
TIMESTEP: 15 MINUTES
NUMBER OF TIMESTEPS IN ANALYSIS: 1367424
NUMBER OF DAYS IN ANALYSIS: 14244

TABLE NUM	DESCRIPTION
1	Fraction of total simulation time flows equal or exceed discharge level.
2	Total length of time discharge levels were equaled or exceeded. Expressed in timesteps.
3	Number of excursions at each discharge level.
4	Average duration of each excursion in table 3. Expressed in timesteps.

MODEL SCENARIO
FRST= Pre-developed land use (forested)
1987= 1987 (Calibration land use).
FH= Future land use without on-site det

SUB-BASIN	RCH	SCEN-ARIO	TABLE NUM	DISCHARGE LEVELS (CUBIC FEET PER SECOND) 0	2	5	10	20	25	30	40	50	60	70	80	90	100	125	150	175	200	250	300	MAX	MIN	MEAN
S6	5	FRST	2	1367000	3989	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S6	5	FRST	3	1	28	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S6	5	FRST	4	1367000	142.5	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S5	6	FRST	1	1	0.0696	0.00525	0.00026	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29.84	0.09264	0.6446
S5	6	FRST	2	1367000	95170	7191	359	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S5	6	FRST	3	1	458	244	46	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S5	6	FRST	4	1367000	207.8	29.47	7.804	1.5	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
S7 CLSD DP	4	FRST	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
S7 CLSD DP	4	FRST	2	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx			
S7 CLSD DP	4	FRST	3	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx			
S7 CLSD DP	4	FRST	4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx			
S4	7	FRST	1	1	0.1008	0.01159	0.00077	0.00004	0.00000	0.00000	0	0	0	0	0	0	0	0	0	0	0	0	0	38.07	0.115	0.8035
S4	7	FRST	2	1367000	137800	15840	1060	55	11	3	0	0	0	0	0	0	0	0	0	0	0	0	0			
S4	7	FRST	3	1	495	360	97	19	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0			
S4	7	FRST	4	1367000	278.4	44.01	10.93	2.895	1.833	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0			
S2	8	FRST	1	1	0.4609	0.2093	0.06784	0.01117	0.00555	0.00268	0.00071	0.00027	0.00013	0.00005	0.00001	0	0	0	0	0	0	0	0	85.82	0.3063	3.499
S2	8	FRST	2	1367000	630200	286200	92760	15280	7599	3672	977	382	188	79	15	0	0	0	0	0	0	0	0			
S2	8	FRST	3	1	190	375	401	178	115	74	39	12	10	11	3	0	0	0	0	0	0	0	0			
S2	8	FRST	4	1367000	3317	763.1	231.3	85.82	66.08	49.62	25.05	31.83	18.8	7.182	5	0	0	0	0	0	0	0	0			
S1	9	FRST	1	1	0.4678	0.2136	0.07079	0.0123	0.00610	0.00293	0.00086	0.00029	0.00014	0.00007	0.00002	0	0	0	0	0	0	0	0	88.21	0.3153	3.573
S1	9	FRST	2	1367000	639700	292100	96800	16820	8344	4009	1188	407	203	97	33	0	0	0	0	0	0	0	0			
S1	9	FRST	3	1	182	350	410	182	123	74	50	12	7	8	3	0	0	0	0	0	0	0	0			
S1	9	FRST	4	1367000	3515	834.6	236.1	92.4	67.84	54.18	23.76	33.92	29	12.12	11	0	0	0	0	0	0	0	0			