Current & Future

Conditions Report

Cedar River

King County
Surface Water
Management
Everyone lives downstream

Cedar River Current and Future Conditions Report

Addenda and Errata

Credits

Page ii, Column 2, Technical Advisors additions:

Hal Michael - Washington State Department of Fisheries
Eric Warner - Muckleshoot Indian Tribe

Chapter 1: Introduction

Page 1-12, Paragraph 1, correction:

According to the 1978 King County Shoreline Management Master Program Supplement, approved by the Washington State Department of Ecology, the lower reach of Rock Creek is a Shoreline of the State, designated as Conservancy~~, because its average annual flow exceeds 20 cubic feet per second (cfs)~~ from the intersection of the County road, railroad right-of-way, and Rock Creek, (approximately RM 0.1 ~~2.6~~) downstream to its confluence with the Cedar River. To be designated a "Shoreline of the State", stream reaches must have a mean annual flow greater than 20.0 cubic feet per second (cfs). The natural mean annual flow of Rock Creek exceeds the 20 cfs mean annual flow up to RM 1.7. However, two major diversions, only one of which is permitted, and several smaller diversions have decreased Rock Creek's mean annual flow, as measured between 1948 and 1973 by the USGS gage at RM 0.1, to less than 20 cfs above RM 0.1. ~~The average annual flow may drop below 20 cfs between approximately RM 1.0 and RM 1.6 because of the City of Kent's diversion of water.~~

Chapter 4: Flooding

Page 4-31, Key Findings, Items 3 and 4, addition:

Including those specifically noted, approximately 120 residences are within the 10-year floodplain of the mainstem of the Cedar River. Approximately 170 homes are within the 25-year floodplain, and approximately 275 homes are within the 100-year floodplain. The number of homes within each floodplain will be more accurately ascertained during the solutions phase of the Basin Plan.

Chapter 6: Water Quality

Page 6-25, Paragraphs 3 and 6; Page 6-27, Paragraphs 2 and 6; Page 6-30, Paragraph 4; Page 6-32, Paragraphs 1, 4, and 5, corrections:

Change Map 15 to Map 16.

Water Quality Appendix - Significance Criteria, see attachment.

Chapter 7: Aquatic Habitat

Page 7-6, Paragraph 1, line 3, correction:

~~Six~~ Seven of these species occur in the BPA.

Page 7-9, Paragraph 1, Lines 1 and 3, corrections:

The Cedar River produces ~~five~~ seven species of salmonids:... trout, ~~and~~ Dolly Varden Charr Salvelinus malma and mountain whitefish (Coregonus clupeaformes).

Page 7-86, Paragraph 4, line 2, correction:

"section 8.5" change to section 7.5.

Page 7-93, Reference correction:

Coccoli, Holly, 1993, Personal communication.

Page 7-97, Reference deletion:

SWD page 14.

Inside Back Cover

Correction:

SWD Seattle Water Department ~~Division of the King County Department of Public Works~~

SWM Surface Water Management, Division of the King County Department of Public Works

Water Quality Significance Ranking

Objective

The objective of the Water Quality Significance Ranking is to provide a conceptual framework to rank or prioritize water quality issues at the Conditions Report (problem analysis) stage of the basin planning process. This ranking was developed to characterize the severity and extent of water quality problems to distinguish levels of significance. At this point in the planning process, the significance is not influenced by the factors included in the solutions analysis (feasibility, management, cost, etc.). The purpose of the ranking is to provide an evaluative process inclusive of, but not limited to water quality standards since many contaminants do not have standards.

Problem Identification

Water quality problems are identified by increases in nonpoint and point source pollution, sediment contamination and nutrient loadings. Associated impacts include degredation of habitat, aquifers and surface water. Problems are identified by either indirect measurement, using facts that indicate that pollutants sources are potentially contributing to water quality problems, or direct measurements by chemical or biological measurements. The potential to exceed a standard, or an actual exceedance constitues a problem.

Significance

Many factors contribute to the significance of a water quality problem. The goal was to develop a framework for defining levels of significance and to describe those factors that influence significance of a water quality problem. This framework attempts to describe the reasoning behind the determination of significance so that consistency can be maintained throughout the process.

This ranking approach applies to water quality problems defined during the basin planning scoping process. It only provides a scale for determining significance of a problem, without regard to possible solutions, ease of implementation or any management aspects.

All water quality problems identified in the planning process will be included in the ranking. The following table lays out the conceptual framework of ranking the extent and severity of the problem. On the vertical axis is the function or value the problem is impacting. Each problem may impact one or more of these values. The problem is assessed a high, medium, or low significance level for both extent and severity. To determine the high, medium or low level, a series of questions follows the table. The questions were developed to assist in the determination but were not designed to be all inclusive. Professional judgement is required. A comment column is included to summarize the reasoning behind the determination.

The questions below attempt describe the factors that influence significance. Significance can be subjective, especially when data is limited. These questions do not describe all the factors that must be considered but should act as triggers for further questions. The major reasons influencing the ranking should be marked in the comment column. It is envisioned that overtime, as problems are put through this ranking, a more complete set of questions will be developed.

Function / value

	EXTENT				SEVERITY			
	Hi	Med	Low	Comments	Hi	Med	Low	Comments
HUMAN HEALTH								
WELFARE								
AQUATIC HEALTH								

Overall: ______________________

Human Health: Human Health values including drinking water and primary and secondary contact.
Welfare: Includes values such as aesthetics and property.
Aquatic Health: Includes RSRA, LSRA and other aquatic resources.

GENERAL QUESTIONS (These factors should be kept in mind for both severity and extent significance because they influence the significance of both.)

How does fate and transport factors influence the problem?

How is it distributed in the system?

What are the characteristics of the pollutant?

Is it stable?

Does it float or sink?

Is it soluble or in a particulate form?

Is it bioavailable or inert?
Is it temporary or long-term? Is it absorbed or organically bound?

Is the problem historic, current, or potential?

What is the frequency? Chronic, seasonal, intermittent, infrequent?

What is the duration? Continuous or event driven?

What is the variability? Consistent, random, seasonally variable?

Is a trend detected?

<u>QUESTIONS FOR EXTENT DETERMINATION:</u> Extent characterizes the distribution, scale or exposure of the stream system to a problem.

What is the spatial distribution of the pollutant/ problem?

Is the problem local or systemic? Basin wide or catchment wide? Can the problem or its effects be measured downstream or is it confined to a specific area?

> Localized problems are land use or activity limited where the extent of the impact is confined. The impact of localized problems can be absorbed by the stream system or has a limited zone of influence. Systemic problems persist throughout a reach or stream segment. This includes situations where a localized problem (or multiple localized problems) overwhelm the system and the impact is not confined, diluted or eliminated by the flow, hydrology or channel morphology. A systemic problem does not have to affect the entire basin, but need only affect a tributary or portion of a tributary.

Does the problem effect a tributary only? Can the problem be detected in the mainstem?

Is the problem linked to one source? Many sources? A landuse activity? A temporary operational practice?

<u>QUESTIONS FOR SEVERITY</u>: Severity characterizes the intensity, toxicity, seriousness or tempestuous nature of the problem or pollutant(s).

Are there one or more than one contaminants detected?
Is there a standard for the contaminant detected?
Is the standard exceeded? How often? When? What duration?

Has it been measured? direct or indirect?

Are the standards for cute or chronic toxicity? Drinking water standards? Recreational contact? Aquatic health?

Who or what are the standards designed to protect? Adult age or juveniles (people or aquatic organisms)? All species or sensitive species?

What is the impact? To whom?
Is it existing or potential?
Does it impact 1 species or many? How many? Food chain impacts?

Are there synergistic effects?

Is there a direct impact? Lethal? Illness?
Are there indirect or secondary impacts?

Has the ecosystem function and/or value been impacted?

How is the receiving body impacted? Eutrophic level? Assimilative capacity? Buffering capacity? Flushing rate?

Are contaminants detected in the sediment?, base flow?, and/or storm flow?

Do hydrologic conditions influence the toxicity?

Basin: ______________________ Subbasin: ______________________

Problem: ____

	EXTENT				SEVERITY			
	Hi	Med	Low	Comments	Hi	Med	Low	Comments
HUMAN HEALTH[1]								
WELFARE								
AQUATIC HEALTH								

Overall: ______________________

Basin: ______________________ Subbasin: ______________________

Problem: ____

	EXTENT				SEVERITY			
	Hi	Med	Low	Comments	Hi	Med	Low	Comments
HUMAN HEALTH[1]								
WELFARE								
AQUATIC HEALTH								

Overall: ______________________

Cedar River Current and Future Conditions Report

April 1993

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Surface Water Management Division

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Executive Summary

Executive Summary

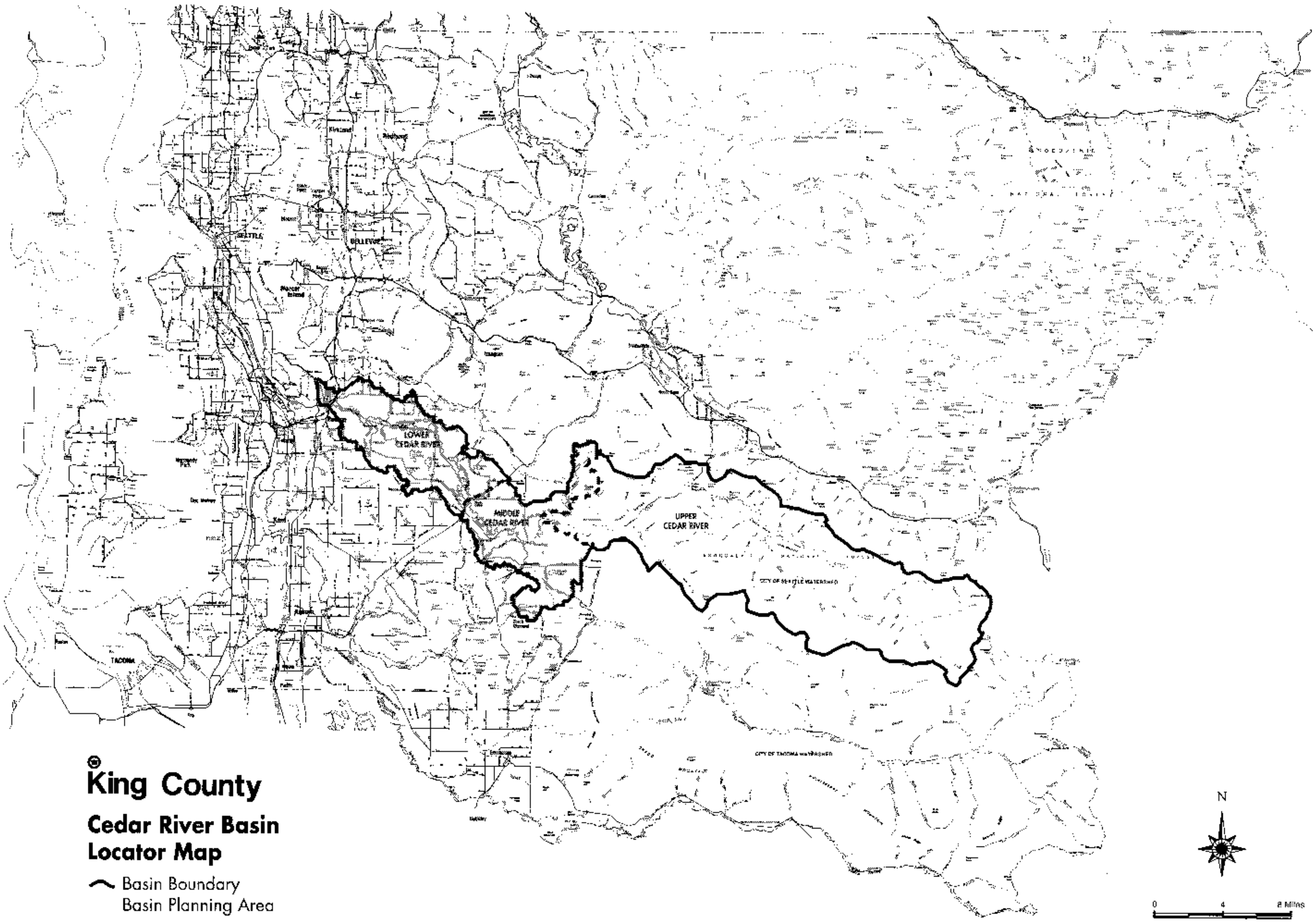
The Cedar River Current and Future Conditions Report provides a comprehensive assessment of the current conditions and predicts future trends in the Cedar River Basin Planning Area (BPA). Its primary purpose is to identify significant conditions and issues to be addressed in the Cedar River Basin/Action Plan. The Basin/Action Plan will recommend solutions and management programs for the significant, and often interrelated, problems related to flooding, erosion and deposition, water quality, and aquatic habitat.

The BPA encompasses approximately 66 square miles, or the lower one-third of the entire Cedar River drainage basin (see the location map on the following page). The BPA is primarily within unincorporated King County, with only six percent of the area in the City of Renton. The middle basin includes all areas that drain into the Cedar River between the Landsburg diversion dam and Maple Valley; the lower basin covers the area from Maple Valley to Lake Washington. There is a diverse mix of land use and land cover types, ranging from urban impervious areas to rural forestry lands. Major communities include the City of Renton—the only incorporated area—and Maple Valley, Fairwood, Maplewood Heights, Summit, Ravensdale (in part), and Georgetown.

The City of Seattle owns 80 percent of the upper two-thirds of the entire Cedar River Basin and manages the lands to maintain high-quality drinking water. The Seattle Water Department (SWD) manages water supply facilities, including the Masonry Dam, to provide 70 percent of the municipal and industrial water needs for the City of Seattle and surrounding metropolitan areas, and for hydroelectric power for 8,000 homes. Currently, SWD diverts an average of 191 cubic feet per second (cfs) from the river. State, tribal, county, and city agencies are concerned with maintaining adequate flows in the Cedar River for Lake Washington's water supply, operation of the Hiram Chittenden Locks, and to maintain fish and wildlife resources.

In the BPA there is a unique and extensive surface-water system that drains the broad plateaus, steep slopes, and river valley. This system includes 65 miles of mapped streams, 892 acres of inventoried wetlands, nine major lakes, and 23 miles of the Cedar River mainstem within a broad floodplain. This natural system, if conserved and enhanced, will contribute to high water quality, valuable fish and wildlife resources, flood storage in the basin, and improved water quality entering Lake Washington.

For its size, the Cedar River system supports one of the largest salmon populations in the state. Nearly pristine habitat areas are found in the Rock, Peterson, and Taylor Creek subbasins, with diverse and abundant wildlife. Elk, black-tailed deer, numerous small mammals, and birds use both the BPA lands and the adjoining upper basin. In addition, the Cedar River shoreline has been designated as a Shoreline of the State from its mouth



King County

Cedar River Basin Locator Map

Basin Boundary
Basin Planning Area

to its headwaters and, in combination with the surrounding basin, provides a wide variety of recreational resources. These recreational resources and the natural beauty of the Cedar River Basin are dependant on conservation of the surface-water system.

The BPA has been subject to rapid growth pressure in recent years, and the population is estimated to increase by one-third between 1990 and 2000. Increased intensity and duration of stormflows, resulting from the loss of forest cover due to development, have overwhelmed the natural ability of the surface-water system to adequately convey peak stormwater discharges, maintain water quality, and sustain healthy aquatic habitat and, therefore, viable fish resources.

Historically, the basin supported large populations of several salmonid species and currently produces one of the largest remaining runs of sockeye salmon in the contiguous United States. However, in the highly urbanized areas the water quality and aquatic habitat have been severely degraded, leaving only remnants of the once excellent pre-development habitat and fish populations. In rural areas, habitat will continue to degrade as development and stormflows increase, unless corrective action is undertaken to regulate development and restore damaged stream channels and wetlands.

The Cedar River Basin's valuable resources have drawn a high degree of interest in the basin planning process from numerous state and local agencies, the Muckleshoot Indian Tribe, and from many citizens. Staff and citizens recognize the importance and value of resolving existing drainage, flooding, sedimentation, habitat, and water quality problems in the basin to save public funds and resources and to reduce the likelihood of future problems. However, choices regarding future actions will be complex and difficult to make because there are underlying regulatory and social factors to consider in addition to the physical problems. These include insufficient land-use planning and development impact regulations, limitations on the effectiveness of regulatory agencies, and the need for more public education and involvement. Therefore, restoring and protecting the basin's resources will require the collective commitment of all interested parties to coordinate an effective basin plan.

SUMMARY OF KEY FINDINGS

Current Conditions

Land Use and Hydrology The total basin population is approximately 55,400, with 40,000 people living in unincorporated King County, primarily in the high-density, single-family residential areas on the upland plateaus. Land development in these urbanized and lower density residential areas, has resulted in substantial deforestation, leaving only 56 percent of the basin currently in forest cover. The more urbanized subbasins in the lower part of the BPA (Ginger, Maplewood, Molasses, Madsen, Orting Hill, and Cedar Grove) have experienced an average increase in peak discharges, or "flood peaks," of 87 percent over pre-developed, forested conditions. Development has been less intense in the middle BPA (Cedar Hills, Webster Lake, and Taylor, Peterson, Dorre Don, and Rock Creeks); consequently, flood peaks have only increased there by an average of 26 percent.

The natural stormwater storage and conveyance elements in the Cedar River mainstem and the lower tributaries have been modified extensively. The Cedar River mainstem has been subjected to a particularly wide variety of human manipulation along its length including dams, revetments, diversion, and channelization. The Seattle Water Department's operation of the Masonry Dam has significantly reduced the peak flows in the lower Cedar River, while water supply diversions at the Landsburg Dam have reduced the mean monthly flows at Renton by 9 to 40 percent less than their natural levels between July and October.

In the lower BPA, well over half of the headwater wetlands have been cleared or filled, and tributaries have been piped or substantially modified and encroached upon by development. Madsen Creek exemplifies the results of these alterations including increased stormwater volume and velocities, reduced flood storage, destabilized channel and banks, and degraded water quality and habitat. The tributaries in the middle BPA have not experienced severe modification. However, increased stormflows from development have increased flooding, erosion and deposition, habitat, and water quality problems.

Flooding Regional, large-scale flooding, generally on the Cedar River mainstem, has significantly damaged or destroyed levees, roads, and residences. Homes at Elliot Bridge, Lower Jones Road, Cedar Grove, and the SR-169 bridge at Maple Valley are within both the 25-year and 100-year floodplains. Above Maple Valley, flooding from both high flows and the natural migration of the river have damaged some riverside homes. Primarily in the tributaries, local, small-scale flooding, beginning at 5-year flood intensities, has damaged structures, roads, or habitat or has threatened public health and safety by preventing access for emergency services.

Erosion and Deposition Prior to development, the tributary channels were generally stable, with relatively low rates of erosion. The most severe erosion problems currently occur on tributaries that enter the Cedar River downstream from Maple Valley, particularly creeks that flow through high-density residential areas in the lower end of the basin. Most of the channels have downcut, with associated bank erosion causing local bank failure and landslides. Tributaries to the middle mainstem have had less development, lower flow increases, and so show less erosion and deposition.

Human modification has greatly changed the erosion and sediment transport pattern of the Cedar River mainstem. Masonry Dam has reduced flood flows, which appear to be the cause of a 30 percent decrease in channel width over the last 80 years. Levee and revetment construction further narrowed the river's width by an equivalent amount and have prevented the normal migration of the river within the floodplain. The 1912 diversion of the lower two miles of the Cedar River into its artificial channel has resulted in sediment being deposited in the lower channel and Lake Washington, which in turn has made this section of the river prone to flooding problems.

Aquatic Habitat Many fish habitats in the Cedar River system have been significantly degraded by increased stormflows, erosion and deposition, and water pollutants from development. Reduction in the quality and quantity of riparian vegetation and loss of large woody debris (LWD) have further destabilized aquatic habitats. The habitat quality in three major fish-bearing tributaries—Madsen, Molasses, and Maplewood creeks—has been severely affected by urbanization, which has nearly eliminated coho and sockeye use of these creeks. In the less urbanized part of the BPA, Taylor and Peterson Creeks show early signs of habitat degradation, while Rock Creek has excellent habitat and is one of the most outstanding streams in King County.

Fish habitat in the mainstem Cedar River has been reduced by approximately 56 percent in the last 80 years due to water diversion and flood control activities in the past century. The river has unexpectedly low number of large pools, LWD, and has been extensively disconnected from the historic floodplain. These changes have simplified the diversity of mainstem habitats.

The Cedar River Basin has a high diversity of wetland resources, including some of the largest and most pristine bogs in western King County. However, a high proportion of the identified wetlands have undergone some degree of buffer removal, clearing, drainage, or filling, especially on the plateaus of the lower basin. Dozens of other uninventoried wetlands are particularly vulnerable to damage because of the lack of awareness of their existence.

Water Quality The historically high water quality in the BPA is being increasingly degraded by land-use activities and associated nonpoint pollution. High concentrations of typical urban pollutants can be found in the tributaries and in some locations in the mainstem Cedar River. Suspended solids, nutrients, and fecal coliform bacteria from failing septic systems are especially severe in the higher density residential areas of Maplewood and Briarwood, around Lake Desire, Shady and Peterson Lakes, and along the lower Cedar River mainstem. Noncommercial animal keeping is another major source of fecal coliform, nutrient, and sediment pollution in the Taylor Creek Subbasin. Relative toxicity of metals, primarily from road runoff, is elevated by the soft water of the Cedar River. Copper toxicity is a particular concern because of its extreme toxicity to salmonids. Various sites in the Renton commercial area exhibit semivolatile organics, PCBs, and extremely high concentrations of metals, and pH levels. Other sources of nonpoint pollution in the basin include forest conversion, composting, metal recycling, gravel mining, and home businesses.

Future Conditions

Land Use and Hydrology Based on the growth estimates in community plans within the BPA, the total basin population in 2010 is projected to be 93,000 (a 68 percent increase from 1990) with approximately 12,548 new housing units. This projected population increase will result in continued clearing and development of forest land, until only an estimated 28 percent of the BPA will remain in forest cover. Stormflows will increase, degrading stream resources, unless mitigation measures are successfully implemented. The largest increases in tributary flood peaks will occur in the more rural subbasins—Taylor, Peterson, Dorre Don, and Rock Creeks—as a result of low-density, residential development that under current regulations could be built without peak flow controls. Those subbasins that are currently near build-out, such as Ginger or Madsen Creeks, will not show a significant change in the future. Increased development in the BPA will have a minimal effect on Cedar River mainstem flood peaks, but will increase the duration of floods. This occurs because the majority of maximum mainstem flows above 4,000 cfs in Renton are primarily caused by peak inflows of similar magnitude from the upper basin.

Flooding Flood problems are not expected to increase significantly for either the 25-year or 100-year flood along the Cedar River mainstem. Tributary flooding problems will experience an increase, particularly in the Maplewood, Molasses, and Taylor Creek subbasins. Without increased detention, these increased flows will 1) destabilize some stream channels that are presently stable, 2) exceed culvert capacities at many sites, 3) increase sediment-related problems, and 4) increase frequency and extent of damage. These problems are the direct result of the cumulative effects of increased development.

Erosion and Deposition Without appropriate management, future development will increase the frequency and magnitude of flows, and thus channel erosion in the tributaries. Under anticipated flow increases, erosion problems in some currently unstable tributaries will increase, and erosion will most likely destabilize streams that are currently stable in the following subbasins: Cedar Hills, Dorre Don, Rock Creek, the north fork of Taylor Creek, and Webster Lake.

Major future issues with the Cedar River mainstem include migration patterns and sediment load. In order to protect many homes located on the Cedar River floodplain, frequent maintenance of revetments will be required in zones of major historic river channel migration. The potential exists for the river to switch channels, affecting development between Maple Valley and Arcadia/Noble. Although the river does not carry an "excessive" sediment load, chronic and localized deposition in the reach in Renton may require periodic dredging to prevent flooding.

Water Quality Changes in land use will increase stormwater flows and thus concentration and transport of nonpoint pollutants to the basin's streams, lakes, and wetlands. Current pollutant concentrations —especially total suspended solids (TSS), fecal contaminants, nutrients, and metals—are expected to increase dramatically in the future as urbanization and development increases. Average pollutant loading increases are predicted to increase by 30 to over 100 percent. Lead concentration increases, already high in the more urbanized catchments, could cause acute toxicity. In less developed areas, such as Peterson and Rock Creeks, increased lead levels could result in toxic concentrations for the first time.

Aquatic Habitat The quality of future aquatic habitat in the BPA depends on restoring, where feasible, damaged habitat and preserving existing habitat. Without proper controls, development will continue to damage stream, wetland, and lake habitat. Habitat that is now in nearly pristine condition will be degraded without adequate protection, such as in the Rock Creek Subbasin where flows may increase up to 67 percent.

Wetlands will be impacted by buffer clearing, filling, trash, noise, and pollution. For example, Wetland 23, at the headwaters of Molasses Creek, will be encircled by a 77 unit subdivision and Wetland 58 will be impacted by expansion of SR-18, including buffer removal and filling. These impacts will continue to affect the natural flood storage, water quality, and habitat functions of these vital resource areas.

Along the Cedar River mainstem, many of the peripheral or "fringe" habitats, such as small wetlands, side channels, and spring-fed tributaries will be highly susceptible to human impact. Their small size or ephemeral nature will make them appear as insignificant to fish production or other aquatic functions even though they are often critical for certain life history stages of many salmonids.

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Chapter 1: Introduction

1.1 BACKGROUND AND PURPOSE

BACKGROUND

During the past century, land uses in the Cedar River Basin have changed dramatically from historic logging of forests and mining of coal, sand, and gravel to ever-expanding urban and semi-rural communities. Impervious surfaces accompanying this urbanization have radically altered the basin landscape from one with a stable continuous complex of stream, wetland, and riverine habitats into one with numerous fragmenting and degrading systems. These conditions not only affect the quality of the natural environment, they are also taking their toll in flood damages and the quality of life for those who live, work, and recreate in this basin.

The effects of these landscape changes are most readily apparent in the response of its streams and wetlands to peak storm events. In many cases the runoff from these events has more than doubled storm discharges, introducing pollutant concentrations that greatly exceed established standards. These flows have also accelerated stream channel erosion, which have, in turn, degraded instream habitat and damaged private property. In some cases, increased stream flows have undercut stream banks causing landslides. Eroded sediment from these sources can suffocate salmonid eggs, bury and cement spawning gravels, and fill stream channels. As channel capacity is lost, flooding problems are aggravated. In other areas, frequent peak flows scour stream channels, which can increase salmonid egg mortality and reduce available habitat, especially in combination with high pollutant concentrations. Thus, increases in peak flow volume and magnitude have had commensurate and interrelated effects on erosion and sedimentation, flooding, habitat loss, fish mortality, and declining water quality throughout the basin. Many of these effects are expected to intensify with future development unless steps are taken to stem runoff and improve the condition of aquatic environments.

PURPOSE

The interrelated nature of surface water issues in the Cedar River Basin requires a broad interdisciplinary analysis to understand the problems and to identify long-term solutions. Hence, this Current and Future Conditions Report (Conditions Report) is a comprehensive assessment of surface water management problems in the Cedar River Basin Planning Area (BPA) as analyzed through several key disciplines. These include effects on flood damage, aquatic habitat, erosion, sedimentation, and water quality conditions. The analysis is based on extensive staff observations throughout the basin, together with information gathered from the public and other agencies.

The Conditions Report marks the completion of the problem identification phase, the first of two stages, in preparing the Cedar River Basin Plan and Nonpoint Source Pollution Action Plan (Basin/Action Plan). While this report includes an inventory of known surface water management conditions in the BPA, the discussion focuses on the most significant among these conditions. As such, the Conditions Report forms the basis for the issues that will be addressed in the Basin/Action Plan.

In the second stage, the solutions phase, the technical team responsible for the Conditions Report will be working with the project committees; local, state, and federal agencies; and the public to identify recommended actions to solve these problems. Basin/Action Plan recommendations can include capital facilities for detaining stormwater or enhancing fish habitat, development standards or changes in land use to reduce excessive runoff and pollutants, or programs to encourage public involvement and stewardship. The Draft Basin/Action Plan is expected to be published for public comment late in 1993. Throughout 1994, the Draft Basin/Action Plan will be revised based on public and agency comment. Early in 1995, it is scheduled to be forwarded to the King County Council, the City of Renton, and other affected entities for adoption. The adopted Basin/Action Plan will then be implemented through capital improvement projects, development permits, and other programs administered by these agencies.

1.2 REVIEW OF CONTENTS

Seven of the eight chapters in this report (*Chapters 2-8*) describe the current and future conditions in the tributary and mainstem systems of the BPA through several disciplinary perspectives. These disciplines include geology and groundwater, hydrology, erosion and deposition, water quality, aquatic habitat, and the public and governmental forces affecting the basin's resources. Conditions are discussed from basinwide and subbasin points of view. Where appropriate, each chapter includes a description of concepts needed to understand the issues, data collection and analysis methods, key findings, a reference list, and an appendix.

Chapter 1: Introduction
Discusses the background and purpose of the report, its organization, and how the major biophysical and cultural elements in the basin have formed its present landscape

Chapter 2: Geology and Groundwater
Describes the effect of geology, glacial history, and groundwater resources on basin conditions

Chapter 3: Surface-Water Hydrology
Discusses streamflow conditions in relation to current and future land use as analyzed using a continuous simulation model

Chapter 4: Flooding
Identifies areas currently prone to flood damage, where flooding is expected in the future, and causal factors

Chapter 5: Erosion and Deposition
Describes the effects of current and future stormflows on conditions in the tributary systems and on erosion and sediment deposition patterns in the Cedar River mainstem

Chapter 6: Water Quality
Describes water quality conditions, current and anticipated future nonpoint source problems, and water quality impacts on aquatic habitat

Chapter 7: Aquatic Habitat
Discusses landscape processes in relation to fish population trends and habitat, describes current and future conditions of stream, riverine, and wetland habitats, and identifies significant habitats

Chapter 8: Private Actions and Public Agency Response
Discusses the underlying factors affecting conditions in the basin and the roles of public agencies in managing natural resources, including development activities and regulatory programs

Appendix A: Observed Conditions Summary
Details all conditions identified in each subbasin from staff observations and complaints

Appendix B: Cedar River Basin Maps
Includes all maps referenced in the document

1.3 REPORT DEVELOPMENT

King County's initial effort to document surface water conditions in the Cedar River Basin was made in 1987 for the Lower Cedar River Basin Reconnaissance Report. That report assessed conditions in the only portion of the BPA within the Surface Water Management (SWM) Division Utility Service Area at the time, the area between the City of Renton and Maple Valley.

Since 1990, more detailed data for the BPA has been collected from precipitation records, drainage complaints, hydrologic modeling, reports and studies from local and state entities, current research, citizen observations, and substantial field studies. Field work entailed stream gaging; habitat, erosion, and sedimentation surveys of the tributaries and Cedar River mainstem; stormwater and sediment sampling for water quality pollutants; an illicit stormwater hook-up survey within the City of Renton; and a groundwater and aquifer recharge study.

The Current (1991) Land Use/Land Cover Map (Map 3, *Appendix B*) is the basis of the hydrologic simulation model used to determine the current risks from flood discharges in the basin drainages (see *Chapter 3: Surface-Water Hydrology)*. The Future Land Use/Land Cover Map (Map 4, *Appendix B*) was derived by assuming the maximum level of development allowed under current zoning by the comprehensive land-use plans for Newcastle, Soos Creek, Tahoma-Raven Heights, and the City of Renton. This map includes significant changes in future land use that have resulted from the Washington State Growth Management Act (GMA), which required the County and cities to delineate the extent of their future urban growth areas. Modeled current and future flood discharges are used in the disciplinary discussions to describe changes in flows with urbanization and to identify threshold discharges at which flood, erosion and sedimentation, and aquatic habitat have been, or are expected to become, problematic.

1.4 PUBLIC INVOLVEMENT

In May 1992, information gathered from field work, hydrologic modeling, and other research was supplemented by two public open houses. These meetings, held in Renton and Maple Valley, identified citizen surface water-related concerns in the BPA. The technical information and the results from the open houses were used to develop this Conditions Report. When the Draft Basin/Action Plan is published, additional community meetings will be held in the basin to solicit public comment.

There are three committees established for developing the Basin/Action Plan: Watershed Management Committee (WMC), Citizen Advisory Committee (CAC), and Technical Advisory Committee (TAC).

The WMC is a policy-making body appointed by agencies and community groups to direct development of the Basin/Action Plan. The WMC duties are to 1) oversee its preparation, including the work program, budget, and schedule, 2) oversee public and agency involvement in the planning process, 3) recommend the proposed Basin/Action Plan to the King County Council, the Renton and Seattle City Councils and affected federal, state, and local agencies, 4) resolve policy conflicts that may arise, and 5) ensure that agencies with jurisdiction in the basin are aware of the requirements in the adopted Basin/Action Plan.

The WMC represents the following agencies or organizations: the King County SWM Division; City of Renton Planning, Building and Public Works Department; the City of Seattle Water Department; the US Army Corps of Engineers; the Muckleshoot Indian Tribe; the King Conservation District; Washington State Departments of Fisheries, Wildlife, Natural Resources, and Transportation; representatives of area businesses and farm forestry, an environmental representative, and the chairman of the CAC.

The CAC was appointed by the WMC to provide a local perspective on problems and solutions throughout the planning process. CAC members, many of whom are long-time residents of the basin, represent a broad spectrum of the basin community including the environment, business, law, fishing, and farming. The committee's primary duty is to provide a conduit between the basin community and the WMC by discussing surface water issues with neighbors and variety of affected interest groups in the basin. The CAC incorporates the concerns raised in these discussions into its Basin/Action Plan recommendations to the WMC. The CAC also develops and participates in Basin/Action Plan-related public involvement activities.

The TAC includes technical staff from WMC member agencies and other affected entities. The TAC makes technical recommendations to the WMC and SWM Division staff and discusses a variety of issues, including hydrologic modeling for the flooding analysis, criteria for determining significant problems, and Basin/Action Plan recommendations.

1.5 WATERSHED CHARACTERIZATION

PHYSICAL OVERVIEW

The Cedar River Basin is located in the southeast region of the Puget Sound Lowland, curving eastward from the south end of Lake Washington to the crest of the Cascade Range (Map 1, *Appendix B*). The entire basin is within King County and drains 188 square miles. The BPA, the primary focus of this report, consists of approximately 66 square miles (42,240 acres) drained by the Cedar River below the Landsburg Dam. Eighty percent of the upper Cedar River Basin, above the Seattle Water Department's (SWD) Landsburg Dam, is owned and maintained by the City of Seattle to protect the quality of the city's water supply.

The climate of the Cedar River Basin has moderate temperatures with annual precipitation ranging from 30 to 50 inches in the BPA, 100 to 200 inches in the upper basin, and snowfall in the Cascades averaging 500 inches per year. Streamflows are highest during periods of high precipitation (November to February) and during high snowmelt (April to May) or during episodes of prolonged precipitation, warm temperatures, and snowmelt.

For planning purposes, the BPA is divided into eight subbasins, or groups of subbasins, of variable topography, land cover, and land use. These are named 1) Renton Reach, 2) Lower Cedar River Mainstem, 3) Lower Cedar River Subbasins, 4) Middle Cedar River Mainstem, 5) Peterson Creek, 6) Taylor Creek, 7) Middle Cedar River Subbasins, and 8) Rock Creek (Map 2, *Appendix B*). The middle subbasins, which drain into the Middle Cedar River Mainstem between Landsburg and Maple Valley, are primarily forested with some low-density residential use. In contrast, the lower subbasins, which drain into the Lower Cedar River Mainstem downstream of Maple Valley, contain a wider variety of land uses and land-cover types, including high-density urban areas, such as the City of Renton, subdivision development on the plateaus east of Renton, and the rural community of Maple Valley, 15 miles upstream.

There are eight major BPA tributaries flowing into the Cedar River along its 21-mile course from Landsburg Dam to Lake Washington: Walsh Lake diversion ditch, Taylor (Downs), Rock, Peterson, Ginger, Molasses, Maplewood, and Madsen creeks (Maps 17-28, *Appendix B*). These creeks and numerous smaller tributaries drain the broad, flat plateaus that rise 100 to 300 feet above the Cedar River valley floor and flow over the steep bluffs into narrow ravines before reaching the Cedar River. The Cedar River flows through a fairly narrow valley from Landsburg to a mile above Maple Valley, where the valley floor broadens. Downstream from Maple Valley the river winds through the valley floor, but is almost entirely constrained by revetments or steep bluffs. For the final two miles, the Cedar River flows in an artificial canal in the industrial section of the City of Renton before discharging into Lake Washington.

The BPA's complex drainage system includes several large lakes and wetlands. Lake Desire and Spring (Otter) Lake are on the plateau to the south of the lower Cedar River, and Walsh Lake is located in the middle basin. Shady, Peterson, Webster, Francis, and Retreat Lakes, and Lake No.12 are smaller lakes located on the plateaus. The artificially created lakes in the upper basin are Chester Morse Lake held by the Overflow Dike and Masonry Pool behind the Masonry Dam. There are a total of 74 inventoried Class I and II wetlands (767 acres) and many uninventoried wetlands scattered throughout the basin. Extensive wetlands abut the shorelines of Lake Desire and Spring, Peterson, Webster, and Francis lakes. Large wetlands are also found in the upper reaches of Taylor and Molasses creeks.

HISTORICAL LANDSCAPE AND SETTLEMENT PATTERN

Prior to twentieth century settlements, the Cedar River Basin was densely covered with stands of cedar, fir, and hemlock trees with a thick understory of vine maple, alder, crabapple, dogwood, devil's club, hazel, salal, and wild grape. Elk, black-tailed deer, black bear, cougar, red fox, coyote, river otter, and beaver were common throughout the basin (Bodurtha, 1989).

The basin settlement pattern began its transformation from Indian settlements to the present landscape with the Georgetown to Renton railroad in 1874. This led to the incorporation of Renton in 1901. At that time the Black River was the southern outlet for Lake Washington, with the Cedar River flowing into the Black about a mile downstream from the lake. Between 1911 to 1916, the Hiram Chittenden Locks were built, the water level of Lake Washington was lowered, the lower end of the Cedar River was diverted into an artificial canal ending at Lake Washington, and the Black River dried up and its channel was filled (Chrzastowski, 1983). The diversion of the Cedar River was to both reclaim land for the growing Renton community and to provide fresh water to operate the Locks.

The lower basin was settled by homesteaders, coal miners, and farmers. Homesteaders, shortly after arrival in the late 1800s, cleared 40 to 80 acres or more per family for their homes. Dairy farming was also established at the turn of the century with cows grazing the valley floor in the present area of the Maplewood Golf Course and Jones Road. Coal was discovered around 1870 and, soon after, a small coal mining town was built at Cedar Mountain. Railroads built in the area for the coal towns also provided transportation for people and goods through the valley. Mining continued in this area until 1947 (Slauson, 1967).

Settlement of the valley and plateaus proceeded slowly along the railroad route due to the difficulty of travel through the thick forest. The roads of the late 1800s and early 1900s were often impassable, but early bridges were built at Renton, Elliott, and Landsburg. By 1920 a reliable road was built between Renton and Maple Valley and the Maple Valley community began to grow rapidly. Roads were built to Hobart and Black Diamond, further expanding transportation of goods, people, and services. Logging roads soon joined these major routes and the virgin forest was clearcut throughout the lower basin, opening the plateau land to development.

The upper basin (above Landsburg) was not developed because the City of Seattle purchased this area for water supply in the 1800s. In 1904, the City of Seattle built a timber crib dam on the Cedar River that transformed a natural lake (Cedar Lake) into Chester Morse Lake. This water was then piped into Seattle. Most of the land downstream from the crib dam was logged by the 1930s, and the dam was replaced with the Overflow Dike in 1988. In 1916, the Masonry Dam was built forming Masonry Pool. In addition to water supply, the City of Seattle began the operation of the Cedar Falls hydroelectric project in 1904, which now supplies more than 8,000 homes with electrical energy (Slauson, 1967).

In the 1920s settlement increased on the valley floor, despite its flood-prone nature, because of the flat open spaces and easy access to the river and the adjacent highway. The 1936 aerial photographs show that the river upstream from the Renton channel was mostly unconstrained, except for a few local levees and revetments built to protect the railroad and roads. After a large flood in 1959, King County's Department of Public

Works built extensive levees and revetments, most of which were completed by the late 1960s. The majority of the river bends between Renton and Maple Valley are now constrained by levees or revetments.

The Cedar River is a very significant regional water supply. The upper basin provides 70% of the municipal and industrial water needs for the City of Seattle and surrounding metropolitan areas. The river provides 54% of Lake Washington's water supply, which is important to the operation of the Hiram Chittenden Locks for commerce, for ship passage, and control of salt water intrusion (URS, 1981). State, Tribal, and County agencies managing fish and wildlife resources are concerned with maintaining adequate flows in the river to enhance the habitat for anadromous (migrating) salmonids and resident fish.

1.6 LAND USE / LAND COVER

The Cedar River BPA has a diverse mix of land use and land-cover types, ranging from urban impervious-surface areas to rural forestry lands (Map 3, *Appendix B*). Major communities include the City of Renton (the only incorporated area) Maple Valley, Fairwood, Maplewood Heights, Summit, Ravensdale (in part), and Georgetown. The population was estimated using the percent of 1990 census tract areas within the basin. There are approximately 15,400 people within the City of Renton's limits and 40,000 people in unincorporated King County, for a total basin population of approximately 55,400 in approximately 18,450 housing units (King County, 1991a).

Conversion of forest cover to urbanization and other development has increased the amount of impervious surface area (e.g., roads, parking lots, roofs, sidewalks,) and grass cover in the BPA. These land covers have increased the volume of stormwater runoff and stream flows (Figure 1-1), with related increases in erosion and sedimentation, habitat degradation, flooding, and nonpoint water pollution problems. The problems are most severe in or surrounding the lower tributary channels and the lower Cedar River mainstem, but they do exist throughout the basin. Areas that are currently affected by these problems, and other areas that are presently unaffected, are expected to see an increase in the frequency and magnitude of problems in the future unless preventative measures can be instituted.

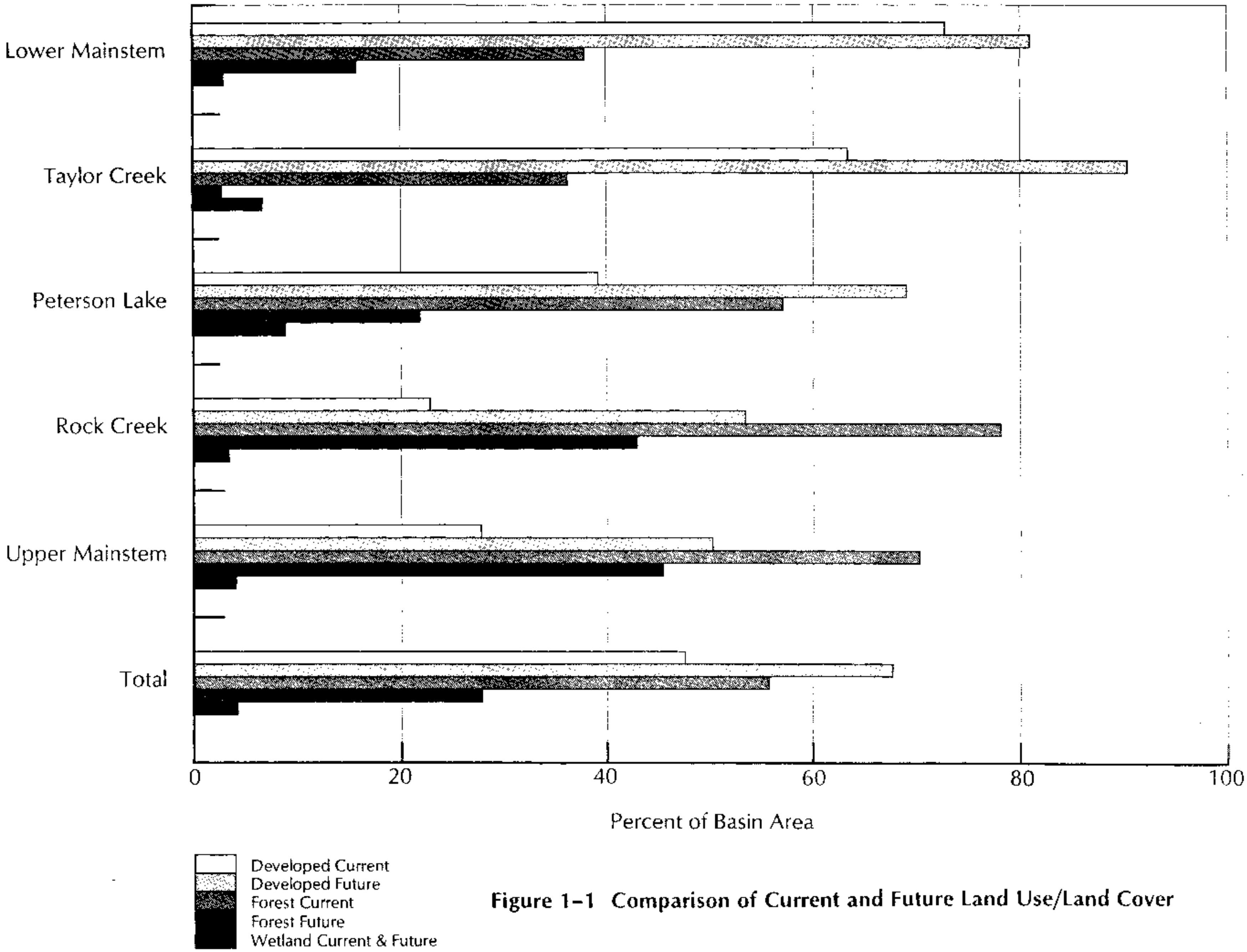

Figure 1-1 Comparison of Current and Future Land Use/Land Cover

CURRENT LAND USE

Residential, industrial, and commercial land uses are currently dispersed throughout the BPA. Residential land-use tends to decrease in density eastward from the urban area of Renton to rural and medium-densities around Maple Valley, to forested, low-density residential areas in the middle basin. The area of Renton within the Cedar River Basin contains multi-family or high-density, single-family residential uses. The high-density, single-family residential pattern extends beyond Renton's city limits onto the plateaus to the east and along the lower reaches of the river, including the large subdivisions of Maplewood, Fairwood, and Maplewood Heights. About halfway between Renton and Maple Valley, residential land use on the plateaus decreases to a mosaic pattern interspersed with forest and grass cover. South of Lake Desire and Cedar Mountain the residential areas become low density, primarily in forest cover, with higher residential densities surrounding the small communities of Maple Valley, Summit, Georgetown, and Retreat Lake and Lake No. 12.

Industrial and commercial land use dominates and creates expansive areas of impervious surface along the lower reach of the Cedar River in Renton. Other areas of major industrial use are located along Cedar Grove Road, including a gravel pit, the King County Cedar Hills landfill site, Cedar Grove Composting, and the Queen City Superfund site. Along SR-169 there is a metal recycling business and there are several small quarries. Interspersed with rural residential uses, there are small farms, small quarries, and rural home occupations.

Commercial forestry is a major land use in the BPA upstream of Maple Valley. The City of Seattle owns extensive forest lands within the BPA to the south and north of the diversion dam at Landsburg. The Rock Creek Subbasin is primarily private forest lands, with large sections of recent clearcut. Below Maple Valley, the City of Seattle owns forest lands around Lake Youngs. There are also private forest lands north of Cedar Mountain.

FUTURE LAND USE

Future land use in the BPA was mapped assuming the maximum level of development allowed under current (1992) zoning by the comprehensive land-use plans for Newcastle, Soos Creek, Tahoma-Raven Heights, and the City of Renton (Map 4, *Appendix B*). The mapping also includes significant changes in future land use that have resulted from the Washington State Growth Management Act (GMA), which required the County and cities to determine the extent of their urban growth areas. Based on the percent of growth estimated in the above comprehensive plans, the total basin population in 2000 is projected to be 73,250 (32% increase from 1990) with approximately 6,000 new housing units. In 2010, the total basin population is projected to be 93,000 (68% increase from 1990) with 12,548 new housing units (King County, 1991a).

Most of the new housing units will be in unincorporated King County and are expected to occur on the plateaus within the urban growth boundary (UGB) established under the GMA. Impervious-surface areas and multi-family residential uses are anticipated to approximately double within the UGB by the year 2000. The plateaus will be almost entirely built out in single-family, high-density residential uses. Only the steep knolls and bluffs above the river will remain in forest. Significant future areas of mixed commercial and high-density residential use will be on the plateau northeast of Renton and along the SR-169 corridor between SR-18 and Summit. Future industrial expansion along Cedar Grove Road will approximately double its current area of industrial land use. All of this high intensity development will add significantly to the impervious surface area that sheds stormwater and urban pollutants. Only the upper areas of the middle basin are planned to remain as undeveloped forest.

In response to the GMA, the area upstream of Maplewood Heights was redesignated from high-density to low-density, residential land uses. Another result of the GMA is that the Georgetown area, in the Rock Creek subbasin, is to remain rural with a small commercial center. The County Council is reviewing the Briarwood area, between 156th and 183rd Street, to determine future residential densities.

STATE SHORELINE DESIGNATIONS

The Cedar River shoreline has been designated as a Shoreline of the State from its mouth to its headwaters. The Shoreline Management Plans of King County and the City of Renton define two environments, "Urban" and "Conservancy," for the designated shorelines. These environment classifications provide a uniform basis to apply policies and land-use regulations within distinctly different shoreline areas. The Urban designation extends from the mouth of the Cedar River to river mile (RM) 2.1 on both banks and from RM 2.1 to RM 3.4 on the right bank (looking downstream). The objective of the Urban designation is to ensure appropriate use of shorelines within urbanized areas by providing for public use, especially access to and along the water's edge, and by managing development so that it enhances and maintains shorelines for multiple urban uses.

The Conservancy environment is on the left shoreline from RM 2.1 to RM 3.4 and on both banks from RM 3.4 to the river's headwaters. The Conservancy designation consists of shoreline areas that are primarily free from intensive development. It is the most suitable designation for shorelines areas of high scenic or historical values, for areas unsuitable for development due to biophysical limitations, and for commercial forest lands. The objective of the Conservancy designation is to protect, conserve, and manage existing areas of irreplaceable natural or aesthetic features in essentially their native state, while providing for limited use of the area. The preferred uses are those that are non-consumptive of the physical and biological resources of the area.

The lower reach of Rock Creek is a Shoreline of the State, designated as Conservancy, because its average annual flow exceeds 20 cubic feet per second (cfs) from RM 2.6 to its confluence with the Cedar River. The average annual flow may drop below 20 cfs between approximately RM 1.0 and RM 1.6 because of the City of Kent's diversion of water.

RECREATIONAL USE

The natural beauty and recreational resources of the Cedar River Basin are dependent on conservation of the natural system. As the basin continues to develop, park systems could serve as natural community separators (formerly termed "greenbelts") while contributing to the health of the natural system. The Cedar River Basin provides a wide variety of recreational resources through its system of parks, hiking, biking, and equestrian trails. In the lower and middle basin, the park and open space system is interconnected with an abundance of streams, wetlands, and lakes, as well as the Cedar River, within a green, open corridor that extends into the Cascade Range. This natural system provides active recreational opportunities, such as swimming, walking, and fishing and passive recreational opportunities, such as picnicking, educational or scientific study, and views of the Cedar River corridor.

The Cedar River Trail was chosen in September 1992 as the top pedestrian-bicycle project to receive regional funding. The trail will run 15 miles from Renton to Maple Valley following the river along the former railroad right-of-way. It will connect existing parks located along the lower reach of the river and could provide a major link in the regional trail system proposed by King County and in the proposed and existing community trail systems of the Tahoma-Raven Heights, Soos Creek, and Newcastle community plans (King County, 1991b, 1984, 1993). Community trails provide access to natural areas and parks, as well as creating linkages between the residential areas and commercial centers. Many of the trails are on early mining, logging, or settlement roads, giving them historical significance as well as recreational value.

In addition to the Cedar River Trail, land near Lake Desire and Spring Lake was acquired through the King County Draft Open Space Program to provide public access to open space for recreation. The wetland corridor and potential shoreline access along Lake Desire qualified the area as one of twelve sites to be acquired in the Open Space Plan (King County, 1988). Currently, the King County Department of Parks and Recreation is developing a comprehensive parks plan that will identify additional recreation and open space sites in the county. The plan will update and expand the 1988 Open Space Plan and is scheduled to be completed in the summer of 1993.

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Chapter 2: Geology and Groundwater in the Cedar River Basin

2.1 INTRODUCTION

The Cedar River drainage basin is unique of the basins in King County because it traverses the landscape from the foothills of the Cascade Range almost to Puget Sound. Extending 15 miles from east to west, it lies directly across the southerly advance of the great ice sheet that covered the lowland 15,000 years ago. The geology of the basin (Map 5) thus displays a variety of glacial deposits, covering environments from near the ice-sheet margin in the east to the ice-sheet interior in the west. These deposits now mantle most of the land surface in the basin, particularly the upland plateaus that flank both sides of the Cedar River valley.

In this basin the structure of the underlying bedrock has exerted very little influence on the modern form of the basin. This stands in marked contrast, for example, to the adjacent Issaquah Creek basin just to the north (King County, 1991a; Booth and Minard, 1991). Although the gross trend of the Cedar River, with eastern headwaters and a western mouth, reflects the uplift of the Cascade Range bedrock, the river itself has carved almost entirely through glacial deposits without any significant constraint from the topography of the bedrock surface. Indeed, drillers' logs suggest that the major east-west bedrock valley, with a maximum depth in excess of several hundred feet below the bottom of the modern Cedar River valley, actually lies about two miles north of the present course of the river.

The Cedar River drainage basin also provides some of the best glimpses into the older glacial history in this part of the Puget Lowland. Along much of its length the Cedar River has sliced through several hundred feet of sediment that predates the last glaciation, offering many examples of the complex sequence of deposits that underlie most of the Puget Lowland but are only rarely displayed at the land surface.

The characteristics of the surface and subsurface deposits control the infiltration, movement, and storage of groundwater. Infiltration at the surface depends on the permeability of the surface sediments and the accessibility of those sediments to precipitation. Thus outwash deposits, consisting of silt-poor sand and gravel, provide the best opportunities for infiltration where exposed at the ground surface. Till, in contrast, has a much higher percentage of silt and clay and so offers significantly more resistance to flow. The soil layer developed on top of the till, however, has much greater infiltration, but the movement of water is largely restricted to that thin upper soil zone ("interflow").

Although groundwater exists by definition in all saturated geological materials, it is accessible for water use or discharge to surface-water bodies only where it can move freely through subsurface deposits. These freely transmitting deposits are characterized by relatively large pores and are known as aquifers. In this basin, the various outwash deposits of the last glaciation form the most common aquifers. In contrast, deposits that restrict the movement of groundwater are called aquitards (if they are moderately restrictive) or aquicludes (if they are strongly restrictive).

Not only the presence but also the sequence of layered aquifers, aquitards, and aquicludes affects groundwater movement. Aquifers exposed at the surface provide not only areas of easy infiltration but also shallow zones of groundwater storage and movement. If shallowly underlain by an aquiclude or aquitard, typically till, then the groundwater is "perched" above deeper zones and may locally appear at the surface as springs or wetlands. Aquifers at greater depth may have less direct access to surface waters, with recharge occurring only by slow percolation through overlying aquitards. Discharge from these deeper aquifers is most commonly at hillside springs and along hillside drainage courses, where the groundwater reemerges along the exposed edge of the deposit. During the course of a year, that discharge may fluctuate, as the water level in the aquifer rises and falls with seasonal precipitation patterns. Conversely, aquifers that are well-isolated from surface recharge areas may show very little seasonal variation in either water-table level or baseflow discharge, because the rate at which water reaches the aquifer is so slow.

In addition to the mapping of geologic materials across the basin (Map 5), the distribution of recharge zones was mapped as well (Map 6). These results were based on the geologic map, SCS Soil Survey maps covering the same area, estimated depths to the water table, and hillslope gradient (EMCON, 1992, unpublished data). Although this map provides little information about where the water goes once it is infiltrated into the ground surface, it does provide a useful starting point for more site-specific studies of groundwater recharge and storage.

The surficial geology of the Cedar River Basin was mapped for this basin plan in 1988, 1990, and 1991 using road cuts, stream exposures, valley sidewall exposures, construction excavations, and selected well logs. Previous work, notably Mullineaux (1965a,b) and Rosengreen (1965), is of particularly high quality and so provided a valuable introduction to the area. Additional information on the bedrock lithology and structure was compiled from Vine (1969) in the eastern part of the basin and from Walsh (1984 and unpublished data). Additional sources include mapping for the adjacent Soos Creek (King County, 1991b) and Issaquah Creek (King County, 1991a) basin plans, Frizzell and others (1984) for parts of the eastern basin planning area, and recent unpublished data by EMCON Northwest on the occurrence of groundwater in the basin.

2.2 REGIONAL HISTORY AND STRATIGRAPHY

BEDROCK LITHOLOGY AND STRUCTURE

The entire east-central Puget Lowland is underlain by Eocene (about 40 million years old) volcanic and sedimentary rocks. In the Cedar River area these rocks are exposed at the surface along the valley bottom near Renton and again near Cedar Grove, and in the uplands east of Ravensdale. Near Renton they are overlain locally by younger sedimentary rocks; and just east of Lake Desire they are intruded by younger volcanic dike rocks.

This sequence of rocks, which is many thousands of feet thick, has been regionally folded along northwest-trending horizontal axes. The dominant fold affecting the basin is the Newcastle Hills anticline, whose axis and corresponding bedrock uplift trend west-northwest to form the Newport Hills. The Cedar River drainage basin thus lies on the southwest limb of that fold. Farther to the southwest, away from the anticline axis and out beyond the edge of the basin, bedrock is buried progressively deeper by glacial sediment and is not exposed at the surface. In the eastern part of the basin, a complex sequence of minor folds and faults, documented by Vine (1969) because of the significance to tracing coal beds for mining, gently warps the bedrock strata.

Although the overall form and trend of the basin are determined by the bedrock structure, even the main Cedar River valley itself is not controlled by that bedrock. Instead, erosion in the underlying rock surface forms a much larger subsurface valley extending southeast out of the Issaquah Creek basin, running beneath what is now the plateau of Cedar Hills, Lake Kathleen, and Maplewood, at a maximum depth of over 500 feet below ground level (Hall and Othberg, 1974; Walsh, unpublished data). The northwest part of the Cedar River Basin lies on the southwest flank of that valley, presumably an infilled arm of an ancestral Puget Sound.

The Eocene sedimentary rocks have been actively mined for coal for about a century. The most recent mine, the John Henry coal mine, lies just west of Lake No. 12 near the southern edge of the basin. Although most of the historic mining activity has taken place just south of the basin planning area, past mining within the basin has occurred just south of Lake No. 12, between Lake No. 12 and Ravensdale Lake, between Ravensdale Lake and the Cedar River, just south of Cedar Grove Road at and beneath the Maple Valley Highway, near Lake Desire, and east of Retreat Lake on the slopes of Sugarloaf Mountain and on the plateau just to the northwest.

ICE OCCUPATION OF THE BASIN

Early Glacial Advances

Multiple invasions of glacial ice into the Puget Lowland have left a discontinuous record of Pleistocene glacial and interglacial periods. Originating in the mountains of British Columbia, this ice was part of the Cordilleran ice sheet of northwestern North America. During each successive glaciation it advanced into the Lowland as a broad tongue called the "Puget lobe" (Bretz, 1913).

The Cedar River drainage basin contains some of the best exposures of multiple glacial advances in the entire east-central Puget Lowland. In particular, the valley sidewalls and ravines adjacent to Jones Road SE, just north of the Cedar River, display multiple exposures of three glacial tills and intervening layers of glacial and nonglacial sediment. The uppermost till lies at or very near to the ground surface of the upland plateau; it was derived from the most recent glacial advance, named the "Vashon" by Armstrong and others (1965), and it was deposited about 15,000 years ago (Booth, 1987).

The two lower tills are not as readily assigned to particular glacial advances because no absolute ages have been determined for either of them. However, the lower till has magnetic properties that place its age at less that 700,000 years old (D. Easterbrook, pers. commun., 1989), suggesting a correlation of the lower Cedar River valley tills with named drift units ("Possession" and "Double Bluff") on Whidbey Island (Easterbrook and others, 1967).

In between these various till layers are sediments that were waterlain in a variety of environments. Their thicknesses vary from a few feet to a few tens of feet, and none can be traced continuously for more than a mile or two (and most for much less). Some are clearly associated with glacial streams, because the grains are sand and gravel composed of a wide mixture of different rock types indicating transport from outside of the river basin. Others reflect lowland nonglacial conditions, with fine sediment and peat beds. Most of the valley walls of the Cedar River display a mixture of the coarse- and fine-grained sediment, which renders the exposed slopes very susceptible to landsliding and greatly impedes the vertical descent of percolating groundwater. In a few areas, sandy sediment clearly dominates and slopes there are well drained.

Some groundwater is pumped from these sediments of older glacial and nonglacial intervals. These deposits are not extensively exposed and have not been penetrated by a large number of wells, and so the details of their lateral continuity and potential productivity is not well known. Groundwater yields are not terribly high and generally require a substantial depth of penetration, except where those wells are started from the relatively low elevations of the Cedar River valley floor (EMCON, 1993, unpublished data). In general, such groundwater is well isolated from surface recharge and therefore is substantially protected from contamination.

The Vashon Ice Advance

The most recent ice-sheet occupation of the Puget Lowland climaxed about 15,000 years ago (see Booth, 1987, for a summary of current age data). At maximum stage ice covered the region to a depth of about 3000 feet, with the ice advance progressively filling drainages and then low-lying upland areas in the north.

Blockage of northward lowland drainage was followed by deposition of river-lain sediments as southerly drainage was established in front of the advancing ice sheet. At any given locality deposition of sand commonly gave way to gravel, reflecting the increasing gradients adjacent to the approaching ice sheet. These "advance outwash" deposits therefore typically coarsen upwards. They form the primary aquifer across much of the basin, with good yields from relatively shallow wells. Protection of the groundwater from surface contaminants in these deposits is generally provided by overlying glacial till. In this basin, these deposits are well exposed on the south side of the Cedar River along Molasses and Madsen Creeks, on the north side of the river below Lake McDonald southeast to Cedar Mountain, along Taylor Creek just east of Maple Valley, and in quarries just southeast of Lake Youngs and just west of the Cedar Hills landfill.

As ice covered the region, lodgment till was deposited by the melt-out of debris at the base of the glacier. This heterogeneous, compact sediment discontinuously blankets the area to depths of, at most, several tens of feet. Where present at the surface it provides a low-permeability cover to underlying aquifers, reducing recharge but also offering protection from surface contaminants. Elsewhere, it is overlain by more permeable sediment, but the till is still present at depth and so slows groundwater migration and recharge. That layer is nearly continuous across the upland plateaus in all but the far southeastern part of the basin and where locally breached by excavations for gravel pits or landfills.

The Vashon Ice Retreat

Recession of the ice sheet was accompanied by both outwash deposits and ice-dammed lakes, analogous to those formed during the ice advance. Water from the melting ice sheet and the Cascade Range drained southward and westward, spilling over divides that were later abandoned as the ice pullback exposed lower routes farther north.

Deposits in the Cedar River drainage basin span much of the recessional period and provide graphic illustration of the withdrawal of ice from the region. Six discrete stages can be distinguished in this basin, with the earliest deposits generally in the east part of the basin and the younger deposits progressively farther west.

Stage 1 is represented in the basin only by ice-contact deposits on the flanks of Taylor Mountain above Walsh Lake. These deposits lie between about 800 and 1200 feet elevation, over 1500 feet below the ice-maximum level in this area. During this time drainage from the Snoqualmie River basin was forced south and east by the ice sheet, flowing through the gap between Rattlesnake Mountain and the main Cascade rangefront, a gap now occupied by Rattlesnake Lake eight miles east of Walsh Lake (the "Cedar Spillway"). South of this gap water reencountered glacial ice and was diverted just east of the basin towards Howard Hansen Reservoir up a valley east of the town of Selleck.

Stage 2 reflected the first drainage of water over ice-free ground in the basin. The dominant water flow was still from the Snoqualmie Valley through the Cedar Spillway, but the ice front had withdrawn to the vicinity of Retreat Lake. Water thus flowed on both sides of Sugarloaf Mountain southwest towards the Green River, with hummocky ice-contact topography stretching in a broad band between Walsh Lake and Retreat Lake to mark the location of the ice margin during this time.

Stage 3 required about three miles of ice-sheet retreat from the Stage 2 position, probably taking a decade or less. It allowed drainage southwest out of the basin through the areas of Georgetown and Ravensdale Lake (just west of the basin), Summit, and just north of Wilderness Lake (2.5 miles south of Maple Valley). This stage was a time of massive drainage and deposition both for the Cedar River Basin and the adjacent Soos Creek basin, during which many square miles of nearly flat, very permeable gravel and sand deposits were spread across the landscape. Across this area surface-water channels are very limited because most of the water today can easily flow through the subsurface.

Stage 4 deposits are distinguished from those of Stage 3 because of small, but critical, changes in the ice front on both sides of the basin. To the southwest, ice withdrawal allowed a lower drainage route to open near Auburn, rapidly allowing a broad valley to incise 100 feet into the Stage 3 deposits one mile south of Maple Valley. This valley now contains Jenkins Creek; it also provides the route for SR-18 as it leaves the Cedar River valley towards the south. Northeast of the basin, ice was retreating north from the upper Issaquah Creek valley and exposed spillways from that valley east of Hobart that drain into the Taylor Creek Subbasin. The area around Francis Lake, including active gravel pits immediately northwest, was deposited during this time.

Stage 5 includes the time of first drainage down what would eventually become the path of the modern Cedar River. Instead of its modern elevation, however, that flow was perched on top of the till uplands, descending from nearly 400 feet elevation near Cedar Grove to about 300 feet elevation just east of downtown Renton. At this lower level, the flow entered Glacial Lake Russell (Thorson, 1980), consisting of the interconnected channels and major lake basins of southern Puget Sound with a southerly spillway near Tumwater into the Chehalis River and then to the Pacific Ocean. The ice margin, at about the latitude of Seattle during this time, blocked northerly drainage out of the lowland. Other drainage channels during the early part of this stage include broad flat-bottomed valleys that drain south out of the modern Cedar River Basin from near Madsen Creek into the head of Lake Youngs and from the Fairwood area into upper Big Soos Creek.

Stage 6 is represented more by the topography of the basin than by specific deposits found within it. Drainage of Puget Sound was reestablished to the north as ice evacuated the lowland, and so the level of Lake Russell fell in two stages back to sea level. The "base level" of the Cedar River thus dropped almost instantaneously by 250 feet, precipitating a rapid downcutting of the river that would have progressed upstream from its mouth at Renton, where the drop was first felt by the water flow. The resulting downcutting has left the modern form of the Cedar River valley, a 2000-foot-wide cut through the glacial landscape and in places over 300 feet below the upland surface. Subsequent to that downcutting, the Cedar River has swung to and fro across the valley bottom, scouring and redepositing its modern floodplain and obliterating any remnant deposits in the valley that might have recorded this time of initial incision. Only along Maxwell Road, between Cedar Grove and Maple Valley, are low terraces preserved, suggesting an intermediate level of the river between its Stage 5 flow, on top of the glacial uplands, and its modern level through the valley-bottom floodplain.

2.3 POSTGLACIAL PROCESSES AND DEPOSITS

DEGLACIATION AND LANDSCAPE CHANGES

In the Cedar River drainage basin, emptying of the regional glacial-age lake was an event of major geomorphic, and ultimately human, importance. As a result of that lake drainage, the Cedar River incised through a complex sequence of glacial and non-glacial deposits, leaving high and steep valley sidewalls that line both sides of the river for over 10 miles. Because of the multiple glaciations represented in these valley-side deposits, the modern Cedar River obviously has not reoccupied its pre-Vashon course, which likely lies a few miles north in the Issaquah and May Creek basins.

Following initial downcutting, the Cedar River has filled part of its present-day valley, and the broad plain on which downtown Renton is located, with thick deposits of sand and gravel. Because of high permeabilities and easy access of Cedar River water into these deposits, groundwater yields are very high and the depth to the water table is minimal, although seasonally fluctuating (EMCON, 1993, unpublished data). The absence of overlying sediment, however, leaves this groundwater source at risk from surface contaminants.

Flanking the river, the valley sidewalls are the scene of particularly severe landsliding and erosion, a consequence of their steep gradient and complex stratigraphy. A prehistoric landslide, in excess of 100 acres, lies on the south side of the Cedar River above Maplewood. Another zone of discrete landslides lies in the Dorre Don area upstream of Maple Valley, where recent meanders of the Cedar River have further undermined the valley walls and initiated very recent movement. Elsewhere in the Cedar River valley, deposits of mass movement, including landslides, are readily identified and line both sides of the valley between Maplewood and the old King County shops three miles upvalley, and again near Cedar Grove. Individual landslides in these areas are too old, too small, or overly obscured by vegetation to individually map.

Valley-side erosion and stream incision are also common in this environment. Almost any discharge over the lip of the valley wall is erosive, because of the gradients; and where sandy deposits of either the Vashon advance outwash or older deposits are encountered, severe erosion results. The major prehistoric ravines of the basin, such as Molasses Creek, Madsen Creek, and Peterson Creek, are testament to this process in the natural environment. In the human-affected environment, increasing runoff has yielded even more rapid erosion in some of these and other tributaries.

On the surrounding uplands, soil formation has proceeded slowly but with profound hydrologic consequences. Bare, unweathered till absorbs water only very slowly; in contrast, the several feet of soil that has developed on that surface since deglaciation have high infiltration capacities and a large capacity to store and slowly release subsurface runoff (see *Chapter 3: Surface Water Hydrology*). This till-derived "Alderwood" soil blankets the majority of the upland plateau. Its hydrologic properties differ dramatically from its underlying parent material, and so the compaction or removal of that soil during typical urban or suburban development result in commensurately large hydrologic effects.

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Chapter 3: Surface-Water Hydrology

3.1 INTRODUCTION

This chapter describes the surface-water hydrology of the Basin Planning Area (BPA), which includes approximately sixty-six square miles draining to the Cedar River below the Seattle Water Department's (SWD) diversion dam at Landsburg. The BPA represents approximately the lower one third of the entire Cedar River Basin; consequently mainstem flows are greatly affected by inflows from the upper basin (above Landsburg) and some analysis of the upper basin, albeit less detailed, is relevant. The discussion focuses on the past (pre-development), current, and future magnitudes of flow rates in the mainstem of the Cedar River and its tributaries within the BPA.

At its mouth in Renton, the Cedar River drains an area of approximately 188 square miles. Average annual precipitation generally increases in the upstream direction (southeast) with increasing elevation, from 42 inches in Renton to 54 inches at Landsburg. In the upper basin, average annual precipitation continues to increase with elevation up to a maximum of 200 inches per year. Elevation in the basin reaches a maximum of 5,400 feet at Tinkham Peak. Snowfall represents the dominant portion of precipitation in approximately the upper third of the basin. Oceanic storms lasting one to three days cause major floods to occur on the Cedar River between the months of October and June. Storms may cause sufficient increases in air temperatures to produce significant melting of snowpack. Upper basin snowmelt combined with rainfall-induced runoff causes many of the largest flood events in the basin. The City of Seattle's Masonry Dam impounds waters from 78.4 square miles of the upper basin, which is approximately 65% of the basin area upstream of the BPA and 42% of the entire basin. Dam operations are primarily for purposes of water supply via the Seattle Water Department (SWD) diversion near Landsburg. Dam operations and flow diversion are significant determinants of both the high- and low-flow regimes of the river from Landsburg to its mouth in Renton.

3.2 HYDROLOGIC CONCEPTS

Runoff can be divided into several related, yet distinct, components. Hillslope runoff that causes high rates of channel flow (i.e., discharge) within a day or so of rainfall is usually classified as storm runoff. Precipitation that percolates to the water table and reaches the stream slowly is called groundwater or baseflow. Storm runoff, in turn, can be generated by one or a combination of several mechanisms: Horton overland flow, saturation overland flow, shallow subsurface flow (interflow), or groundwater flow.

HORTON OVERLAND FLOW

Horton overland flow is generated when the rainfall intensity is in excess of the current infiltration capacity of the soil, which is a function of soil type and antecedent moisture content. Over the Puget Lowland, the 100-year, one-hour rainfall is about one inch per hour. Most undisturbed, vegetated soils in this area have a limiting infiltration rate of two to six inches per hour. As a result, under natural conditions little Horton overland flow is generated, because even the maximum rainfall intensity is easily exceeded by the minimum infiltration rates. However, once the land surface has been disturbed by removal of vegetative cover or compaction of the permeable surface soil layer, the probability of Horton overland flow is greatly increased.

SATURATION OVERLAND FLOW

Saturation overland flow is produced by rain falling directly on saturated soils. In this case, unlike Horton overland flow, the water is failing to soak into the ground because the ground is already full of water, not because the soil has low permeability. This mechanism commonly occurs under moderate to wet antecedent conditions in topographic hollows and wetlands and adjacent to stream channels, where the land surface becomes saturated by a rising water table. Irrespective of soil infiltration rates, the ground cannot absorb any additional precipitation, and all additional rainfall will flow over the surface.

INTERFLOW

Interflow is shallow subsurface flow generated by the rapid infiltration of rainwater and subsequent movement of this water through near-surface soil layers. This runoff mechanism is commonly associated with hillslopes underlain by nearly impermeable substratum (typically glacial till or bedrock) covered by shallow, much more permeable soils. The flow rate is proportional to the slope of the restricting layer. At breaks in slope or topographic convergences, water can reemerge to the surface (return flow), resulting in a 10- to 100-fold increase in flow velocity.

GROUNDWATER FLOW

Groundwater flow is generated by the infiltration and transmission of precipitation via flow paths that are modeled as much longer than those followed by shallow subsurface flow. Groundwater is a dominant runoff mechanism in areas where permeable soils are underlain by glacial outwash. The flow rate is proportional to the slope of the water table, which is generally low in outwash deposits. The longer flow paths, lower driving gradients, and generally larger storage capacities result in dramatically attenuated flow responses when compared to those of shallow subsurface flow or overland flow.

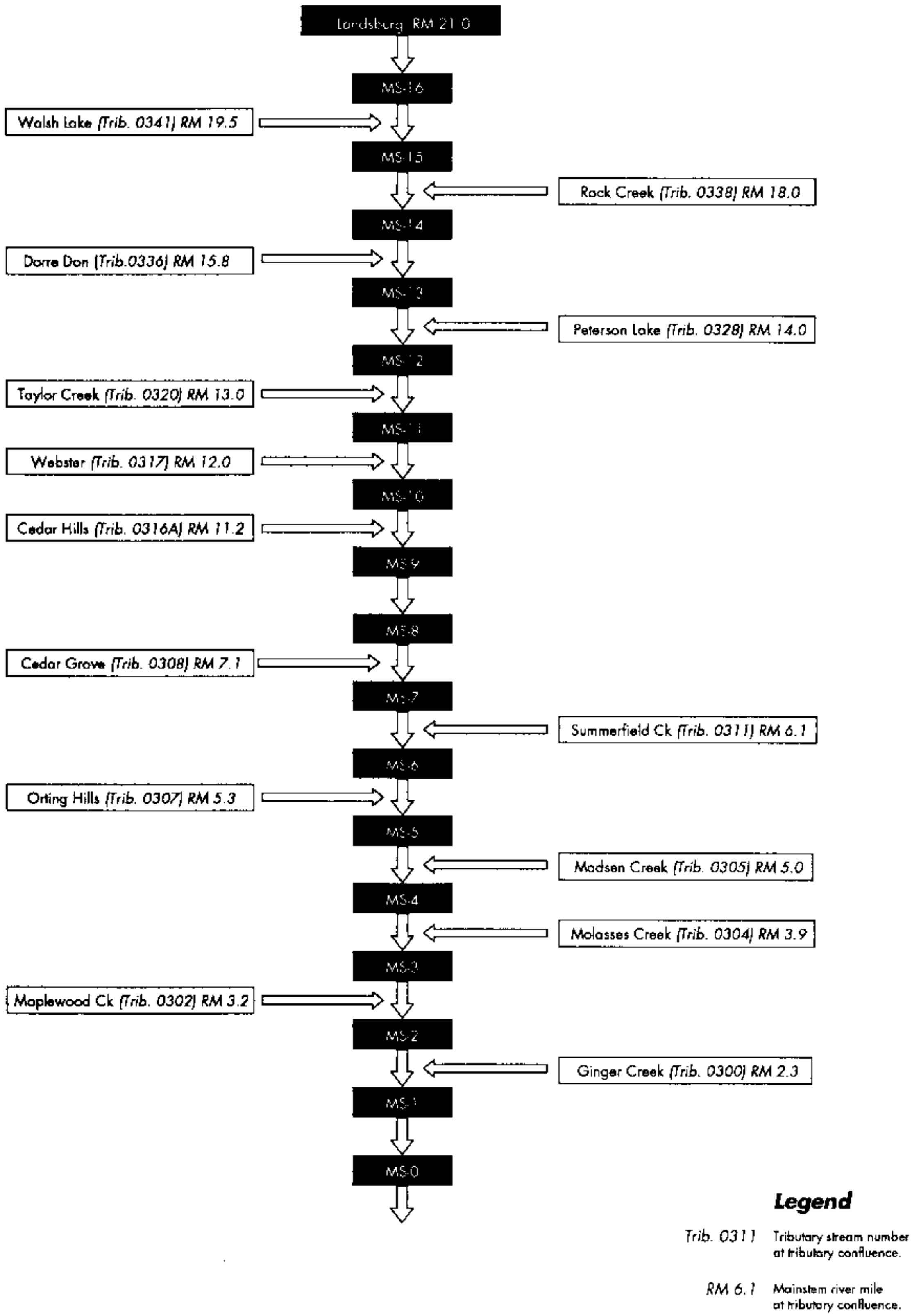
3.3 METHODS OF HYDROLOGIC DATA COLLECTION AND ANALYSIS

For purposes of the hydrologic analysis, the Cedar River Basin was partitioned as shown in Map 1 (*Appendix B)* into the upper basin and the BPA. The upper basin is largely owned and controlled by the City of Seattle as a watershed for water supply purposes. The middle and lower basin, or BPA, has been further partitioned into a series of subbasins and the subbasins into catchments. The subbasin arrangement is shown schematically in Figure 3-1, (note that these subbasin boundaries were used only for purposes of hydrologic modeling and may be different than those used elsewhere in this report). Land drained by each major tributary to the lower Cedar River is treated as a distinct subbasin. Additionally, land areas immediately adjacent to the Cedar River itself and labeled MS-0 through MS-16 are also treated as a subbasin. Subbasins have been further subdivided into catchments in order to distinguish and analyze flows in specific subbasin drainage components such as particular stream reaches, tributary branches, wetlands, ponds, or lakes.

In order to characterize flows in the Cedar River and its tributaries within the BPA for past, current, and future conditions, several statistical descriptors common in surface-water hydrology are utilized in this report. These include mean annual or mean monthly flow, annual maximum flow frequencies, and flow duration analysis among others. In order to be meaningful, these descriptors must be calculated from stream flow records of sufficient detail, quantity, quality, and consistency. The analysis of surface-water hydrology in this report relies on both measured climate and stream flow data. The most important climate data include rainfall and evaporation. In recent years, King County Surface Water Management (SWM) Division has collected contemporaneous, short-term records of both precipitation and stream flow on several tributaries in the BPA.

Ideally, accurate field measurements at all the locations and for all the situations of interest would provide the best flow records for analysis. However, such comprehensive data do not exist and would be impossibly time consuming and expensive to collect. Consequently, this report relies on the technique of hydrologic simulation modeling to extend limited field data in both space and time and to investigate stream flow behavior under different scenarios. These stream flow records, paired with the rainfall data, were utilized mainly for adjusting parameters in the Hydrologic Simulation Program-Fortran (HSPF) model to reflect site-specific conditions in subbasins of the BPA (KC-SWM

CEDAR RIVER HSPF FLOW CHART



Cedar River Basin Model Calibration Report, 1993). Long term precipitation and evaporation records collected by the National Weather Service (NWS) and United States Geological Survey (USGS) were used as data input in simulations of flows by the calibrated HSPF model. Additionally, historical records of both river discharges and diversions were utilized to characterize the general hydrologic behavior of the mainstem of the Cedar River.

HSPF MODEL

HSPF (EPA, 1984) is a general, continuous, hydrologic model. Surface, shallow subsurface (interflow), and groundwater flows can be simulated, lagged, and combined as discharge into a drainage network. In application, the basin to be modeled is divided into a number of catchments connected by channel reaches. This subdivision is based on topography, hydrological characteristics, the channel network, and locations of desired model output. The primary model output of interest in this report is a decades-long, continuous, hourly time series of stream flows, which can be used in flood frequency and other hydrologic analyses. This contrasts with event-type models, which only provide flow information about runoff from single storm events.

Individual catchments are further divided into pervious and impervious land segments. Impervious land segments represent the effective impervious area (EIA) within the catchment. The EIA is the total impervious surface area that is connected directly to the drainage system. Pervious segments are assumed to be homogeneous with respect to soils, vegetation, topography, and precipitation. Individual segments are simulated separately, with the results combined with other segments to yield the total catchment discharge.

Flows from catchments are combined and routed through the drainage network using a storage routing routine. Any conveyance system with a fixed relationship between depth, surface area, volume, and discharge can be modeled. This includes stream channels, lakes, retention/detention ponds, and reservoirs.

Model Application to the Basin Planning Area

Application of the HSPF model to the BPA required several steps. These may be classified as follows: basin segmentation, identification and quantification of hydrologically homogeneous land types, calibration of land-type parameters, hydraulic characterization of channels and impoundments, and definition of upstream flow conditions on the mainstem. Additionally, model input changes reflecting pre-development and future conditions had to be established.

Basin Segmentation and Land Type Calculations The segmentation of the BPA into tributary subbasins and the subbasin segmentation into catchments was described earlier in this section. As mentioned previously, each catchment is assumed to drain to a single hydraulic drainage element such as a stream reach, channel, lake, pond, or reservoir.

The total surface area belonging to each land type within each catchment was computed for input into the HSPF model based on zoning, topographic, soils, and surficial geology maps (see *Chapter 2: Geology*), aerial photos, and field reconnaissance. A summary of these computations is shown in Table 1 of the Hydrology Appendix at the end of this chapter. The model computes hydrologic response of each land type within a subbasin on a per-unit-area basis and apportions the amount of surface runoff, interflow, and groundwater entering the drainage element of each catchment consistent with the computed land-type area totals. Consequently, the model represents the hydrologic effect of spatial distribution of land types to the extent that land-type composition varies among catchments of a subbasin. However, it ignores the effects of the landscape position of land types **within** individual catchments.

There are three primary determinants of the hydrologic response of a system: soils, land cover, and slopes:

<u>Soils:</u> For hydrologic modeling purposes, all soils were classified as either till, outwash or wetland. Till deposits contain large percentages of silt or clay and have low percolation rates compared to outwash soils. Only a small fraction of infiltrated precipitation reaches the groundwater table. The rest moves laterally through the thin surface soil above the till deposit (as shallow subsurface flow), often re-emerging at the base of hillslopes. Soils may become saturated in large storms and produce significant amounts of surface runoff. The peak runoff rate from till areas is therefore generally much higher than from outwash 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 outwash deposits often intersect the groundwater table and receive most of their flow from groundwater discharge, unless the channel bed is located above the water table. Even for the largest storms, stream-flow response is slow, with peak flow often lagged up to several days.

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 provide some baseflow to streams in the summer months and attenuate storm flows via temporary storage and slow release in the winter.

<u>Land Cover:</u> Four land cover classes were considered in analyzing the BPA hydrology: forest, grass/pasture, impervious, and saturated. The percentages of each catchment

belonging to these four classes were determined from land-use delineations, which mapped nine land uses in the BPA. The relationship between the nine mapped land uses and the four HSPF-modeled cover classes are shown in Table 3-1.

Table 3-1 Land Use and Percentages of HSPF Cover Classes

Land Use	Percentages of HSPF Cover Classes			
	% Forest	% Grass	% Impervious	%Saturated
Commercial Uses	0	15	85	0
Residential Uses				
Multi-Family (7-30 du/ac)	0	56	48	0
High Density (3-7 du/ac)	0	75	25	0
Medium Density (1-3 du/ac)	0	90	10	0
Low Density-Grass (0.2-1 du/ac)	0	96	4	0
Low Density-Forest (<0.2 du/ac)	96	0	4	0
Grass/Park/Pasture	0	100	0	0
Dedicated Forest	100	0	0	0
Lake/Wetland	0	0	0	100

Forested areas generate the least amount of surface runoff. Forest cover is most significant in regions of glacial till where tree root systems open pores in low-permeability soil, allowing for increased infiltration. Forest litter provides additional soil-water storage and protects against compaction of near-surface soils. Interception of rainfall by leaves and removal of soil-water by evapotranspiration is also greater in forested areas than in the other cover categories.

Grassed areas produce more surface runoff than forested areas. When forest vegetation is removed to create grassed areas, surface soils are generally compacted during clearing, reducing infiltration capacities. Furthermore, because grass is shallow rooted, it does not contribute to infiltration as forest cover does. Grassed areas therefore saturate more quickly and produce more overland flow in large storms than forested areas.

Impervious areas consist of roads, rooftops, sidewalks, parking lots, driveways, and other constructed surfaces. They produce the most surface runoff of all cover categories. The infiltration rate in impervious areas is zero and water storage in surface depressions is minimal. As a result, virtually all rainfall runs directly off to produce high peak flows.

Saturated areas such as stream channels, 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, volume, and shape of the drainage element. Of these, volume has the most effect on reducing peaks. Thus, wetlands and lakes by virtue of their larger storage volume are typically more effective than channels at reducing flow peaks.

Slopes: Slopes influence the rate at which runoff discharges to the creek in till and bedrock soils. Slopes in these areas were grouped into three broad categories: flat (0-6%), moderate (6-15%), and steep (>15%). Steeper slopes have faster responses than moderate slopes. This allows the thin surface soil in steeper sloping areas to drain faster than soils in moderately sloping areas.

In outwash deposits, groundwater flow rates are proportional to the slope of the water table, but the water table is usually only mildly sloping in these deposits. As a result, no slope classification is used for outwash soils.

The Hydrology Appendix at the end of this chapter contains tables that summarize both the land-use (Table 2) and HSPF land-type composition (Table 1) of the BPA.

Calibration of Land Type Parameters The HSPF uses eighteen different parameter values affecting different components of the hydrologic computations to distinguishes the different hydrologic responses of each of the ten land types. Twelve of these parameters are assumed to take on typical values estimated for the lower Puget Sound region (Dinicola, 1990). Six parameters were calibrated using short-term rainfall and stream discharge records. Calibration data allowed the estimation of subbasin-specific parameter sets for the five till and outwash land types. Regionally constant parameters values were used for the wetland (W) and impermeable (I) land types. A detailed discussion of calibration procedures and results for the BPA is given in a separate calibration report (K.C., 1993).

Hydraulic Characterization of Channels and Impoundments HSPF computes outflows from all channel segments, ponds, reservoirs, and lakes using a level pool routing method. The model user must input a storage-outflow table for each element of the drainage system in order for the model to perform unsteady flow routing. Ponds and reservoirs with engineered outlets usually have well-defined relationships between water level, and storage volume and discharge. For lakes and ponds with natural stream outlets, the storage-outflow relationship was estimated based on field observations and weir equations (Chow, 1959). The storage-discharge relationship for subbasin stream reaches with no obvious control point was computed from field estimates of cross-sectional geometry and channel roughness that were used as inputs into the Manning equation for uniform flow to determine discharges at different flow depths. For the mainstem Cedar River catchments, a series of HEC-2 backwater computations were used to estimate the storage-discharge relationships for each catchment river reach (see *Chapter 4: Flooding*).

Upstream Inflow at Landsburg: HSPF simulation of flows in the mainstem of the Cedar River within the BPA required the routing of flows from three sources: BPA tributary streams, BPA mainstem catchment runoff, and upper basin inflow at Landsburg. Tributary discharges were computed by making separate hourly time-step runs for the 40-year precipitation record on each of the tributary subbasins. Flows from the upper basin were computed using the Seattle Water Department's Seattle Forecasting Model (SEAFM) (Marino, undated). SEAFM is a hydrologic model that has been expressly customized for the Cedar and South Fork Tolt River basins and includes components that simulate natural hydrology of the upper Cedar River Basin as well as the City of Seattle's operations at Chester Morse Lake and the Landsburg Diversion Dam. SEAFM's hydrologic algorithms are almost identical to HSPF's. SEAFM was used to create an hourly time series of flows at Landsburg that reflect the Seattle Water Department's current operational procedures (R.W. Beck, 1988). The SEAFM-simulated hourly flows were used in BPA simulations instead of the USGS gaged flows at Landsburg. The City of Seattle's operations have changed at intervals over the years with the most recent changes occurring in 1988 when major improvements to the Masonry Dam outlet works were completed. Consequently, the SEAFM-simulated flows were judged to be more consistent and more representative of **current** flow conditions than the historical record.

Pre-development, Current, and Future Conditions Continuous hydrologic simulations in the BPA were carried out under three separate development scenarios: pre-development (forest), current, and future.

Pre-development or forest condition simulations provide statistical indices by which current and future hydrologic conditions of BPA streams and the Cedar River can be judged. Field observations show that streams draining catchments and subbasins where forest cover has been undisturbed for several decades tend to be more geomorphically stable, provide more and better aquatic habitat, evidence higher water quality, and have much lower flood peaks than catchments where forests have been cleared. Consequently, the pre-development stream flow regime is assumed to represent a benchmark from several points of view. For the purposes of hydrologic simulations, pre-development stream flows were generally represented solely by converting all currently observed grass and impervious land-type areas to forest cover land-types. There were two notable exceptions to this rule. First, in the Cedar Hills Subbasin, both forest cover and outwash soil replaced mined areas modeled as grass-tills under current conditions because of the past removal of outwash by mining operations. Second, existing, constructed sediment or retention/detention ponds are eliminated from flow routing in a few subbasins such as Madsen Creek.

Current cover conditions in the BPA were determined primarily from aerial photos taken in July, 1989. Photogrammetric data were supplemented to determine catchment land-type composition using zoning, soils and topographic maps, as well as field reconnaissance during 1990 and 1991.

Future conditions in the BPA were modeled by assuming the maximum level of land development allowed under current (1992) zoning by the comprehensive plans for Newcastle, Soos Creek, and Tahoma-Raven Heights in King County and the City of Renton Comprehensive Plan, as well as the Growth Management Act (GMA). Future conditions were modeled with two scenarios, development with mitigation and development with no mitigation. The mitigated scenario included the following assumptions:

1. Future development in medium or higher density zones is mitigated by construction of retention/detention (R/D) ponds that are designed to maintain 2-year and 10-year return period storm discharge levels at their pre-development levels (King County SWM Design Manual, 1990).

2. Future development in all low-density zones includes no mitigation because most of this development is expected occur as projects that would be too small to be governed by R/D pond regulations.

Under the unmitigated future scenario, R/D ponds are not included regardless of zoning.

The same (current conditions) SEAFM simulated record of hourly inflows at Landsburg is utilized for all development scenarios in modeling BPA mainstem flows. Thus, current and future simulation results in the lower Cedar River reflect past and anticipated future changes within the BPA given constant conditions in the upper basin.

3.4 CHARACTERIZATION OF BASIN STREAM FLOWS

GENERAL

The focus of this section is stream flow in the BPA tributaries and the mainstem of the Cedar River below the SWD's diversion at RM 21.6. However, conditions in this part of the mainstem are greatly affected by inflows from the upper basin. Consequently, the discussion of stream flows in this section is divided into three parts: upper basin effects, BPA tributary stream flows, and BPA mainstem flows.

UPPER BASIN EFFECTS

Flows in the Cedar River are greatly affected by the City of Seattle's water supply and power generation facilities in the upper part of the basin. A schematic of these facilities is shown in Figure 3-2. The Overflow Dike and Masonry Dam, located at RM 37.2 and 35.6 impound stream flows in Chester Morse Lake from an area of 78.4 square miles, which represents 65% of the upper basin and 42% of the total Cedar River Basin area. The water surface elevation-storage relationship for these dams is shown in Figure 1 of the Hydrology Appendix at the end of this chapter. The area above the dams is mostly mountainous, forested terrain that receives substantially more snow and rain than lower areas. Over 50% of the water yield of the entire basin passes through the reservoir (Chester Morse Lake). At RM 21.6, above Landsburg, a diversion dam allows the SWD to withdraw up to 340 cfs from the river, although the amount of water actually withdrawn depends on seasonal municipal and industrial demand, instream flow requirements, and the amount available from upstream. On average the SWD diverts 190 cfs, which is somewhat in excess of the amount of the average flow contributed by the BPA between the diversion and the mouth of the river. Thus, the average Cedar River flow as measured by the USGS gage in Renton (638 cfs) is somewhat **less** than the average flow as measured by the USGS upstream of the diversion near Landsburg (682 cfs).

Table 3-2 shows the relationship among the upper basin flows, SWD diversions, BPA flow contributions and Renton flows on a monthly basis. On average, 77% of the Cedar River's flow at Renton is contributed from the upper basin and 23% comes from the BPA. Historically, the SWD has diverted an average of 28% of the flow of the upper basin for water supply purposes.

Seattle may release water from Chester Morse Lake via several outlets depending on upstream inflows, reservoir levels, and downstream needs. These outlets include power generation penstocks with a total capacity of approximately 750 cfs, a low level outlet with a maximum capacity of 650 cfs, a service spillway with a maximum capacity of 4,400 cfs, and three gated emergency spillways with a combined maximum capacity of 70,000 cfs.

The emergency spillway gates were installed as part of the "Headworks Improvement Project" (R.W. Beck 1988) completed by Seattle in 1988. This installation was required by the Department of Ecology, Dam Safety Section to allow Masonry Dam to pass the probable maximum flood (PMF) without exceeding safe water surface elevations or overtopping. Since the PMF is supposed to represent the largest flood event theoretically possible, its probability of occurrence is vanishingly small. Thus, the installed emergency spillway capacity of 70,000 cfs is many times the maximum discharge of record on the Cedar River (14,200 cfs, USGS, 1992), which occurred in 1911 at Landsburg as a result of flashboard failure at the timber crib dam (a precursor to the current Overflow Dike).

Figure 3-2

Schematic of the Seattle Water Department's Facilities Above Landsburg

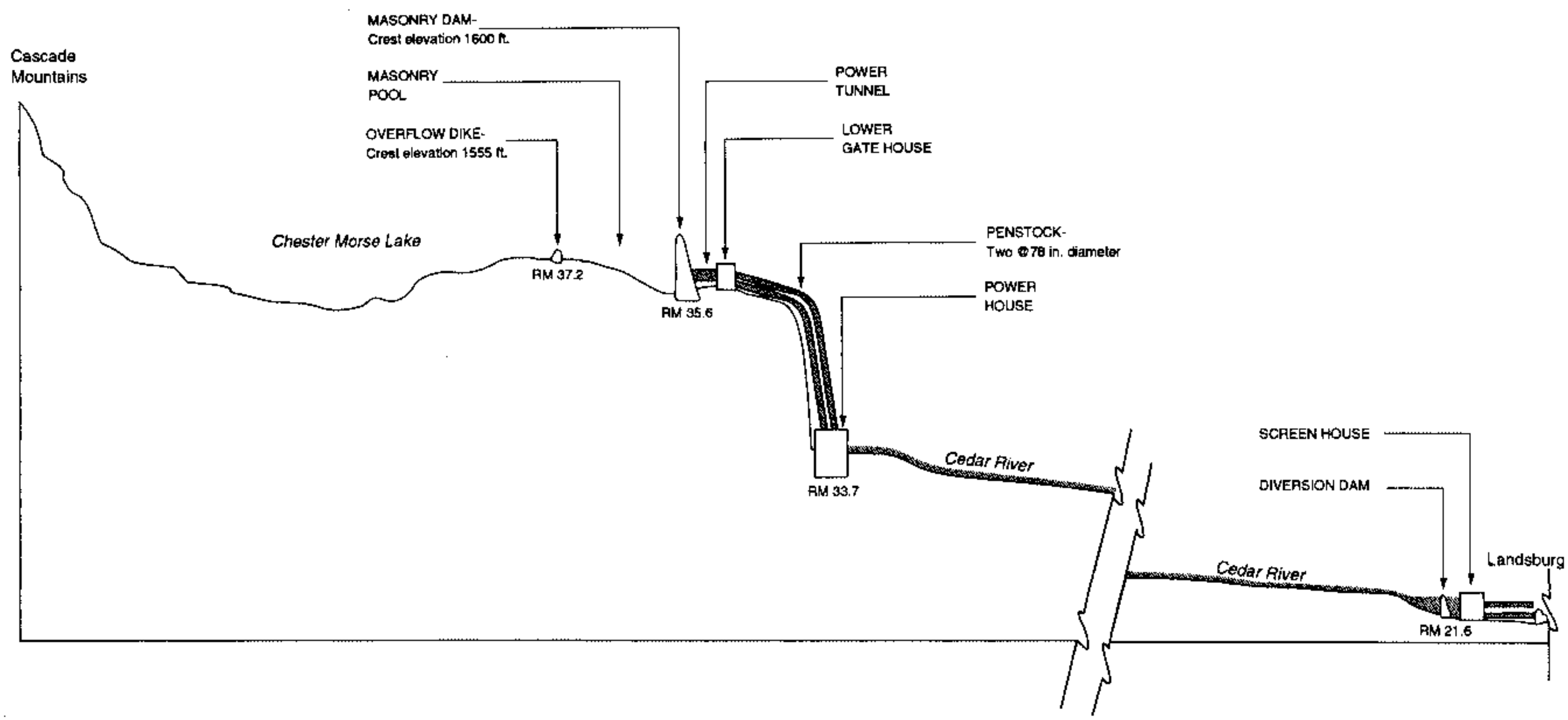


Table 3-2 Mean Monthly Flows and Diversion Rates

Month	Upper Basin[1] (CFS)	Diversion[2] (CFS)	BPA[3] (CFS)	Renton[1] (CFS)
January	1020	186	284	1118
February	940	186	248	1002
March	802	193	237	846
April	765	195	169	739
May	774	192	112	694
June	727	215	98	609
July	450	252	68	266
August	366	239	56	183
September	344	163	56	236
October	397	130	67	335
November	630	153	133	610
December	966	181	235	1020
Mean Annual	**682**	**190**	**147**	**638**

[1]From USGS gage data, 1962-1989
[2]From Seattle Water Department (SWD) data, 1962-1989
[3]From flow balance (BPA = RENTON + DIVERSION - UPPER BASIN)

Water released through Masonry Dam via the spillways or low-level outlet flows directly into the Cedar River channel immediately below the dam whereas flows released through the power penstocks return to the Cedar River below the power house at RM 33.7.

City of Seattle Water Rights and Instream Flow Targets

Seattle claims a water right to divert an average annual flow of 300 MGD (464 cfs) from the Cedar River (URS, 1981). As shown in Table 3-2, this claim is more than twice the rate of diversion that has been made in recent decades. However, in drought years, even historical average diversion rates may pose problems for downstream fish resources, water levels of Lake Washington, and the operations of the Hiram Chittenden Locks. In recognition of these issues, the City of Seattle cooperates with interested parties including the Department of Ecology (DOE), Department of Fisheries (DOF), Department of Wildlife (DOW), the Corps of Engineers (COE), and the Muckleshoot Indian Tribe to set minimum target flow levels (instream flows) at Renton. The purpose of these flows is primarily to protect fishery resources in the Cedar River, and secondarily to maintain a minimum water surface elevation in Lake Washington (R. W. Beck, 1988), and to allow operation of the Hiram Chittenden Locks for boat passage from Lake Washington and Lake Union to Puget Sound. The minimum instream flow targets are presented in Table 3-3. By consensus of the agencies involved, 1992 was designated "critical", and lower flow targets were invoked in recognition of the prevailing drought conditions in the region.

Table 3-3 Instream Flow Target Levels at Renton

Month	Normal Minimum (cfs)	Critical Minimum (cfs)
January	370	250
February	370	250
March	370	250
April	370	250
May	370	250
June	340	215
July	160	110
August	130	110
September	170	110
October	270	180
November	370	250
December	370	250

Limits on Masonry Pool Levels

The portion of Chester Morse Lake immediately upstream of Masonry Dam (Masonry Pool) has exhibited leakage into porous glacial soils on the north side of the pool, upstream of the dam (Bliton, 1989). Between 1916 and 1918 the pool was drawn down and various techniques were employed to seal the leaks. These techniques were not successful. In December of 1918, during the refilling of Masonry Pool, seepage caused a build-up of pressure in the Cedar embankment, which was suddenly relieved by a disastrous landslide and flood (the "Boxley Burst") in Boxley Creek, more than a mile north of the dam in the neighboring Snoqualmie River basin. Ever since, Seattle has limited

Masonry Pool water elevations. In 1974, 1975, and 1976, the Seattle District U.S. Army Corps of Engineers (COE) and the Seattle Water Department conducted a joint study of the effect of Masonry Pool elevations on groundwater, stream (including Boxley Creek), and lake levels in the affected area north and west of the dam (COE, 1979). COE recommendations and selected data from this study were subsequently incorporated into a geotechnical consultant's report (Shannon and Wilson, 1976) that concluded that Masonry Pool levels should be limited to an absolute maximum of 1,570 feet during peak flood conditions lasting up to a week and a maximum of less than 1,565 for periods of up to a few months. These limits were one of the reasons for the installation of PMF-capacity, emergency spillway gates, which was completed in 1988.

Compared to the original (1914) spillway elevation of 1,588 feet, the 1,570-foot limit has resulted in a loss of approximately 44,000 acre-feet of storage, which would otherwise have been available for water supply, power generation, or flood control purposes. Coincidentally, 44,000 acre-feet is roughly the same amount of storage as is still available under current flood-season operations between elevation 1,550 feet and 1,570 feet.

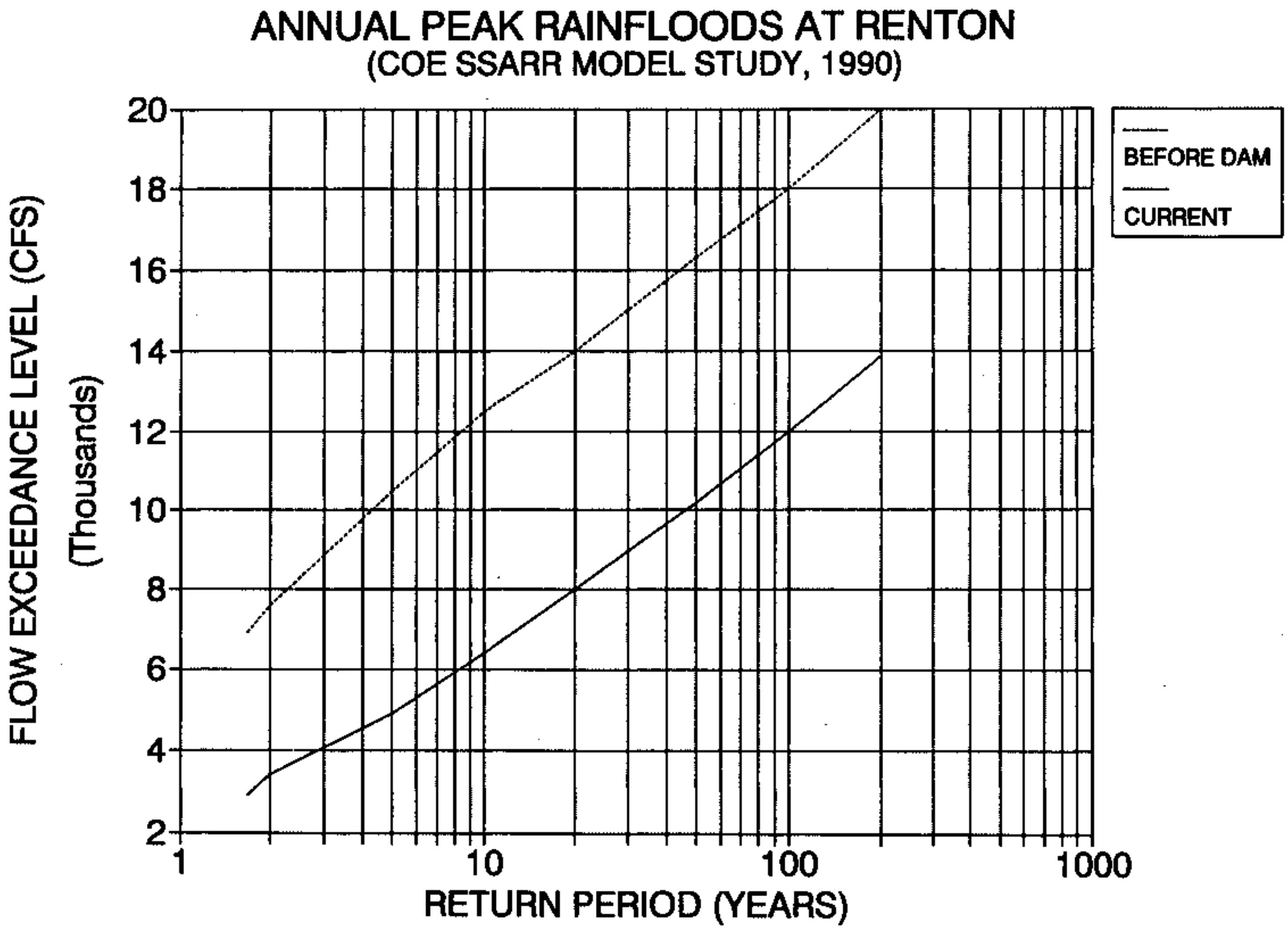
Effects of Seattle Water Department's Facilities on Mainstem Flow Regime

The effect of the City of Seattle's facilities on river flows between Landsburg and Renton depend in large measure on how those facilities are operated. These effects may be broadly categorized as wet season, flood-flow effects and dry season, low-flow effects. Under most circumstances, dams add to storage in a river system and consequently reduce downstream flood discharges. However, structural or operational failures can cause a dam to aggravate or cause a flood. Structural failure generally refers to a partial or complete rupture of a dam or its abutments and results from improper dam siting, design flaws, faulty construction, or other factors. Operational failure refers to sudden increases in reservoir outflows caused by overly rapid or excessive opening of flood gates. Electrical, mechanical, or logical malfunctions of gate control systems, as well as human error, can all contribute to operational failure. Such failures can cause reservoir discharges that are larger than peak reservoir inflows during a flood event and thus increase downstream flooding.

Flood operations for the Masonry Dam are defined by Seattle's "Operations and Maintenance Handbook - Cedar Falls Headworks Masonry Dam and Overflow Dike" (R.W. Beck, 1988). These operational instructions are designed to preclude most failures of the operational type from occurring at Masonry Dam. Basically, the handbook stipulates that during the flood season (October 1-March 31) the service spillway gate (4,400 cfs capacity) is to remain fully open. According to the handbook, this spillway is designed to pass floods up to the 100-year event without exceeding a reservoir level of 1568 feet. The emergency spillway gates (70,000 cfs capacity), however, are to be opened only under very infrequent, well-defined circumstances in which high reservoir elevations (greater than 1,560 ft) coincide with high rates of increase in reservoir level indicating extreme flood conditions. Under these conditions, the emergency spillway gates are to be opened only enough to arrest excessive increases in reservoir level and thus protect the dam's stability.

Masonry Dam spillway configurations are somewhat problematic in that emergency spills require carefully considered human intervention informed by continuous monitoring of reservoir levels. Additionally, emergency spills require the reliable functioning of complex circuitry, large electric motors, and machinery under what are likely to be less than optimal environmental conditions. Though the physical plant and associated procedures outlined in the handbook appear adequate to protect the dam from unsafe water levels and excessive discharges, the emergency spillway system at Masonry Dam is significantly less reliable than a free overfall spillway like the service spillway (with gate open). Unfortunately, the service spillway does not have sufficient capacity to accommodate emergency conditions.

Figure 3-3


ANNUAL PEAK RAINFLOODS AT RENTON
(COE SSARR MODEL STUDY, 1990)
FLOW EXCEEDANCE LEVEL (CFS)
(Thousands)
20
18
16
14
12
10
8
6
4
2
1
10
100
1000
RETURN PERIOD (YEARS)
BEFORE DAM
CURRENT

Estimated Effect of City of Seattle Current Operations on Mainstem Floods

The COE has studied alternative operating scenarios for Masonry Dam for the purposes of reducing flood damage in Cedar River (COE, 1990). Part of that work included a computer simulation study of the effect of current dam operations on annual flood frequencies at Renton. The COE estimated that the 100-year flood is reduced by approximately 33% from 18,000 down to 12,000 cfs and the 10-year flood is reduced by 46% from 12,000 down to 6,500 cfs for pre-dam conditions as compared with current dam operating conditions (see Figure 3-3) . According to this analysis, the flood attenuation effects of Masonry Dam and the Overflow Dike are substantial; however, it should be noted that the pre-dam analysis (upper curve in Figure 3-3) did not account for storage effects of Cedar Lake, a natural, smaller impoundment (some 25,000 ac-ft in size) that was inundated by Chester Morse Lake when the timber crib (precursor to the current Overflow Dike) dam was built in 1904. If it is assumed that the active storage in the lake was small in comparison to its volume, then the effect of Cedar Lake on pre-dam flood flows was probably minor, especially for larger and less frequent flood events. Thus, the pre-dam curve in Figure 3-3 would be only slightly high as a result of ignoring the lake's effect. Another factor to consider in evaluating the apparent flood reduction benefits shown in Figure 3-3 is the potential for significant human errors in dam operations and/or mechanical failures to degrade flood protection performance below what is implied by the difference between the two flood frequency curves. These types of contingencies are rare and very difficult to model.

Potential for Additional Flood Mitigation by Masonry Dam

In spite of the partial flood mitigation benefits of Seattle's current and past operations of Masonry Dam, substantial flood damages still occur between Landsburg and Renton (see *Chapter 4: Flooding*). Consequently, there has been a continuing interest in recent years on the part of both citizens and public agencies in securing additional flood protection for the lower Cedar River. Responding to these concerns, in 1986 the city of Seattle began a cooperative study with King County, the City of Renton, and the DNR. The cooperators contracted the COE to evaluate alternative operations of Masonry Dam to reduce flood damage along the Cedar River. Although the COE study was never completed, preliminary results illustrated several important points that should be addressed in the analysis of any proposed operational alternative:

a. Masonry Dam has limited potential to control flows in Renton, because some flood waters enter the Cedar River downstream of the dam. The COE used the Streamflow Synthesis and Reservoir Regulation (SSARR) model to investigate the feasibility of changing Masonry Dam flood operation to limit discharges at Renton to less than 4,000 cfs. They found that the dam could only maintain this level of control up to a 20-year return period rainfall event because of inflows to the Cedar River from tributaries downstream of the dam.

b. Changes in dam operation to reduce the frequency of very high annual flood peaks may increase the incidence and duration of lower, but still damaging, discharge levels. For example, the COE investigated one scenario that controlled flows in Renton at 4,000 cfs, but as a consequence the frequency and duration of discharges approaching the 4,000 cfs level increased. This resulted from the stipulation that flood storage taken up by an initial storm event should be rapidly recovered by power penstock and spillway discharges in order to provide storage for a subsequent flood event. The scenario was not acceptable to the City of Seattle and its cooperators because of anticipated flood and resource damages of discharges approaching the 4,000 cfs level.

c. Flood storage behind Masonry Dam is constrained by Seattle's primary obligation to provide its customers a reliable water supply. The COE found that annual peaks at Renton ranging from the 5-year to 100-year events could be significantly reduced without increasing the frequency of smaller flood peaks if reservoir levels were dropped from 1,546 to 1,540 feet during the flood season. Additionally, flood peaks in Renton could be controlled to less than bankfull discharge (5000 cfs) for events up to a 50-year return period. The SWD analyzed the effects of the COE's proposed scenario (Greenburg, 1990) and found that the firm yield of the reservoir would be reduced from 116 MGD down to 113 MGD. The cost of this loss was estimated "at a net present worth of $3 million for the project life" (COE, 1990).

d. The benefits of controlling flows to specific levels in Renton are dynamic. The COE (1990) noted that sedimentation of the channel between Interstate 405 and the mouth reduces channel capacity and lowers the threshold of nondamaging discharges. In contrast, dredging the channel would potentially maintain or increase that threshold (see *Chapter 4: Flooding* and *Chapter 5: Erosion and Deposition*).

King County (Bean, 1991) has made a preliminary analysis of an alternative flood-season operational strategy for the Masonry Dam that differs from previous approaches. This option would utilize a series of flood target discharges instead of a single one. Analysis suggests that both improved floodplain and fish resource protection might be possible given 45,700 ac-ft of fully controlled flood season storage at Chester Morse Lake. Although this analysis is very approximate in that it made no attempt to specifically model Masonry Dam's outlet works or to consider flood effects of uncontrolled local inflows downstream of the dam, the concept of a series of target dam releases may bare further investigation.

Based on past experience, the following points must be addressed in the evaluation of alternative flood control scenarios for Masonry Dam:

1. Any losses of power production and firm water yield resulting from changing Masonry Dam operations must be quantified, evaluated and reviewed by the City of Seattle and other agencies involved in water resources concerns on the Cedar River.

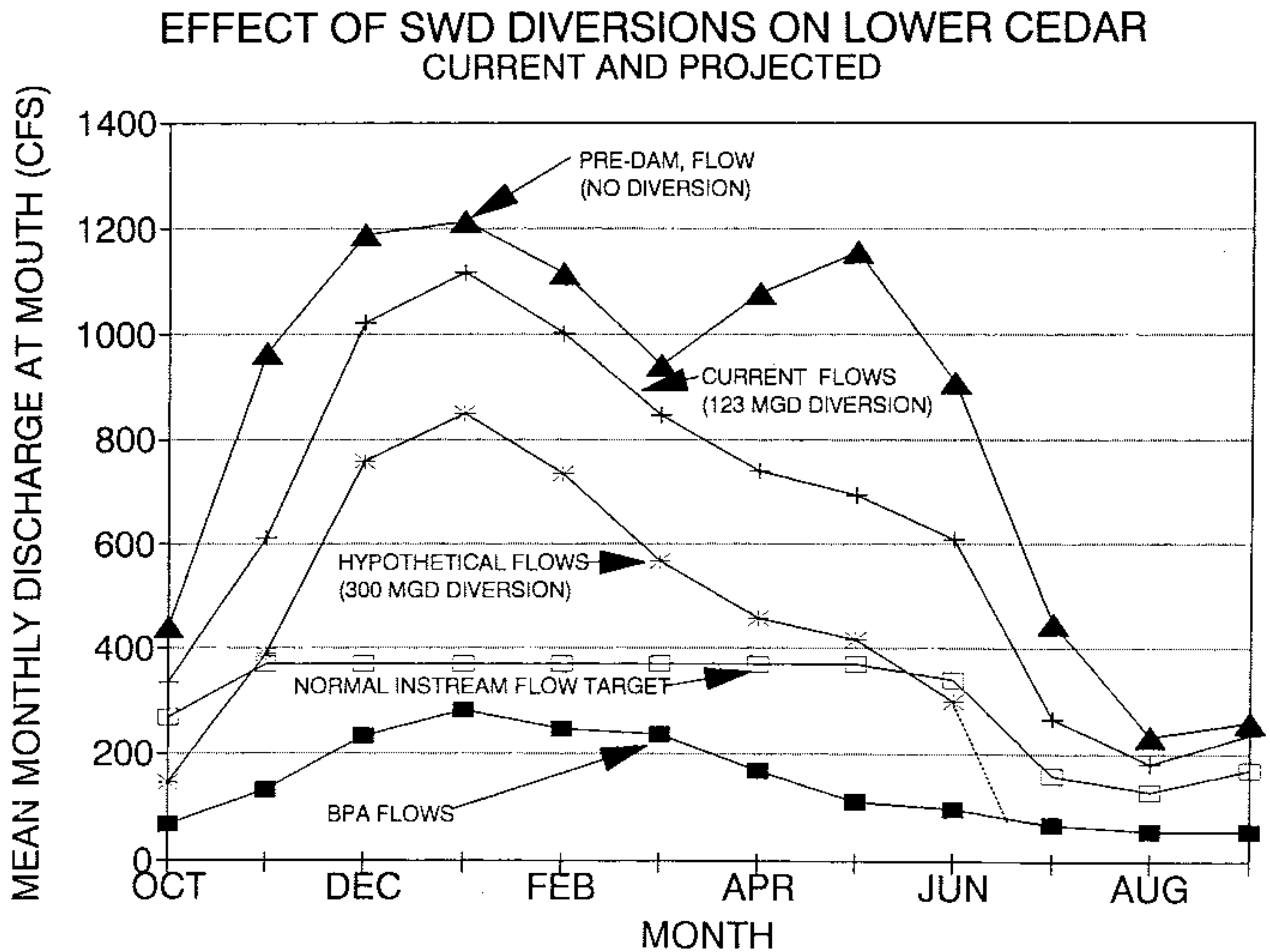
2. Hydrologic routing analysis should be utilized to account for modification of floods between Landsburg and Renton when comparing current Masonry Dam operation with alternative scenarios.

3. Benefits of flood control levels in Renton should be judged in relation to channel capacity, which is potentially changeable due to continued sedimentation or future dredging.

4. Durational analysis of flood flows resulting from current and alternative operational scenarios should be performed to assess comparative benefits for fish resources and sediment transport regimes of the mainstem.

5. Safety and reliability ramifications of service and emergency spillway gate procedures need to be evaluated for both current and alternative flood operation scenarios.

Figure 3-4



EFFECT OF SWD DIVERSIONS ON LOWER CEDAR
CURRENT AND PROJECTED
MEAN MONTHLY DISCHARGE AT MOUTH (CFS)
1400
1200
1000
800
600
400
200
0
PRE-DAM, FLOW
(NO DIVERSION)
CURRENT FLOWS
(123 MGD DIVERSION)
HYPOTHETICAL FLOWS
(300 MGD DIVERSION)
NORMAL INSTREAM FLOW TARGET
BPA FLOWS
OCT
DEC
FEB
APR
JUN
AUG
MONTH

Estimated Effects of City of Seattle Facilities on Low Flows

The current and potential future effects of SWD diversions on low flows in the Cedar River can be estimated from current stream flow gage records. Figure 3-4 shows a comparison of mean monthly discharges at the **river's mouth** for the following scenarios:

1. Pre-dam, pre-diversion conditions (triangles)

2. Current, 123 MGD diversion (pluses)

3. City of Seattle water claim, 300 MGD diversion (asterisks)

4. Normal instream target flows (squares)

Pre-dam, pre-diversion conditions in the lower Cedar River were estimated by reconstructing the pre-dam, mean monthly flows from the upper basin and adding mean monthly flows from the BPA. The upper basin, **pre-dam**, monthly flows were estimated based on an annual mean flow of 682 cfs with a monthly distribution based on USGS gage records for natural, uncontrolled streams in the upper basin. Two gages were used; the gage located 1.4 miles upstream of Chester Morse Lake on the Cedar River, and the gage on Taylor Creek (not the same Taylor Creek as in the BPA) near Selleck, which is an uncontrolled tributary entering the river between Masonry Dam and Landsburg. The resultant pre-dam, monthly distribution at the River's mouth plotted in Figure 3-4 reflects a Cedar River system with neither active reservoir storage nor diversion of water.

The effect of current dam operations and water diversions on the mean monthly flow regime at Renton is shown by comparing pre-dam (triangles) with current conditions (pluses) curves in Figure 3-4. Aside from the obvious reduction in flow throughout the year, current operations have had the effect of eliminating the second, May peak from the natural hydrograph, which had resulted from the melting of the winter snowpack in the Cascades. Less dramatic, though perhaps more important from the standpoint of fish resources, current condition low flows from July through October are on average from 9 to 40% less than pre-dam conditions.

The line connecting the asterisks in Figure 3-4 represents a hypothetical hydrograph of mean monthly flows in Renton with a diversion equivalent to the City of Seattle's water right claim of an average annual withdrawal of 300 MGD. This hydrograph was constructed assuming that the future monthly flow diversions would be distributed through the year in the same pattern as they are currently **and** that no additional reservoir storage would be added in the upper basin (the City of Seattle Watershed). The resultant hydrograph shows that mean monthly flows would routinely violate the normal instream flow requirement from June through October. Additionally, from July through September, the diversions would require more water than the current total river flow at Landsburg for those months. Thus, without additional upper basin storage, the 300 MGD diversion is not even physically possible in a water year with average monthly flows. Thus, increasing diversions on the Cedar River, or for that matter significantly enhancing the reliability of both the current 123 MGD diversion and instream flows, depends on additional storage. Although definition of the amount of additional storage required to accommodate the 300 MGD diversion is beyond the scope of this study, it would certainly be considerable in comparison to the amount of storage currently available at Chester Morse Lake.

BPA TRIBUTARY STREAM FLOWS

Continuous HSPF simulations of over 42 years of stream flows in each BPA subbasin tributary were conducted to characterize flow regimes under pre-developed, current, and future conditions. Simulations produced a 42-year time series of hourly discharges for each modeled flow element of each subbasin.

Water Yield

Average annual water yield of a basin is the portion of precipitation that discharges as stream flow. Expressed in another way, it is the remaining portion of average annual precipitation after evaporation, transpiration and deep percolation below the surface drainage system have been subtracted. In the absence of water diversions from a basin, average annual water yield equals the product of mean annual flow (e.g., cfs) and time (e.g., the number of seconds in a year) divided by the basin area (e.g., ft^2). Water yield is usually reported as depth in the same units as rainfall or as a percentage of rainfall.

Average annual simulated water yield for each of the tributary subbasins is tabulated in Table 3-4. For current conditions, water yield varies among the subbasins from 48 to 60% of precipitation. Water yield variations among subbasins depend on basin characteristics such as soils, cover, and the presence or absence of lakes. Land development and urbanization generally increase water yield in a basin. Areas cleared of forest cover infiltrate and transpire less water and produce more frequent and higher rates of surface runoff. Consequently, total evaporative loss from the subbasin diminishes and surface water yield increases. A fair correlation ($r^2 = 0.67$) exists between clearing and development of forested till soils and increases in water yield as shown in Figure 3-5. The percentage increase in water yield over pre-developed, forested conditions rises linearly with percentage of the basin that has been deforested. Scatter about the regression line is largely the result of differences in land-type composition of deforested land among the subbasins. Conversion of forested land to impervious surface causes a larger increase in total subbasin water yield than does a forest to grass conversion. Likewise, conversion of forest to grass cover causes a larger water yield increase on till soils than on outwash soils.

Table 3-4 Catchment Water Yield (based on HSPF simulations)

Catchment	Area (acres)	Mean Annual Rain (in)	Forested Conditions water yield (in)	Forested Conditions water yield (%)	Current Conditions water yield (in)	Current Conditions water yield (%)	Future Conditions water yield (in)	Future Conditions water yield (%)
Ginger	634	41.9	19.2	45.8	26.0	62.1	27.4	65.5
Maplewood	1099	43.1	20.6	47.7	25.3	58.8	29.4	68.4
Molasses	1161	45.3	25.4	56.1	29.2	64.4	31.9	70.3
Madsen	1419	45.7	23.9	52.2	29.4	64.3	31.2	68.3
Orting Hill	650	45.7	26.7	58.3	30.6	66.9	32.1	70.2
Summerfield	140	45.7	25.8	56.4	27.0	59.1	30.5	66.8
Cedar Grove	723	45.7	26.4	57.8	28.8	63.1	30.9	67.5
Cedar Hills	805	44.4	24.8	56.0	28.1	63.3	30.1	67.8
Webster	596	44.4	24.8	55.9	26.2	59.1	28.8	64.8
Taylor	3311	48.7	27.4	56.3	29.6	60.8	31.5	64.7
Peterson Ck	4043	44.4	19.3	43.6	21.1	47.5	24.7	55.7
Dorre Don	860	51.4	29.8	58.0	31.0	60.3	35.5	69.0
Rock Creek	7695	54.1	30.3	55.9	31.0	57.4	38.5	71.1
Walsh Lake	4218	54.1	28.0	51.8	28.0	51.8	28.0	51.8

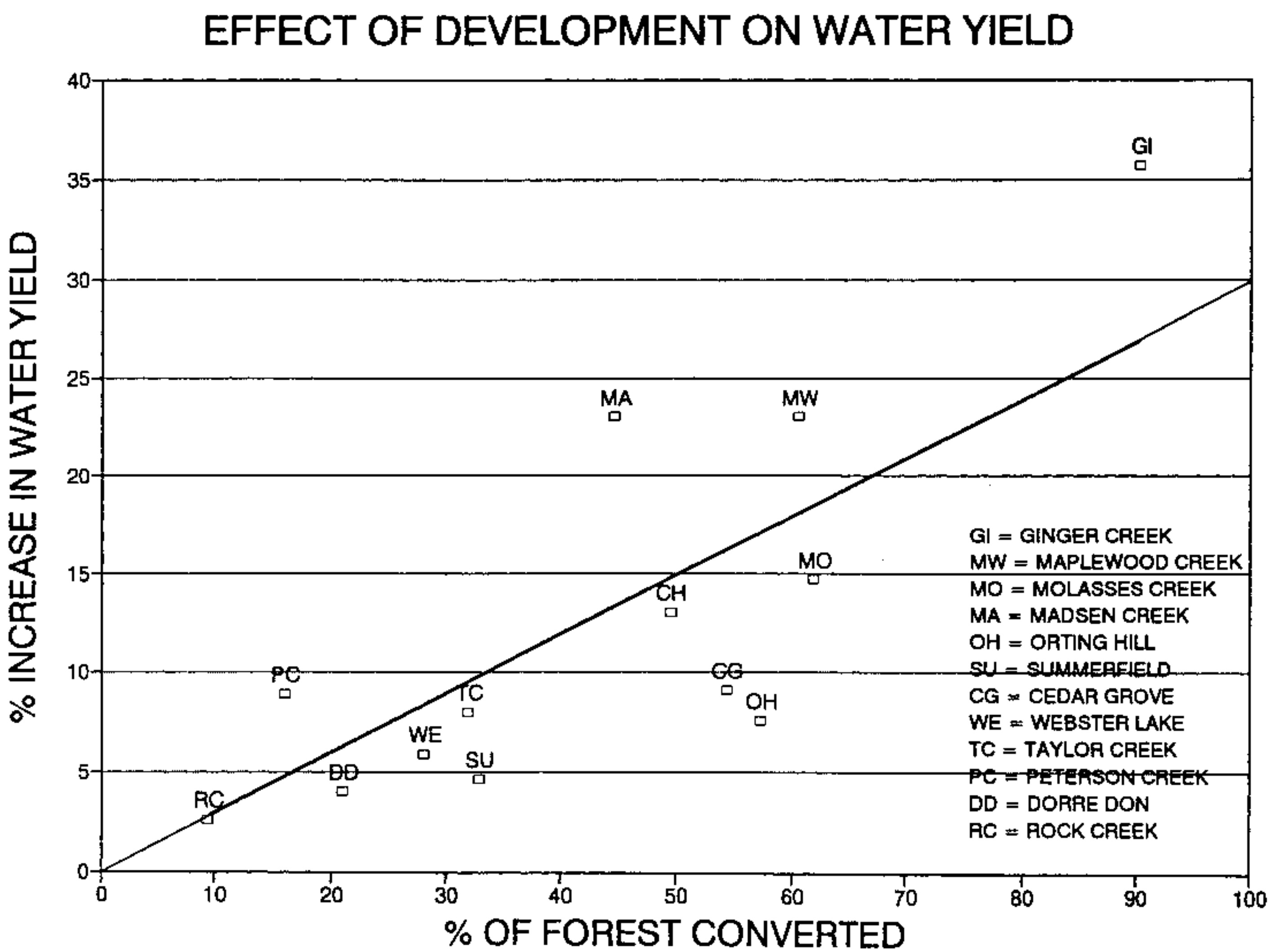
Mean Annual Flow

Mean annual flow is used to determine whether the filling of woodlands adjacent to a channel is subject to U. S. Army Corps of Engineers (COE) "Nationwide 26" permits (flow less than 5 cfs) or COE "Individual Section 404" permits (flows equal to or greater than 5 cfs). Channels with mean annual flows greater than 20 cfs are considered a "Shoreline of the State" and are designated Class 1 under the King County Sensitive Areas Ordinance, and as Type 1 in the King County Surface Water Design Manual. Map 7 (*Appendix B*) presents mean annual flow at the outlets of all modeled tributaries and at upstream catchments where mean annual flow is at or above the COE's 5 cfs threshold under current conditions.

As shown in Map 7 (*Appendix B*), Rock creek Exceeds the 20.0 cfs shoreline threshold from its confluence with the Cedar River upstream to approximately RM 1.7. This is based on the natural mean annual flow of Rock Creek. Gage data (USGS, 1985) spanning the 28-year period from 1946 to 1973 indicate a mean annual flow of 20.0 cfs ar RM 0.1. However, two major and an unknown number of minor diversions lowered the creek's mean annual flow and continue to do so today.

One major diversion directs a significant portion of drainage from Lake No. 12 and Wetland 92 at RM 4.4, Tributary 0339 in catchment R-7. The ditch has partially drained the lake and wetland to the Green River, at least since the early 1960s (Wolcott, 1965). A field check in the spring of 1993 indicated that the ditch diverted approximately a third of the flow (5.0 cfs) on that day.

Figure 3-5


EFFECT OF DEVELOPMENT ON WATER YIELD
% INCREASE IN WATER YIELD
% OF FOREST CONVERTED
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
90
100
GI
MA
MW
MO
CH
CG
OH
PC
TC
WE
SU
DD
RC
GI = GINGER CREEK
MW = MAPLEWOOD CREEK
MO = MOLASSES CREEK
MA = MADSEN CREEK
OH = ORTING HILL
SU = SUMMERFIELD
CG = CEDAR GROVE
WE = WEBSTER LAKE
TC = TAYLOR CREEK
PC = PETERSON CREEK
DD = DORRE DON
RC = ROCK CREEK

The second major diversion of Rock Creek is make by the city of Kent at its Clark Springs site (RM 1.7 of Tributary 0338 in catchment R-2). Kent has diverted water for municipal use from this site since the early 1900s. USGS records suggest that diversions increased form less than 1.0 to 4.0 cfs during the 1946-1973 gaging period. Kent's diversions continue today and have averaged 6.2 cfs in recent years—26% of Rock Creek's mean annual flow. More importantly, current diversions represent the majority of the creek flow during the low-flow months of September and October. For example, for two weeks in October 1992, only 1.7 cfs remained in the creek while the City of Kent diverted 5.8 cfs (City of Kent, 1992). The depletion of flows in Rock Creek and associated downstream fish resource problems have been a concern for several years (DOF, 1984).

According to Department of Ecology records (DOE, 1993a, 1993b) Kent holds one certificate of surface water right for 5.0 cfs, and two certificates of ground water rights-one for 5.0 cfs and the other for 12.0 cfs associated with their facilities on Rock Creek. Kent does not currently exercise the surface water diversion right because of water quality concerns, but uses an infiltration trench to collect water directly under and adjacent to the stream - as permitted by in their 5.0 cfs groundwater certificate. The other groundwater certificate for 12.0 cfs permits pumping from shallow wells adjacent to the Creek. These pumps have rarely been used because the sustained yield from pumping is no greater than the diversion by gravity using the infiltration trench. Additionally, the certificate that authorizes pumping also requires maintenance of minimum instream flows while the two other certificates do not.

There are several outstanding questions regarding Kent's diversions on Rock Creek:

1. How much of Rock Creek's flow is allocated to Kent- i.e., to what extent are the three certified rights additive or mutually exclusive?

2. What threshold activates the instream flow requirements specified on the 12.0 cfs groundwater certificate? For example if Kent diverts more than the 5.0 cfs limit specified on the infiltration trench certificate as they apparently have in recent years (6.2 cfs), are the instream flow requirements specified by the pumping permit supposed to be activated?

3. If an opportunity to augment Rock Creek minimum flows arose, would the instream flow regimen specified in Kent's 12.0 cfs groundwater certificate be adequate for maintenance of downstream fish habitat?

Maximum Annual Flow Frequencies

Maximum annual flow levels (quantiles) for 2, 5, 10, 25, 50, and 100-year return periods were calculated for forested, current, future-mitigated (with standard detention ponds), and future-unmitigated (no detention ponds) conditions. For example, the 25-year discharge at the outlet of Maplewood Creek (Q_{25}) is currently 97 cfs. This suggests that if current conditions persist, the maximum discharge at the creek outlet in any given year would have a 1 in 25 (or 4%) chance of equaling or exceeding 97 cfs. Flow quantiles for the outlets of each subbasin in the BPA are shown in Table 3-5. More detailed simulation results for all modeled catchments are tabulated in Table 3 of the Hydrology Appendix at the end of this chapter.

Flood Intensity Index (FII): The flow quantiles in Table 3-5 are individually useful for hydraulic analysis and design; however, it is easier to characterize the flood-flow behavior of each subbasin using a single number. For purposes of this discussion, the FII is defined as the 25-year return-period discharge divided by the subbasin area in square miles.

Table 3-5 Peak Annual Flow Quantiles of BPA Tributaries

		Return Period					
Tributary		2	5	10	25	50	100
Ginger Creek	Forest	17	27	35	47	57	69
	Current	63	86	101	121	137	152
	Fut/mit	63	85	101	123	140	157
	Fut./Un	69	93	111	134	152	172
Maplewood Creek	Forest	20	33	42	54	64	73
	Current	51	69	81	97	109	120
	Fut/mit	65	82	94	109	121	133
	Fut./Un	98	125	143	168	187	207
Molasses Creek (Fairwood)	Forest	35	56	72	96	116	138
	Current	96	131	153	180	200	220
	Fut/mit	99	132	154	183	205	227
	Fut./Un	130	171	200	238	268	299
Madsen Creek	Forest	48	75	96	127	153	182
	Current	132	182	217	262	297	331
	Fut/mit	145	199	236	284	321	360
	Fut./Un	156	213	251	302	341	382
Orting Hill (Jones)	Forest	29	44	56	74	90	108
	Current	54	77	93	114	130	147
	Fut/mit	52	73	89	112	131	151
	Fut./Un	88	117	136	160	177	195
Summerfield	Forest	5	8	9	12	13	15
	Current	4	6	7	8	9	9
	Fut/mit	6	7	9	11	12	14
	Fut./Un	7	8	10	13	14	16

Cedar Grove	Forest	40	55	65	79	88	99
	Current	59	79	92	109	121	134
	Fut/mit	60	79	93	112	128	144
	Fut./Un	84	110	129	154	174	196
Cedar Hills	Forest	6	8	9	11	12	13
	Current	8	11	13	15	16	18
	Fut/mit	11	15	18	21	24	28
	Fut./Un	11	15	18	21	24	28
Webster Lake	Forest	5	6	7	8	8	9
	Current	5	7	8	9	10	11
	Fut/mit	7	7	10	12	14	15
	Fut./Un	7	9	10	12	14	15
Taylor Creek	Forest	105	142	166	194	216	236
	Current	134	181	209	241	262	282
	Fut/mit	150	209	251	308	353	400
	Fut/un	150	209	251	308	353	400
Peterson Creek	Forest	86	141	180	233	275	319
	Current	104	171	218	281	329	377
	Fut/mit	151	221	268	329	374	419
	Fut/un	176	258	311	377	424	471
Dorre Don	Forest	23	38	49	65	78	91
	Current	34	53	56	85	99	115
	Fut/mit	59	84	102	126	145	164
	Fut/un	59	84	102	126	145	164
Rock Creek	Forest	70	112	136	190	227	264
	Current	80	130	158	221	264	308
	Fut/mit	117	203	256	371	453	538
	Fut/un	125	214	268	389	475	566
Walsh Lake Ditch	Forest	79	95	103	113	120	127
	Current	79	95	103	113	120	127
	Fut/mit	79	95	103	113	120	127
	Fut/un	79	95	103	113	120	127

Choice of the 25-year discharge is somewhat arbitrary; however past experience has shown that it often approximates the mean of the 2, 5, 10, 25, and 100-year discharges. The 25-year flow is divided by the basin area to facilitate comparison of the flood characteristics of subbasins of different sizes. Thus, the FII is useful both for tracking the flood effects of development within a subbasin as well as for comparing the flood behavior of different subbasins. FII values for each subbasin under forested, current, and both future conditions are given in Table 3-6.

Table 3-6 Flood Intensity Index Values (Q_{25}/Area in cfs/mi^2)

Tributary	Forested	Current	Future-Mit	Future-Un
Ginger Creek	47.4	122.1	124.2	135.3
Maplewood Creek	31.4	56.5	63.4	97.8
Molasses Creek	52.9	99.2	100.9	131.2
Madsen Creek	57.3	117.6	127.4	136.2
Orting Hill	69.4	107.0	105.0	150.1
Summerfield	54.9	34.3	48.0	57.2
Cedar Grove	69.9	96.5	99.1	136.3
Cedar Hills	8.7	11.9	16.7	16.7
Webster Lake	8.6	9.7	12.9	12.9
Taylor Creek	40.4	50.1	76.7	76.7
Peterson Creek	36.9	44.5	50.3	59.6
Dorre Don	48.4	63.3	93.7	93.7
Rock Creek	15.2	17.7	29.6	31.1
Walsh Lake Ditch	17.1	17.1	17.1	17.1

Forested Conditions: Under forested or 'natural' conditions, human impacts associated with land development are removed and FII variations among the subbasins are largely a function of variations in geology, soils, slopes, rainfall, the distribution of lakes, and other natural factors. Under forest conditions, the subbasins in the BPA can be divided into three categories, depending on their FII values: high, medium, and low.

The high category includes Cedar Grove, Orting Hill, Madsen, Summerfield, and Molasses with forest FII values greater than 50 cfs/square mile. These subbasins do not have lakes to buffer flood runoff and they are strongly dominated by till soils, which exhibit much higher storm runoff than outwash soils.

The medium group includes Ginger Creek, Dorre Don, Taylor, Peterson, and Maplewood with values between 30 and 50. In this group, Peterson flood intensities are moderated by the presence of Lake Desire, Spring (Otter) Lake, Shady Lake, and Peterson Lake accounting for about 9% of the subbasin area. Taylor Creek Subbasin has a similar percentage of its area in wetlands as well as 23% outwash soils. There are no obvious physical differences between the subbasins in the high group and Ginger Creek, Dorre Don, and Maplewood Subbasins of the middle group; however, simulation results supported by field data indicate that they do in fact have lower flood peaks.

The low group includes Rock Creek, Walsh Lake, Cedar Hills, and Webster Lake. Rock Creek peaks are greatly attenuated by the dominance of outwash soils, which cover 73% of the subbasin area. Outwash soils combined with significant surface-water storage from lakes or large ponds with highly restricted outlets account for the very low flood intensity index values associated with Walsh, Cedar Hills, and Webster Lake Subbasins.

Current Conditions

Current FII values reflect both natural variations among the subbasins and hydrologic impacts of land clearing and development. The effect of land development is dramatically illustrated by the difference in subbasin flood index ranking between forested and current conditions. For example, under forested conditions, the Ginger Creek Subbasin is estimated to produce the sixth highest FII, while under current conditions, it produces the most intense flood peaks of all the subbasins. This is the direct result of the conversion of 84% of Ginger Creek Subbasin's area to high-density residential land use and 9% to commercial use, making it by far the most urbanized subbasin in the BPA under current conditions.

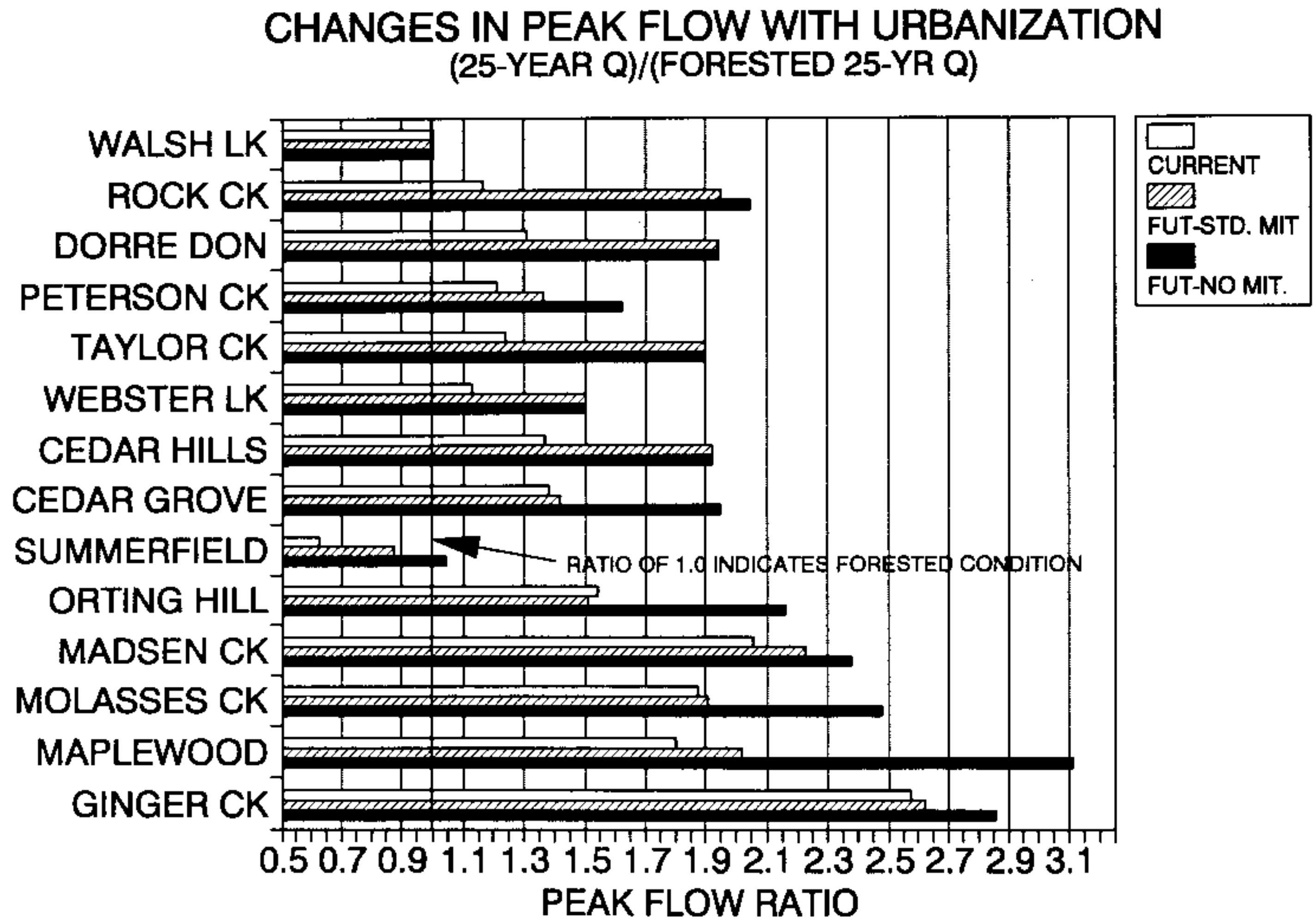
As shown in Table 3-6, the more urbanized subbasins in the lower part of the BPA (Ginger, Maplewood, Molasses, Madsen, Orting Hill and Cedar Grove) have experienced an average increase in flood peaks of 87% over pre-developed, forested conditions. This increase results from a conversion of 60% forest cover to 43% high-density residential, 14% low-density residential and 3% commercial development. Summerfield Subbasin is exceptional- while urbanization has claimed 33% of its forest cover, its current flood peak index value is 38% less than the value for forested conditions. This apparent contradiction results from the recent construction of a storm water diversion pipe that re-routes runoff from about the upper 50% of the subbasin. Consequently, the natural stream channel drains only half the original subbasin area.

Development has been less intense in the upper part of the BPA (Cedar Hills, Webster Lake, Taylor Creek, Peterson Creek, Dorre Don, and Rock Creek subbasins)- consequently, flood peaks have only increased by an average of 26%. This increase results from an average loss of 36% forest cover to 19% low-density residential, 14% grassed open space, and 3% high-density residential and commercial uses. Walsh Lake Ditch Subbasin represents another special case. The ditch only drains Walsh Lake and its surrounding tributary area. This area has been in forest cover for an extended period and is expected to remain so. Thus, peak flows for forested conditions are assumed also to be valid for current and future conditions in the Walsh Lake Ditch. It should also be noted that the lack of a difference in forested, current, and future peak flows in the ditch is not as suggestive of stable channel conditions as it would be for the natural streams draining the other subbasins (see *Chapter 5: Erosion and Deposition*).

Future Conditions with and without Mitigation

Future conditions assume full build-out or maximum land development consistent with current zoning. This includes the conversion of forest cover to grass or impervious cover in all areas not explicitly zoned for forest use. Under current regulations, land developers are generally required to install retention/detention (R/D) ponds to mitigate the hydrologic impact of urbanization on streams (King County, 1990). These ponds are

Figure 3-6


CHANGES IN PEAK FLOW WITH URBANIZATION
(25-YEAR Q)/(FORESTED 25-YR Q)
WALSH LK
ROCK CK
DORRE DON
PETERSON CK
TAYLOR CK
WEBSTER LK
CEDAR HILLS
CEDAR GROVE
SUMMERFIELD
ORTING HILL
MADSEN CK
MOLASSES CK
MAPLEWOOD
GINGER CK
RATIO OF 1.0 INDICATES FORESTED CONDITION
0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3 2.5 2.7 2.9 3.1
PEAK FLOW RATIO
CURRENT
FUT-STD. MIT
FUT-NO MIT.

designed to receive and detain the increases in surface runoff and interflow caused by the replacement of forest cover with less pervious grass cover and impervious surfaces. The ponds release storm water at a lower rate than the inflow rate but over a longer period of time. Thus, potential increases in stream flood peaks caused by development can be substantially reduced.

For comparison purposes, future conditions simulations were conducted both with R/D pond mitigation and without mitigation. Ponds were included in the future-mitigated simulations by designing a series of typical R/D ponds using the modified, 7-day, SCS-SBUH (Barker, 1992) procedure. This method is intended to limit 2-year and 10-year discharge levels after development to their pre-development levels. These ponds may be larger by 100% or more than ponds designed using methods outlined the 1990 Surface Water Design Manual. Those methods have been found to be inadequate in meeting post-development discharge standards (Barker, 1992) and the current methods are likely to be superseded sometime in 1993. Thus, use of the larger ponds in the simulations was judged to be more realistic in representing future conditions even though it is recognized that some urbanization will have been vested under the 1990 manual. As a result, the future-mitigated simulation results may slightly underestimate peak discharges. R/D ponds were inserted as storage routing elements in each of the catchments and long term simulations of full build-out conditions were conducted. Surface runoff and interflow from all areas converted to medium or higher urban density were routed through the ponds. It was assumed that areas to be converted from forest to low-density residential uses would not require detention because this type of development does not typically exceed regulatory thresholds.

Simulation results for both the future-mitigated (with R/D ponds) and future-unmitigated (no ponds) are also summarized in Tables 3-5 and 3-6 and in Figure 3-6. This figure depicts ratios of current, future-mitigated and future-unmitigated 25-year flood peaks to forested 25-year flood peaks for each subbasin. For example a ratio of 2.0 for a future-unmitigated condition signifies that without R/D pond construction, the future 25-year peak flow will be twice as high as the forested 25-year peak flow.

The BPA subbasins fall into three broad categories with regard to future conditions:

1. Subbasins that are currently almost completely built out: These basins are characterized by large (>2.0) current-to-forested peak ratios. Future-to-forest ratios are not much larger than current-to-forest ratios because most development has already occurred in these subbasins. This category includes Ginger Creek and Madsen Creek.

2. Subbasins that will experience substantial conversions of current forest cover to intense land uses: Owing to existing drainage regulations, these conversions are assumed to be mitigated by R/D ponds. Subbasins in this category include Maplewood Creek, Molasses Creek, Orting Hill, and Cedar Grove. In Figure 3-6,

current-to-forest ratios are less than 2.0 for these sub-basins. Future-mitigated-to-forest ratios are similar in size to current-to-forest ratios reflecting the effectiveness of the R/D ponds. Both of these ratios are significantly less than future-unmitigated-to-forest ratios.

3. Subbasins that will experience substantial future conversion of forest land to residential, low-density uses: Owing to existing drainage regulations, this conversion is not expected to be mitigated by R/D ponds. Consequently, future-mitigated-to-forest ratios are not much less than future-unmitigated-to-forest ratios. Both future-to-forest ratios are substantially larger than current-to-forest ratios. Cedar Hills, Webster Lake, Taylor Creek, Dorre Don and Rock Creek are in this category. Both Taylor Creek and Rock Creek may be of special interest in this regard. Residents living near Taylor Creek are experiencing flooding problems under current conditions and simulation results suggest that peaks may increase up to another 53%. Rock Creek is a large subbasin that is rich in fish habitat; flows in this subbasin may increase up to 67% over current conditions.

Peterson Creek Subbasin is by itself in an intermediate category between groups 2 and 3 above. It is projected to experience significant increases in both high-density and low-density residential development. Consequently, mitigation will reduce future peak flows to a level between current and future-unmitigated conditions.

Simulation and analysis suggest that the subbasins that are most at risk from the point of view of increased flooding are those that may undergo substantial low-density residential development. These are the subbasins in the upper part of the BPA. The apparent paradox of greater flood increases being caused by lower density development results from current regulatory thresholds that allow low-density development to occur without R/D mitigation. In the lower part of the BPA where more intense development is expected, mitigation will generally be required. In these areas R/D ponds are generally expected to be successful in reducing peak flows if they are sized using the 7-day design procedure or its functional equivalent.

Caveats Regarding R/D Pond Mitigation

Some cautionary observations regarding mitigation of hydrologic impacts of urbanization by R/D ponds should be raised. Even under ideal conditions, R/D ponds can not completely protect streams from changes caused by development because they do not truly mimic the behavior of complex drainage pathways that are characteristic of forested conditions. Additionally, there may be several situations in which ponds may not perform as designed. Some of the imperfections of R/D ponds include the following:

1. They are limited by design to maintain discharges of specified return periods at

their pre-developed levels. For example, in this study 2-year and 10-year pre-developed levels were utilized in the design of R/D ponds in the future-mitigated simulation scenario. Inevitably, frequency and duration of pond discharge levels below the 2-year level will increase substantially over pre-developed levels. Additionally, peaks with return periods greater than the 10-year level will also increase in spite of the pond.

2. R/D ponds do not reduce the concentration of flow caused by development. Under pre-developed conditions, subsurface storm influent to a stream reach is generally diffused along the length of the channel. Urbanization reduces subsurface flow and increases surface flow that typically discharges at one point to the channel. Although peak flows may be mitigated, discharge and flow energy are still concentrated at a point.

3. Ponds must be properly located, constructed, and maintained. Inadvertent bypassing of constructed ponds because of poor siting or upstream drainage design, poor construction practices, or clogging of pond outlets are just some of a host of problems that can greatly reduce a pond's performance.

4. R/D ponds are generally not designed for mitigation of water quality impacts of urbanization. Although some incidental water quality benefits may result, the actual water quality effects are uncertain but probably limited at best.

5. R/D ponds are subject to vandalism or other tampering that may impair their performance under critical storm conditions.

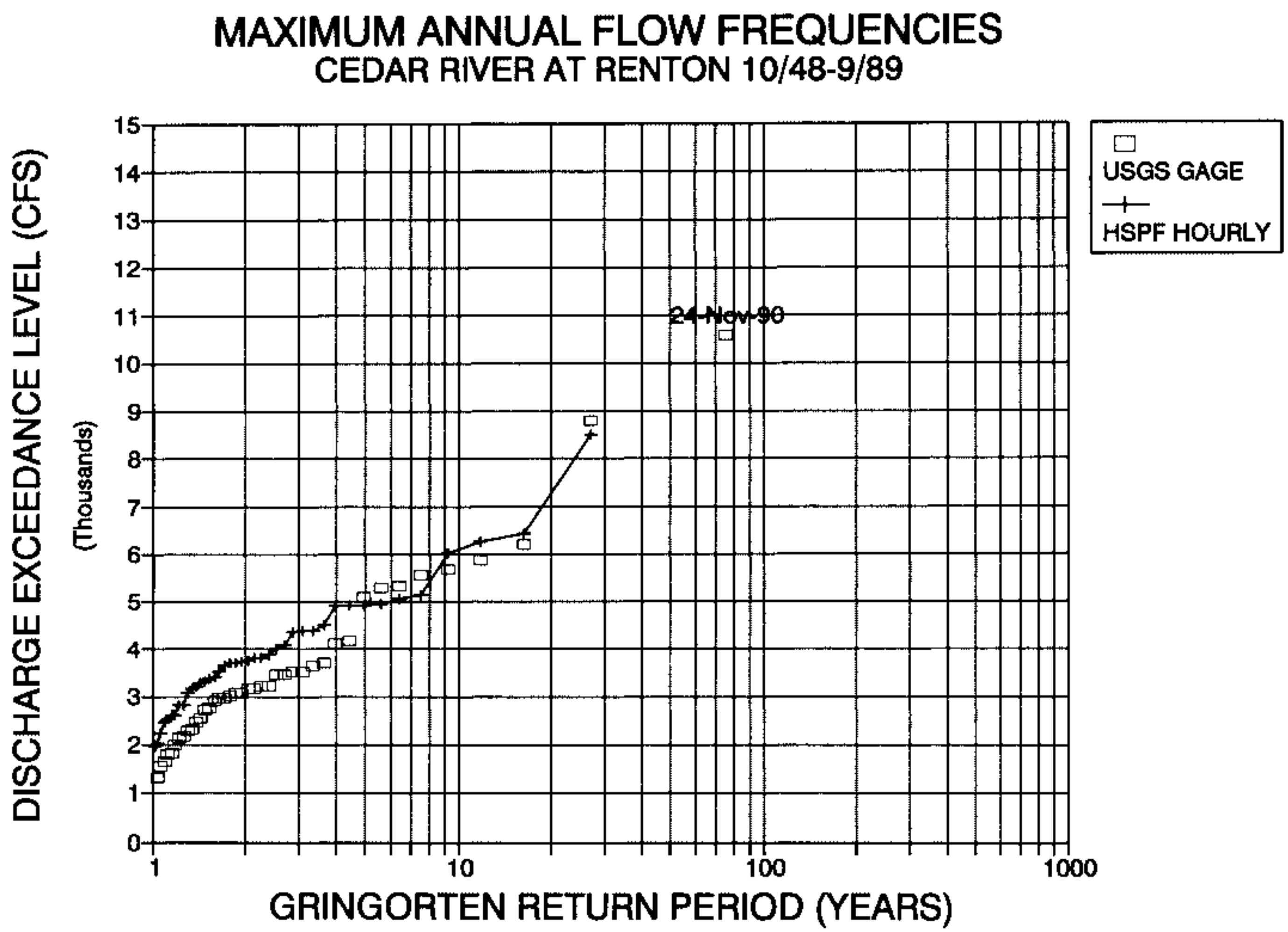
BPA MAINSTEM FLOWS

Hourly flows in the BPA mainstem were simulated using the SEAFM and HSPF models. Simulation results represent the period from October 1948 through September 1989, or forty water years. These flows were characterized in terms of mean annual flow, maximum annual flow frequencies, and peak-flow durations.

Mean Annual Flow

Simulated mean annual flow at Renton for the forty-year period is approximately 668 cfs. This is within 2% of the published mean flow of 675 cfs for the USGS gage at Renton (USGS, 1992). This agreement suggests that the simulations do a good job of representing the long term water balance of the basin. Simulated mean monthly flows differ more with the gage record because of differences in the historical operations of Masonry Dam and the set of consistent operations assumed for the simulations as discussed earlier.

Figure 3-7


MAXIMUM ANNUAL FLOW FREQUENCIES
CEDAR RIVER AT RENTON 10/48-9/89
DISCHARGE EXCEEDANCE LEVEL (CFS)
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1
10
100
1000
GRINGORTEN RETURN PERIOD (YEARS)
USGS GAGE
HSPF HOURLY
24-Nov-90

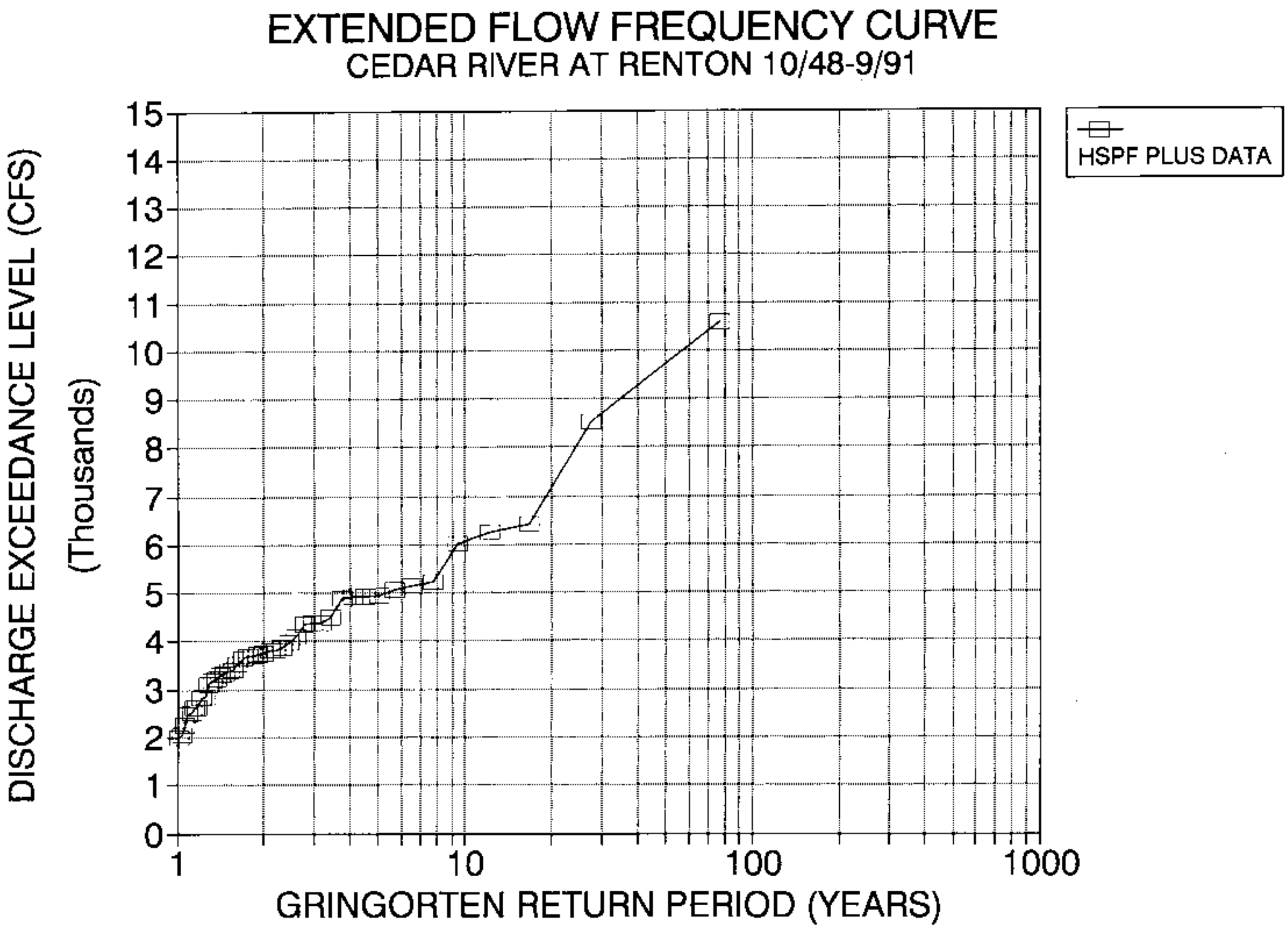
Peak Annual Flow Frequencies

Figure 3-7 compares maximum annual flow frequencies for Renton based on the forty-one-year simulation record (1948-89) with frequencies based on USGS gage data for the same time period. Differences between the two frequency curves are mainly confined to maximum annual flows with return periods of 5 years or less. These differences are to be expected given that the simulation results reflect constant land-use conditions in the BPA and current handbook operational rules at Masonry Dam, while the historical record does not. The similarity of the larger annual maxima is helpful because it suggests that additional gage data for water years 1990 (5240 cfs) and 1991 (10,600 cfs) may be combined with the simulated annual maxima without significantly impairing the homogeneity of the data set. The 1991 water year peak occurred on November 24 1990 and was the largest flood of record at Renton. Its inclusion in the frequency analysis greatly improves the estimation of more extreme events such as the 25, 50, and 100-year return-period peaks that are important parameters in floodplain planning and regulation.

Figure 3-8 shows the extended flood frequency curve. Based on this curve, the following discharge exceedance levels are estimated for the Cedar River at Renton: Q_2=3,800, Q_5=4,900, Q_{10}=6,100, Q_{25}=8,000, Q_{50}=9,700, and Q_{100}=11,100 cfs.

Peak flows in Renton are most often, though not always, correlated with and caused by peak flows entering the mainstem from the upper basin. Figure 3-9 shows all of the simulated daily maximum flows at Renton that exceeded 4,000 cfs over the 40 year simulation period plotted against Landsburg (RM 21.0) maximum flows for the same days. Over the simulation period, there were 53 days with maximum flows in excess of 4,000 cfs. For 42 of these days, flows at Renton can be very well estimated (within 15% error) by simply adding 450 cfs to the Landsburg flows. For 11 of the days, however, the relationship is not as good. It may be inferred from these results that a substantial majority of flood flows at Renton can be largely attributed to inflows from the upper basin. Typical simulated peak lag time between Landsburg and Renton is approximately 5.0 hours. Peaks at Landsburg come from two sources, the 65% of upper basin area controlled by Masonry Dam, and the 35% of the upper basin area downstream of the dam, which is uncontrolled. Generally, flows from BPA tributaries cause lower, earlier peaks in Renton, which are followed by larger peaks from the upper basin. A minority of flood peaks above 4,000 cfs at Renton are caused by a combination of inflow from the upper basin and local flows from the BPA.

Figure 3-10 compares flood frequency curves for pre-developed, current, future-mitigated, and future-unmitigated conditions. These curves reflect only the effects of land-use change in the BPA; i.e., upper basin inflows were the same for all four scenarios. As illustrated by the figure, BPA urbanization has and will continue to have a noticeable albeit small effect on peak flows in Renton because upper-basin inflows dominate peak flows in the mainstem. Under current conditions, peaks have increased 7% over forested conditions and will increase another 8% after future build-out.


EXTENDED FLOW FREQUENCY CURVE
CEDAR RIVER AT RENTON 10/48-9/91
DISCHARGE EXCEEDANCE LEVEL (CFS)
(Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1
10
100
1000
GRINGORTEN RETURN PERIOD (YEARS)
HSPF PLUS DATA

EFFECT OF UPPER BASIN ON RENTON FLOODS
(DAILY MAX ABOVE 4000 CFS IN RENTON)

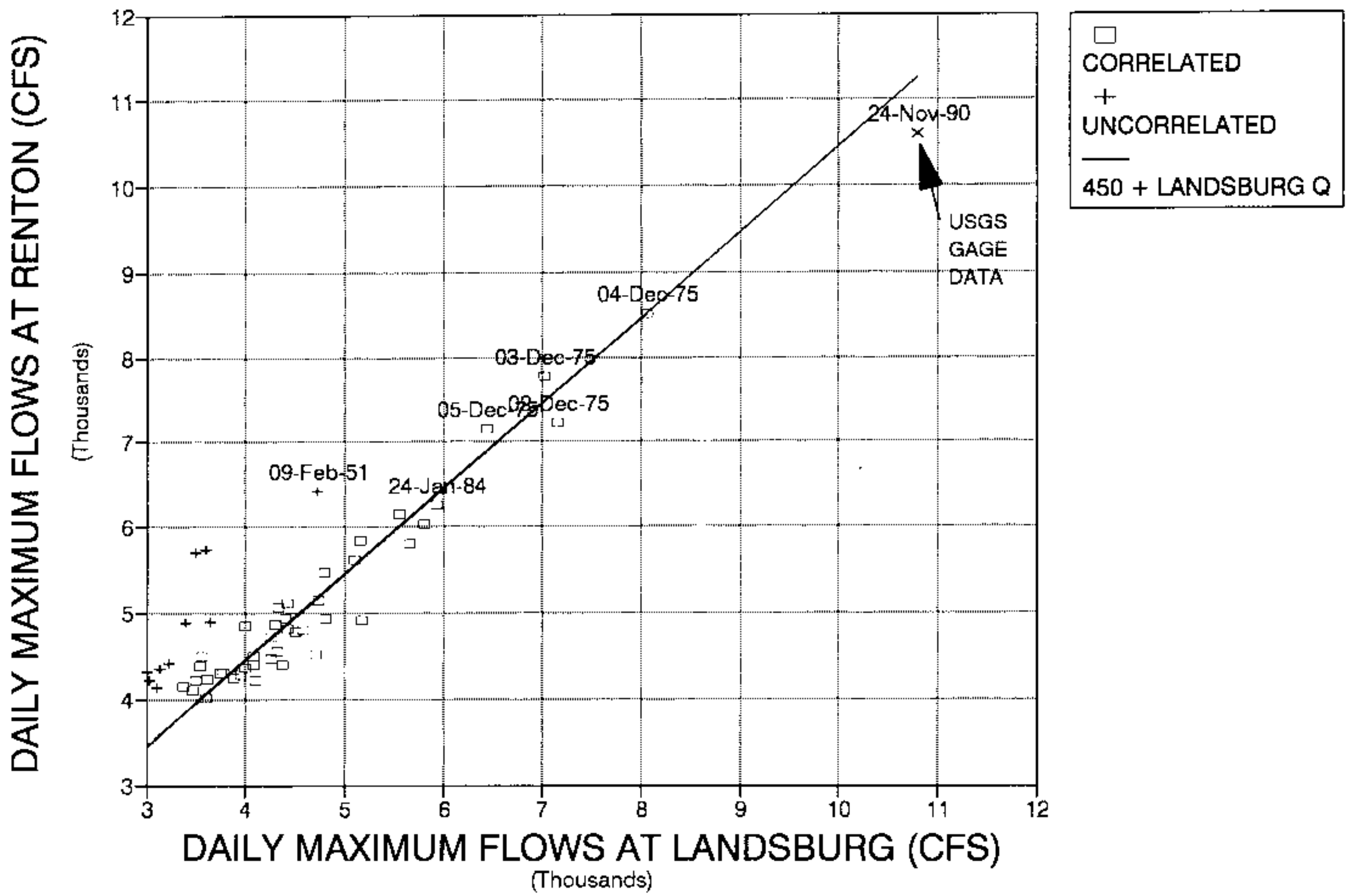


Figure 3-9

Flood frequency curves for future-mitigated and future-unmitigated conditions are nearly identical. Much of the BPA future development is projected to be low-density housing, which is assumed to require no R/D facilities. Additionally, even if R/D facilities were required for **all** future development in the BPA, significant reductions in peak mainstem flows below future-unmitigated levels would not necessarily occur. Although tributary peaks are attenuated by R/D ponds, they are also delayed and extended in time. Thus, additional storage in the BPA tributaries could theoretically increase mainstem peaks in Renton by synchronizing BPA tributary and upper basin flow contributions; although this is not expected to occur to any significant degree.

Peak Flow Durations

As discussed above, peak flood flows at Renton are generally only about 10% higher than at Landsburg. In contrast, durations of these flood flows are significantly longer inRenton. Four durational analysis curves reflecting current conditions at RM 21.6 (Landsburg), RM 16.0, RM 13.0, and Renton are shown in Figure 3-11. The number of hours over the period of record during which flow levels are exceeded consistently increases from Landsburg downstream to Renton. Flows above 3,000 cfs occur at Renton for two to three times as many hours as at Landsburg. Based on these results and the relationship of flood peaks at Renton to peaks at Landsburg, it appears that the typical flood wave traveling downstream from Landsburg diffuses while simultaneously it is augmented by BPA tributary flows. The result at Renton is a flood hydrograph with a marginally higher peak and a significantly longer duration than the influent hydrograph at Landsburg.

The effect of BPA urbanization on flood flow durations in Renton is shown in Figure 3-12, which shows increases in current and future flood durations above forest conditions. For current conditions, the number of hours during which the Cedar River at Renton exceeds flood levels between 3,000 and 8,500 cfs has increased by an average of 12% over forested conditions. For future conditions, the number of hours above these levels will increase an additional 15% over current conditions, for a total of 27% over forested conditions. Similar to the flood frequency results, R/D ponds in BPA subbasins have minimal overall effect on mainstem flow durations.

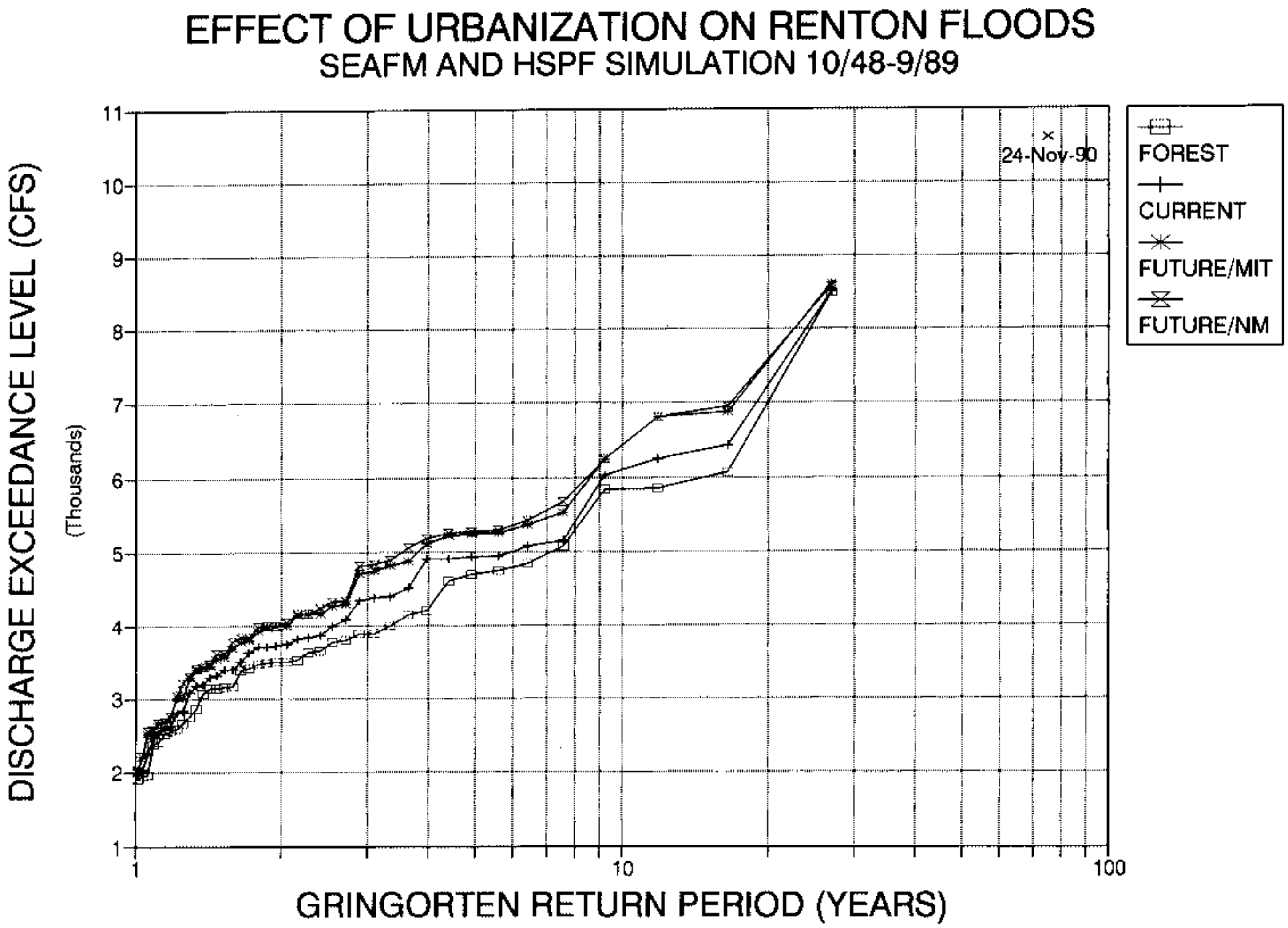
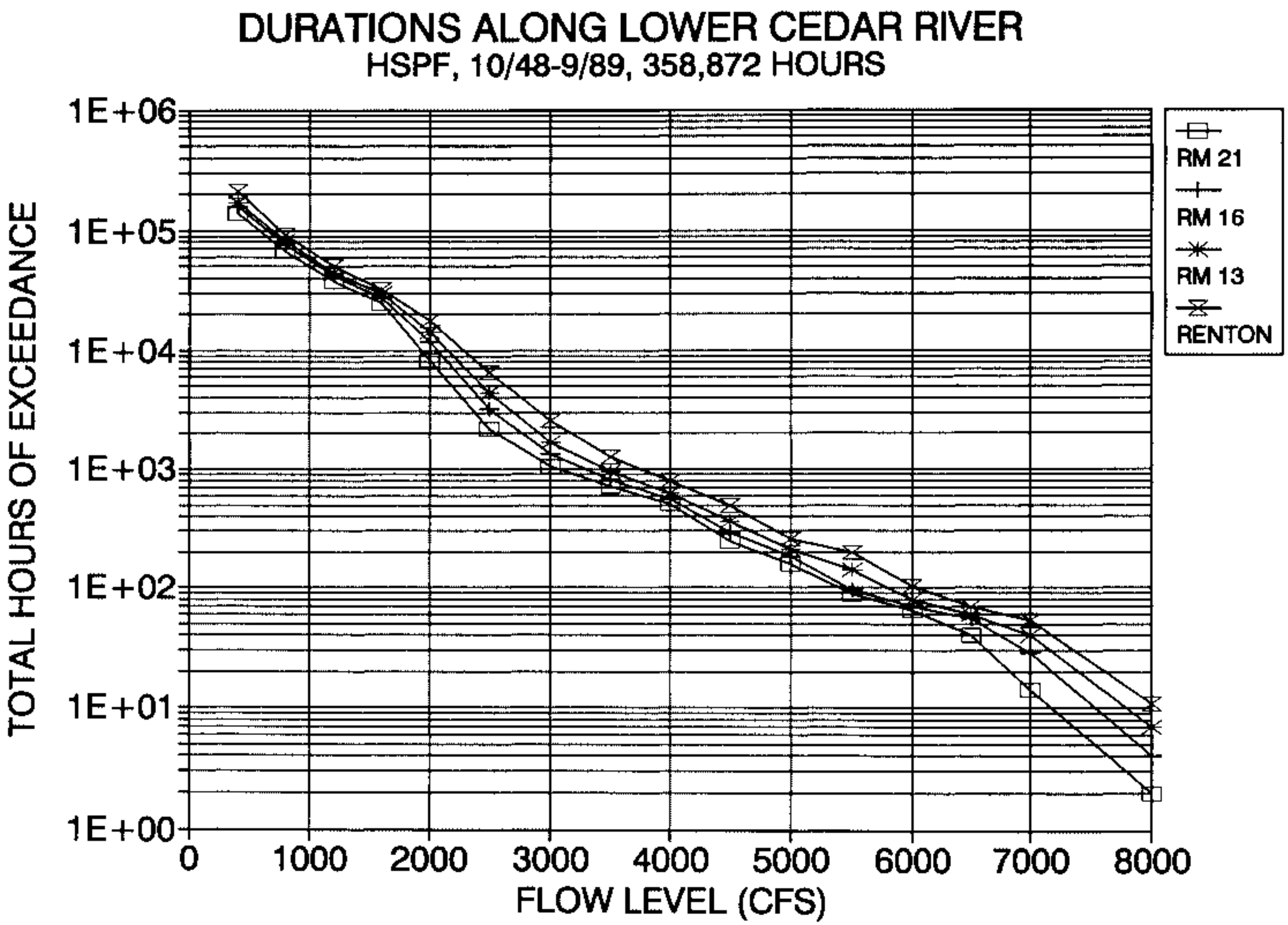

EFFECT OF URBANIZATION ON RENTON FLOODS
SEAFM AND HSPF SIMULATION 10/48-9/89
DISCHARGE EXCEEDANCE LEVEL (CFS)
(Thousands)
11
10
9
8
7
6
5
4
3
2
1
1
10
100
GRINGORTEN RETURN PERIOD (YEARS)
24-Nov-90
FOREST
CURRENT
FUTURE/MIT
FUTURE/NM

Figure 3-10

Figure 3-11



DURATIONS ALONG LOWER CEDAR RIVER
HSPF, 10/48-9/89, 358,872 HOURS
TOTAL HOURS OF EXCEEDANCE
1E+06
1E+05
1E+04
1E+03
1E+02
1E+01
1E+00
0
1000
2000
3000
4000
5000
6000
7000
8000
FLOW LEVEL (CFS)
RM 21
RM 16
RM 13
RENTON

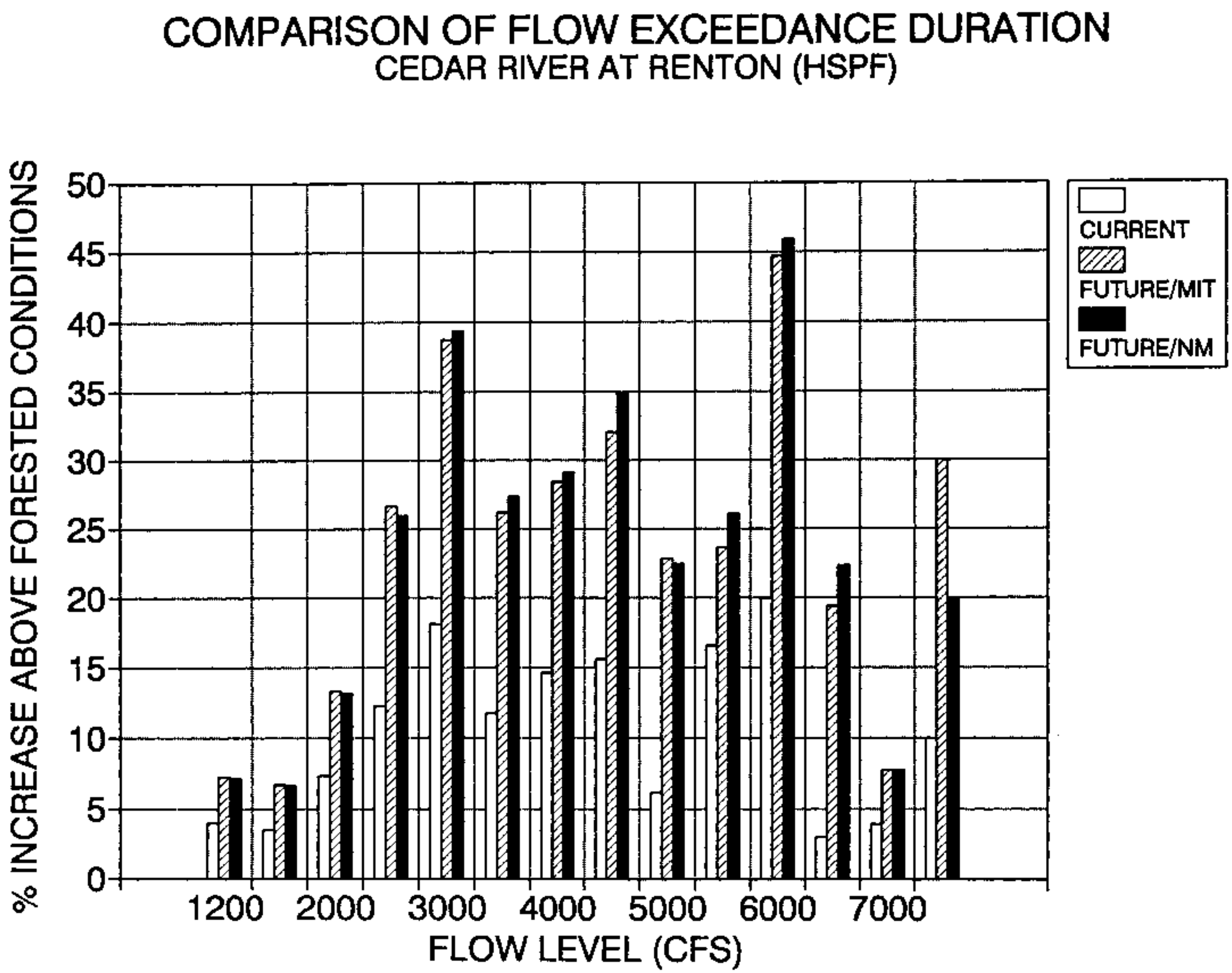

COMPARISON OF FLOW EXCEEDANCE DURATION
CEDAR RIVER AT RENTON (HSPF)
% INCREASE ABOVE FORESTED CONDITIONS
50
45
40
35
30
25
20
15
10
5
0
1200
2000
3000
4000
5000
6000
7000
FLOW LEVEL (CFS)
CURRENT
FUTURE/MIT
FUTURE/NM

Figure 3-12

3.5 KEY FINDINGS

UPPER BASIN

- ★ A previous study indicates that Masonry Dam provides significant peak flow reductions in Renton. The study assumed dam operations consistent with Seattle's "Operations and Maintenance Handbook" and the absence of any mechanical or operational failures that might aggravate downstream flooding.

- ★ Past studies suggest that there is a potential to augment downstream flood protection by operational changes at Masonry Dam; however both the costs and benefits of changes require a more detailed and comprehensive analysis than has been conducted to date.

- ★ Diversions at Landsburg cause mean monthly flows at the river's mouth to be from 9 to 40% less than their natural levels from July through October. Significant increases in diversions will require additional upper basin water storage to maintain current levels and reliability of instream flows at Renton.

BPA TRIBUTARIES

- ★ Water yields have increased as a result of deforestation and land development, especially in the lower BPA subbasins. Most of these increases occur during the winter flood season in the form of increased peak discharges.

- ★ Current mean annual flow exceeds 5.0 cfs at the outlets and in some upstream reaches of Taylor, Peterson, Rock, and Walsh Lake subbasins. Wetland filling adjacent to these reaches is subject to the U. S. Army Corps of Engineers (COE) "Individual Section 404" permit process.

- ★ The City of Kent's diversion on Rock Creek causes a significant depletion of the creek's dry-season flows from RM 1.6 to the creek's confluence with the Cedar River.

- ★ Based on estimates of natural flow, Rock Creek is a "Shoreline of the State" from its confluence with the cedar River upstream to approximately RM 1.7.

- ★ As urbanization and land development continue, the largest increases in flood peaks will occur in the more easterly tributaries of the BPA because most of the low-density development projected for these areas will not out require peak flow mitigation under current regulations. Potentially large increases in peak flows are expected in Rock Creek, Taylor Creek, and Dorre Don and to a lesser extent in Cedar Hills and Webster Lake subbasins.

BPA MAINSTEM

- ★ The 2-year and 100-year return period peak flows at Renton are estimated to be 3,800 and 11,100 cfs respectively based on forty years of simulations assuming consistent Masonry Dam operations under current BPA land-use conditions **and** gaged annual peaks for the 1990 and 1991 water years.

- ★ The majority of maximum daily flows above 4,000 cfs in Renton are composed largely of peak inflows of similar magnitude from the upper basin and much smaller contributions from the BPA.

- ★ Urbanization in the BPA tributaries has caused a 7% increase in mainstem flood peaks and will cause an additional 8% increase as a result of future build-out.

- ★ BPA flows have a minor impact on mainstem peak discharges but do increase mainstem flood durations at Renton significantly. Current levels of BPA urbanization have increased flood flow durations at Renton by 12% over forested conditions. Projected future land development will result in durations that are 27% longer than forested condition durations.

- ★ R/D pond mitigation in the BPA subbasins has minimal effect on mainstem flood peaks or durations.

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Hydrology Appendix

Table 1 HSPF Land Type

Land Use Scenario	Sub-Catchment	Land Type (acres) T-F-F	T-F-M	T-F-S	T-G-F	T-G-M	T-G-S	OF	OG	SAT	IMP	TOTAL
PreDev.	MS-0	0	0	0	0	0	0	522	0	21	0	543
Current		0	0	0	0	0	0	0	180	21	342	543
Future		0	0	0	0	0	0	0	130	21	392	543
PreDev.	MS-1	140	0	62	0	0	0	464	0	13	0	680
Current		46	0	57	71	0	3	71	226	13	193	680
Future		13	0	57	55	12	2	27	221	13	281	680
PreDev.	B1	72	0	18	0	0	0	0	0	0	0	90
Current		11	0	12	39	0	6	0	0	0	22	90
Future		1	0	13	45	0	8	0	0	0	23	90
PreDev.	B2	225	39	1	0	0	0	0	0	0	0	265
Current		44	1	1	138	28	0	0	0	0	53	265
Future		0	0	0	156	30	2	0	0	0	77	265
PreDev.	B3	275	12	0	0	0	0	0	0	1	0	289
Current		2	0	0	208	9	0	0	0	1	68	289
Future		1	0	0	205	9	0	0	0	1	73	289
PreDev.	MS-2	372	0	220	0	0	0	486	0	14	0	1092
Current		23	0	145	228	0	65	82	301	14	233	1092
Future		2	0	130	213	0	76	62	192	14	404	1092
PreDev.	MW1	21	3	44	0	0	0	36	0	0	0	103
Current		0	0	42	16	2	2	12	21	0	8	103
Future		0	0	10	16	0	36	1	28	0	12	103
PreDev.	MW2	367	12	10	0	0	0	3	0	0	0	392
Current		160	3	8	144	8	1	0	3	0	65	392
Future		0	0	7	218	23	3	0	0	0	140	392
PreDev.	MW3	457	55	0	0	0	0	85	0	19	0	616
Current		166	22	0	264	29	0	14	54	19	49	616
Future		2	1	3	338	21	3	1	63	19	164	616
PreDev.	MS-3	60	0	29	0	0	0	210	0	4	0	303
Current		12	0	22	37	0	7	86	99	4	36	303
Future		0	0	27	42	0	15	80	99	4	36	303
PreDev.	F1	109	5	23	0	0	0	93	0	0	0	230
Current		9	5	17	88	7	5	39	41	0	20	230
Future		2	0	12	95	1	10	37	45	0	29	230
PreDev.	F2	178	84	15	0	0	0	35	0	0	0	312
Current		31	36	12	122	41	3	9	18	0	39	312
Future		0	0	1	116	38	11	2	28	0	115	312
PreDev.	F3	73	62	5	0	0	0	3	0	43	0	185
Current		0	27	1	35	30	3	0	2	43	44	185
Future		0	2	0	54	27	7	1	5	28	62	186
PreDev.	F4	294	25	85	0	0	0	24	0	21	0	449
Current		111	20	57	120	4	26	19	3	21	68	449
Future		37	13	11	157	19	42	1	22	21	126	449
PreDev.	MS-4	1	0	95	0	0	0	245	0	25	0	367
Current		0	0	87	1	0	8	98	148	25	0	367
Future		0	0	31	0	0	59	27	206	25	19	367
PreDev.	M1	0	0	15	0	0	0	85	0	0	0	100
Current		0	0	11	0	0	3	29	50	0	6	100
Future		0	0	10	0	0	1	28	40	0	20	99
PreDev.	M2	85	0	61	0	0	0	41	0	0	0	187
Current		42	0	59	38	0	2	37	4	0	5	187
Future		7	0	30	58	0	31	9	29	0	22	187
PreDev.	M3	146	0	7	0	0	0	11	0	0	0	164
Current		23	0	4	102	0	2	8	3	0	23	164
Future		0	0	2	117	0	9	2	7	0	28	164
PreDev.	M4	221	75	0	0	0	0	1	0	6	0	303
Current		71	3	0	114	47	0	0	1	6	62	303
Future		71	2	0	109	47	0	0	1	6	67	304
PreDev.	M5	221	14	0	0	0	0	60	0	3	0	297
Current		40	6	0	126	6	0	14	36	3	66	297
Future		3	5	0	139	7	0	9	45	3	86	297
PreDev.	M6	183	123	9	0	0	0	45	0	16	0	375
Current		61	91	7	92	25	2	27	13	16	41	375
Future		17	8	4	111	119	7	17	22	16	54	375

Table 1 HSPF Land Type (cont)

Land Use Scenario	Sub-Catchment	Land Type (acres)										TOTAL
		T-F-F	T-F-M	T-F-S	T-G-F	T-G-M	T-G-S	OF	OG	SAT	IMP	
PreDev.	MS-5	0	0	28	0	0	0	30	0	3	0	61
Current		0	0	24	0	0	3	15	12	3	5	61
Future		0	0	8	0	0	15	8	21	3	6	61
PreDev.	J1	49	0	23	0	0	0	133	0	0	0	205
Current		11	0	22	34	0	1	36	75	0	26	205
Future		0	0	4	36	0	18	8	97	0	43	205
PreDev.	J2	197	0	0	0	0	0	83	0	0	0	280
Current		113	0	0	78	0	0	13	54	0	23	280
Future		0	0	0	150	0	0	0	59	0	70	280
PreDev.	J3	144	20	1	0	0	0	17	0	0	0	182
Current		51	13	0	82	5	0	17	0	0	13	182
Future		2	4	0	107	13	0	0	11	0	45	182
PreDev.	MS-6	59	0	93	0	0	0	214	0	12	0	377
Current		33	0	73	23	0	12	102	84	12	39	377
Future		13	0	41	40	0	36	69	113	12	53	377
PreDev.	SU1	31	51	44	0	0	0	14	0	0	0	140
Current		9	43	42	21	6	3	14	0	0	2	140
Future		3	1	14	22	38	33	6	8	0	16	140
PreDev.	MS-7	40	97	180	0	0	0	295	0	36	0	648
Current		16	19	145	22	51	21	117	133	36	85	648
Future		0	0	104	28	62	44	64	167	36	141	648
PreDev.	CG1	0	4	12	0	0	0	49	0	0	0	65
Current		0	2	4	0	2	6	40	8	0	4	65
Future		0	0	0	0	0	9	10	39	0	6	65
PreDev.	CG2	0	148	89	0	0	0	39	0	4	0	280
Current		0	101	57	0	34	23	12	21	4	27	280
Future		0	0	0	0	118	65	0	33	4	60	280
PreDev.	CG3	0	39	5	0	0	0	34	0	0	0	78
Current		0	15	1	0	18	3	26	7	0	8	78
Future		0	0	0	0	26	3	5	28	0	16	78
PreDev.	CG4	0	29	39	0	0	0	0	0	5	0	74
Current		0	12	2	0	13	28	0	0	5	13	74
Future		0	0	1	0	22	29	0	0	5	17	74
PreDev.	CG5	0	166	57	0	0	0	1	0	4	0	228
Current		0	63	20	0	83	27	1	0	4	30	228
Future		0	0	0	0	124	38	0	1	4	60	228
PreDev.	MS-8	162	178	282	0	0	0	485	0	72	0	1179
Current		94	85	274	47	86	8	299	175	72	40	1179
Future		23	7	262	118	135	28	256	221	72	58	1179
PreDev.	MS-9	412	171	247	0	0	0	334	0	20	0	1184
Current		251	151	190	153	105	49	150	74	20	39	1183
Future		15	14	171	314	224	85	111	149	20	81	1184
PreDev.	CH1	1	38	0	0	0	0	149	0	15	0	205
Current		1	0	0	0	38	0	131	18	15	0	205
Future		1	0	0	0	75	0	18	92	15	3	205
PreDev.	CH2	135	74	0	0	0	0	0	0	0	0	209
Current		79	25	0	47	49	0	0	0	0	9	209
Future		0	0	0	101	95	0	0	0	0	12	209
PreDev.	CH3	18	345	0	0	0	0	5	0	23	0	392
Current		11	114	0	8	231	0	5	0	23	0	392
Future		0	8	0	8	351	0	2	0	23	0	392
PreDev.	MS-10	1	17	84	0	0	0	128	0	0	0	230
Current		1	13	79	0	4	5	48	77	0	4	230
Future		8	1	73	2	17	7	23	87	0	13	230

Table 1 HSPF Land Type (cont)

Land Use	Sub-	Land Type (acres)										
Scenario	Catchment	T-F-F	T-F-M	T-F-S	T-G-F	T-G-M	T-G-S	OF	OG	SAT	IMP	TOTAL
PreDev.		12	4	5	0	0	0	77	0	3	0	100
Current	W1	11	0	5	0	4	0	41	35	3	2	100
Future		0	0	0	11	19	4	1	62	0	3	100
PreDev.		6	53	0	0	0	0	31	0	4	0	93
Current	W2	6	0	0	0	53	0	23	7	4	0	93
Future		0	0	0	3	70	0	1	14	4	1	93
PreDev.		24	0	0	0	0	0	79	0	3	0	106
Current	W2A	13	0	0	11	0	0	49	29	3	2	106
Future		0	0	0	22	3	0	4	73	0	4	106
PreDev.		155	9	2	0	0	0	34	0	30	0	230
Current	W3	153	9	2	2	0	0	12	21	30	1	230
Future		9	0	0	140	9	2	1	35	27	8	230
PreDev.		33	0	17	0	0	0	0	0	18	0	68
Current	W4	33	0	17	0	0	0	0	0	18	0	68
Future		6	0	2	26	0	13	0	0	18	2	68
PreDev.		47	62	144	0	0	0	233	0	14	0	500
Current	MS-11	46	31	130	0	30	13	100	125	14	11	500
Future		0	4	95	46	59	51	2	214	14	16	500
PreDev.		55	8	14	0	0	0	118	0	19	0	214
Current	T1	41	6	14	13	2	0	91	23	19	5	214
Future		0	0	2	28	17	32	3	104	19	10	214
PreDev.		52	47	25	0	0	0	14	0	7	0	145
Current	T2	34	22	14	16	19	8	13	1	7	14	145
Future		29	2	3	22	33	17	7	6	7	18	145
PreDev.		123	189	51	0	0	0	28	0	72	0	464
Current	T2A	67	81	44	50	103	2	15	11	72	18	464
Future		0	5	34	44	225	9	13	14	72	47	464
PreDev.		579	294	149	0	0	0	336	0	145	0	1502
Current	T3	398	145	96	159	141	48	230	95	145	44	1502
Future		241	5	0	195	475	47	33	300	145	61	1502
PreDev.		63	109	29	0	0	0	10	0	5	0	216
Current	T4	34	60	25	26	46	3	10	0	5	6	216
Future		0	1	0	0	182	6	2	8	5	11	216
PreDev.		74	88	47	0	0	0	110	0	41	0	360
Current	T5	57	75	42	15	11	4	66	41	41	7	360
Future		0	25	7	77	56	24	9	110	41	11	360
PreDev.		18	0	0	0	0	0	85	0	1	0	104
Current	T6	11	0	0	6	0	0	75	7	1	4	104
Future		0	0	0	18	0	0	0	81	1	4	104
PreDev.		191	41	12	0	0	0	145	0	2	0	391
Current	T7	152	34	9	35	6	3	87	54	2	9	391
Future		0	0	0	187	53	5	7	121	2	15	391
PreDev.		0	41	35	0	0	0	123	0	15	0	214
Current	MS-12	0	41	29	0	0	6	40	78	15	5	214
Future		0	1	26	0	38	8	1	117	15	7	214

Table 1 HSPF Land Type (cont)

Land Use	Sub-	Land Type (acres)										
Scenario	Catchment	T-F-F	T-F-M	T-F-S	T-G-F	T-G-M	T-G-S	OF	OG	SAT	IMP	TOTAL
PreDev.		131	407	190	0	0	0	51	0	10	0	788
Current	P1	85	301	184	43	99	4	48	3	10	11	788
Future		0	2	48	120	399	141	6	33	10	28	788
PreDev.		178	60	29	0	0	0	58	0	42	0	367
Current	P2	111	50	16	63	10	13	40	18	42	5	367
Future		0	0	0	150	60	22	13	40	42	39	367
PreDev.		16	30	6	0	0	0	16	0	61	0	128
Current	P3	11	29	4	4	0	2	1	15	61	1	128
Future		2	0	2	13	28	3	4	25	48	3	128
PreDev.		37	102	168	0	0	0	21	0	88	0	417
Current	P4	32	98	155	3	1	8	9	9	88	13	417
Future		0	21	13	34	80	142	2	16	88	21	417
PreDev.		191	0	23	0	0	0	6	0	10	0	230
Current	P5	189	0	23	1	0	0	6	0	10	0	230
Future		14	0	7	168	0	15	5	1	10	9	230
PreDev.		158	171	29	0	0	0	0	0	72	0	430
Current	P6	152	159	28	3	8	0	0	0	72	8	430
Future		16	0	19	90	142	24	0	0	72	67	430
PreDev.		195	116	63	0	0	0	0	0	61	0	435
Current	P7	109	112	61	78	0	2	0	0	61	12	435
Future		19	3	2	142	91	56	0	0	61	61	435
PreDev.		227	16	0	0	0	0	0	0	20	0	263
Current	P8	147	16	0	71	0	0	0	0	20	9	263
Future		46	12	0	138	5	0	0	1	20	41	263
PreDev.		712	219	0	0	0	0	60	0	13	0	1005
Current	P9	611	196	0	92	16	0	55	5	13	17	1005
Future		453	180	0	188	60	0	68	15	13	27	1005
PreDev.		240	110	96	0	0	0	715	0	44	0	1204
Current	MS-13	125	86	82	109	21	11	401	244	44	80	1204
Future		4	2	59	240	107	32	123	391	44	202	1204
PreDev.		0	11	3	0	0	0	67	0	0	0	82
Current	MV1	0	4	3	0	6	0	47	15	0	6	82
Future		0	0	2	0	10	1	20	42	0	7	82
PreDev.		300	106	7	0	0	0	10	0	4	0	428
Current	MV2	212	94	7	82	11	0	1	7	4	10	428
Future		22	0	0	249	111	8	0	10	4	24	428
PreDev.		247	0	55	0	0	0	20	0	28	0	350
Current	MV3	219	0	53	25	0	1	4	16	28	2	350
Future		9	0	2	125	108	43	0	21	28	14	350
PreDev.		82	25	67	0	0	0	744	0	25	0	943
Current	MS-14	50	17	63	31	8	3	624	91	25	32	943
Future		10	3	46	57	33	5	109	429	25	224	943

Table 1 HSPF Land Type (cont)

Land Use Scenario	Sub-Catchment	Land Type (acres) T-F-F	T-F-M	T-F-S	T-G-F	T-G-M	T-G-S	OF	OG	SAT	IMP	TOTAL
PreDev.	R1	0	150	70	0	0	0	787	0	0	0	1007
Current		0	150	70	0	0	0	630	94	0	62	1007
Future		0	5	0	0	132	66	36	556	0	213	1007
PreDev.	R2	0	208	126	0	0	0	127	0	5	0	466
Current		0	193	110	0	14	16	93	32	5	2	466
Future		0	92	70	0	110	45	93	40	5	10	466
PreDev.	R3	55	139	197	0	0	0	2940	0	35	0	3366
Current		48	117	155	7	22	42	2652	270	35	19	3366
Future		56	68	50	40	90	145	734	2053	35	94	3366
PreDev.	R4	0	4	120	0	0	0	276	0	0	0	400
Current		0	4	120	0	0	0	263	13	0	1	400
Future		0	0	103	0	5	11	144	130	0	7	400
PreDev.	R5	0	0	0	0	0	0	120	0	2	0	123
Current		0	0	0	0	0	0	109	5	2	7	123
Future		0	0	0	0	0	0	51	63	2	7	123
PreDev.	R6	0	0	0	0	0	0	217	0	52	0	269
Current		0	0	0	0	0	0	165	36	52	16	269
Future		0	0	0	0	5	0	2	185	52	25	269
PreDev.	R7	67	150	338	0	0	0	807	0	54	0	1416
Current		26	144	338	41	6	0	735	59	54	13	1416
Future		0	165	308	0	23	29	585	243	46	18	1416
PreDev.	R8	26	176	356	0	0	0	342	0	147	0	1047
Current		26	176	356	0	0	0	342	0	147	0	1047
Future		30	138	328	0	23	28	342	9	147	2	1047
PreDev.	MS-15	34	69	86	0	0	0	210	0	18	0	417
Current		7	56	80	26	12	4	208	0	18	7	417
Future		2	0	64	32	63	28	58	142	18	11	417
PreDev.	WL1	179	215	127	0	0	0	533	0	10	0	1064
Current		175	169	126	4	45	0	520	11	10	6	1066
Future		119	232	101	47	160	35	264	86	10	12	1066
PreDev.	WL1A	201	102	50	0	0	0	183	0	31	0	567
Current		110	77	48	86	22	1	95	76	31	20	567
Future		68	9	10	139	92	27	25	142	31	25	566
PreDev.	WL2	20	177	1615	0	0	0	529	0	249	0	2590
Current		20	177	1615	0	0	0	529	0	249	0	2590
Future		20	177	1615	0	0	0	529	0	249	0	2581
PreDev.	MS-16	42	102	174	0	0	0	823	0	27	0	1168
Current		39	60	146	2	41	27	710	97	27	20	1168
Future		37	46	52	26	60	94	559	230	27	38	1168

Table 2 Land Use

Land Use	Catchment	C	MF	H	MD	LD-G	20 AC/DU	25 AC/DU	GRASS	FOREST	WETLAND	TOTAL
FUTURE	B1	17	2	29	0	0	0	0	28	15	0	91
CURRENT		17	2	29	0	0	0	0	27	17	0	91
FUTURE	B2	24	0	226	0	0	0	0	14	0	0	264
CURRENT		2	0	203	0	1	0	0	13	45	0	264
FUTURE	B3	3	0	284	0	0	0	0	1	1	1	289
CURRENT		2	0	264	0	0	0	0	19	2	1	289
FUTURE	MW1	0	0	43	0	36	0	0	15	11	0	106
CURRENT		0	0	32	0	0	0	0	17	57	0	106
FUTURE	MW2	24	143	206	0	0	0	0	12	8	0	392
CURRENT		20	21	142	0	29	25	0	7	148	0	392
FUTURE	MW3	14	50	510	0	10	0	0	5	7	19	617
CURRENT		0	0	157	0	212	35	0	24	169	19	617
FUTURE	F1	0	0	112	0	13	0	0	54	51	0	230
CURRENT		0	0	78	0	0	0	0	82	70	0	230
FUTURE	F2	85	1	169	0	4	0	0	51	3	0	312
CURRENT		17	0	100	0	0	0	0	107	89	0	312
FUTURE	F3	33	27	87	0	0	0	0	12	3	28	189
CURRENT		33	0	64	0	0	0	0	21	43	28	189
FUTURE	F4	43	52	271	0	0	0	0	0	62	21	449
CURRENT		34	8	124	0	23	79	0	28	131	21	449
FUTURE	M1	17	13	0	0	0	0	0	31	39	0	100
CURRENT		0	13	0	0	0	0	0	47	40	0	100
FUTURE	M2	8	0	47	0	64	0	0	23	45	0	187
CURRENT		0	0	20	0	0	0	0	29	139	0	187
FUTURE	M3	8	0	88	0	7	0	0	62	4	0	169
CURRENT		1	0	88	0	0	0	0	48	32	0	169
FUTURE	M4	2	68	138	0	0	0	0	21	73	6	307
CURRENT		0	52	138	0	0	0	0	25	87	6	307
FUTURE	M5	37	0	217	0	7	0	0	16	18	3	299
CURRENT		19	0	200	0	6	0	0	11	60	3	298
FUTURE	M6	14	0	157	0	104	0	0	44	46	16	381
CURRENT		3	0	153	0	1	1	0	26	181	16	381
FUTURE	J1	0	0	166	0	27	0	0	0	11	0	204
CURRENT		0	0	99	0	36	3	0	0	66	0	204
FUTURE	J2	2	0	276	0	0	0	0	19	0	0	297
CURRENT		0	0	73	0	67	7	0	4	144	0	297
FUTURE	J3	2	0	173	0	0	0	0	1	5	0	182
CURRENT		0	0	47	0	61	9	0	2	63	0	182
FUTURE	SU1	12	0	14	0	46	0	0	45	23	0	140
CURRENT		0	0	10	0	0	14	0	23	94	0	140
FUTURE	CG1	0	0	21	0	28	0	0	5	10	0	65
CURRENT		0	0	13	0	2	11	0	5	34	0	65
FUTURE	CG2	0	0	234	0	42	0	0	4	0	4	284
CURRENT		0	0	98	0	5	47	0	0	130	4	284
FUTURE	CG3	0	0	69	0	11	0	0	1	2	0	83
CURRENT		0	0	31	0	0	2	0	5	45	0	83
FUTURE	CG4	0	0	69	0	0	0	0	0	0	5	74
CURRENT		0	0	54	0	0	0	0	0	15	5	74
FUTURE	CG5	6	0	210	0	0	0	0	0	1	4	222
CURRENT		2	0	102	0	34	20	0	0	59	4	222
FUTURE	CH1	0	0	0	0	84	0	0	85	20	15	204
CURRENT		0	0	0	0	9	0	0	48	132	15	205
FUTURE	CH2	2	0	34	0	57	0	0	117	0	0	209
CURRENT		1	0	30	0	0	0	0	74	104	0	209
FUTURE	CH3	0	0	0	0	0	0	0	359	10	23	392
CURRENT		0	0	0	0	0	0	0	239	131	23	392

Table 2 Land Use (cont'd)

Land Use	Catchment	C	MF	H	MD	LD-G	20 AC/DU	25 AC/DU	GRASS	FOREST	WETLAND
FUTURE	B1	18.9%	2.4%	31.4%	0.0%	0.0%	0.0%	0.0%	31.3%	16.1%	0.0%
CURRENT		18.2%	2.4%	31.4%	0.0%	0.0%	0.0%	0.0%	29.1%	18.9%	0.0%
FUTURE	B2	9.1%	0.0%	85.6%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%
CURRENT		0.8%	0.0%	77.0%	0.0%	0.4%	0.0%	0.0%	4.8%	16.9%	0.0%
FUTURE	B3	0.9%	0.0%	98.3%	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	0.4%
CURRENT		0.9%	0.0%	91.4%	0.0%	0.0%	0.0%	0.0%	6.6%	0.8%	0.4%
FUTURE	MW1	0.0%	0.0%	40.9%	0.0%	34.1%	0.0%	0.0%	14.2%	10.6%	0.3%
CURRENT		0.0%	0.0%	30.2%	0.0%	0.0%	0.0%	0.0%	16.1%	53.4%	0.3%
FUTURE	MW2	6.0%	36.4%	52.6%	0.0%	0.0%	0.0%	0.0%	3.0%	2.0%	0.0%
CURRENT		5.0%	5.3%	36.1%	0.0%	7.5%	6.5%	0.0%	1.9%	37.7%	0.0%
FUTURE	MW3	2.3%	8.2%	82.7%	0.0%	1.6%	0.0%	0.0%	0.9%	1.2%	3.1%
CURRENT		0.0%	0.1%	25.5%	0.0%	34.4%	5.7%	0.0%	3.9%	27.3%	3.1%
FUTURE	F1	0.0%	0.0%	48.8%	0.0%	5.8%	0.0%	0.0%	23.4%	22.0%	0.0%
CURRENT		0.0%	0.0%	34.0%	0.0%	0.0%	0.0%	0.0%	35.5%	30.4%	0.0%
FUTURE	F2	27.3%	0.2%	54.0%	0.0%	1.2%	0.0%	0.0%	16.3%	0.9%	0.1%
CURRENT		5.4%	0.0%	32.0%	0.0%	0.0%	0.0%	0.0%	34.2%	28.3%	0.1%
FUTURE	F3	17.6%	14.0%	45.8%	0.0%	0.0%	0.0%	0.0%	6.5%	1.5%	14.7%
CURRENT		17.6%	0.0%	33.7%	0.0%	0.0%	0.0%	0.0%	11.1%	22.9%	14.6%
FUTURE	F4	9.6%	11.5%	60.3%	0.0%	0.0%	0.0%	0.0%	0.0%	13.9%	4.8%
CURRENT		7.7%	1.7%	27.6%	0.0%	5.2%	17.5%	0.0%	6.3%	29.1%	4.8%
FUTURE	M1	16.8%	13.1%	0.0%	0.0%	0.4%	0.0%	0.0%	30.9%	38.7%	0.0%
CURRENT		0.0%	13.1%	0.0%	0.0%	0.0%	0.0%	0.0%	46.7%	40.2%	0.0%
FUTURE	M2	4.5%	0.0%	25.3%	0.0%	34.1%	0.0%	0.0%	12.2%	23.9%	0.0%
CURRENT		0.0%	0.0%	10.6%	0.0%	0.0%	0.0%	0.0%	15.4%	74.0%	0.0%
FUTURE	M3	4.8%	0.0%	52.1%	0.0%	4.2%	0.0%	0.0%	36.8%	2.2%	0.0%
CURRENT		0.7%	0.0%	52.0%	0.0%	0.0%	0.0%	0.0%	28.1%	19.2%	0.0%
FUTURE	M4	0.6%	22.0%	44.9%	0.0%	0.0%	0.0%	0.0%	6.8%	23.9%	1.8%
CURRENT		0.0%	16.8%	44.9%	0.0%	0.0%	0.0%	0.0%	8.2%	28.4%	1.8%
FUTURE	M5	12.5%	0.0%	72.8%	0.0%	2.4%	0.0%	0.0%	5.5%	5.9%	0.9%
CURRENT		6.3%	0.0%	67.1%	0.0%	2.1%	0.0%	0.0%	3.7%	20.0%	0.9%
FUTURE	M6	3.6%	0.0%	41.3%	0.0%	27.4%	0.0%	0.0%	11.5%	12.1%	4.2%
CURRENT		0.7%	0.0%	40.2%	0.0%	0.2%	0.4%	0.0%	6.7%	47.6%	4.2%
FUTURE	J1	0.0%	0.0%	81.4%	0.0%	13.2%	0.0%	0.0%	0.0%	5.3%	0.0%
CURRENT		0.0%	0.0%	48.3%	0.0%	17.8%	1.4%	0.0%	0.0%	32.4%	0.0%
FUTURE	J2	0.6%	0.0%	93.0%	0.0%	0.0%	0.0%	0.0%	6.2%	0.2%	0.0%
CURRENT		0.0%	0.0%	24.8%	0.0%	22.6%	2.5%	0.0%	1.4%	48.7%	0.0%
FUTURE	J3	1.3%	0.0%	95.4%	0.0%	0.0%	0.0%	0.0%	0.4%	2.9%	0.0%
CURRENT		0.0%	0.0%	25.8%	0.0%	33.5%	5.0%	0.0%	1.2%	34.5%	0.0%
FUTURE	SU1	8.7%	0.0%	9.7%	0.0%	32.9%	0.0%	0.0%	32.0%	16.7%	0.0%
CURRENT		0.0%	0.0%	6.8%	0.0%	0.0%	10.3%	0.0%	16.1%	66.7%	0.0%
FUTURE	CG1	0.0%	0.0%	32.8%	0.0%	43.7%	0.0%	0.0%	7.9%	15.6%	0.0%
CURRENT		0.0%	0.0%	19.7%	0.0%	2.5%	17.4%	0.0%	7.2%	53.1%	0.0%
FUTURE	CG2	0.0%	0.0%	82.3%	0.0%	14.7%	0.0%	0.0%	1.5%	0.0%	1.5%
CURRENT		0.0%	0.0%	34.5%	0.0%	1.9%	16.6%	0.0%	0.0%	45.6%	1.5%
FUTURE	CG3	0.0%	0.0%	82.6%	0.0%	13.0%	0.0%	0.0%	1.7%	2.7%	0.0%
CURRENT		0.0%	0.0%	37.2%	0.0%	0.0%	2.9%	0.0%	5.8%	54.2%	0.0%
FUTURE	CG4	0.0%	0.0%	93.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%
CURRENT		0.0%	0.0%	73.1%	0.0%	0.0%	0.1%	0.0%	0.0%	20.1%	6.7%
FUTURE	CG5	2.9%	0.0%	94.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	1.8%
CURRENT		1.0%	0.0%	46.1%	0.0%	15.4%	9.0%	0.0%	0.0%	26.7%	1.8%
FUTURE	CH1	0.0%	0.0%	0.0%	0.1%	41.2%	0.0%	0.0%	41.6%	9.6%	7.5%
CURRENT		0.0%	0.0%	0.0%	0.0%	4.5%	0.0%	0.0%	23.3%	64.7%	7.5%
FUTURE	CH2	1.0%	0.0%	16.0%	0.0%	27.1%	0.0%	0.0%	55.8%	0.0%	0.0%
CURRENT		0.7%	0.0%	14.4%	0.0%	0.0%	0.0%	0.0%	35.2%	49.8%	0.0%
FUTURE	CH3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	91.6%	2.6%	5.8%
CURRENT		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	60.9%	33.3%	5.8%

Table 2 Land Use (cont)

Land Use	Catchment	C	MF	H	MD	LD-G	20 AC/DU	25 AC/DU	GRASS	FOREST	WETLAND	TOTAL
FUTURE	W1	0	0	0	0	80	0	0	19	1	3	103
CURRENT		0	0	0	0	18	20	0	22	40	3	103
FUTURE	W2	0	0	0	0	18	0	0	70	1	4	92
CURRENT		0	0	0	0	0	2	0	60	27	4	92
FUTURE	W2a	0	0	0	0	98	0	0	4	4	0	106
CURRENT		0	0	0	0	24	18	0	20	44	0	106
FUTURE	W3	0	0	0	0	191	0	0	2	10	30	233
CURRENT		0	0	0	0	16	19	0	7	161	30	233
FUTURE	W4	0	0	0	0	43	0	0	0	8	18	69
CURRENT		0	0	0	0	0	0	0	0	51	18	69
FUTURE	T1	2	0	1	0	146	0	0	0	4	2	155
CURRENT		2	0	1	0	39	60	0	0	51	2	155
FUTURE	T2	16	0	27	0	102	0	0	1	13	7	165
CURRENT		10	0	18	0	1	23	0	24	83	7	165
FUTURE	T2a	34	0	11	0	388	0	0	2	17	43	495
CURRENT		12	0	8	0	99	99	0	64	171	43	495
FUTURE	T3	12	0	0	35	1278	0	0	16	38	130	1509
CURRENT		6	0	0	0	358	406	0	94	515	130	1509
FUTURE	T4	3	0	9	8	204	0	0	0	3	5	232
CURRENT		0	0	9	0	64	23	0	8	123	5	232
FUTURE	T5	0	0	0	0	319	0	0	1	15	41	375
CURRENT		0	0	0	0	70	102	0	19	142	41	375
FUTURE	T6	0	0	0	0	105	0	0	0	0	0	105
CURRENT		0	0	0	0	14	80	0	2	9	0	105
FUTURE	T7	0	0	0	0	378	0	0	4	7	2	391
CURRENT		0	0	0	0	87	140	0	14	148	2	391
FUTURE	P1	0	0	0	0	710	0	0	12	56	10	788
CURRENT		0	0	0	0	118	167	0	52	440	10	788
FUTURE	P2	32	0	0	0	291	0	0	12	16	42	394
CURRENT		0	0	0	0	80	44	0	42	186	42	394
FUTURE	P3	0	0	0	0	71	0	0	0	8	48	128
CURRENT		0	0	0	0	5	20	0	17	38	48	128
FUTURE	P4	0	0	43	38	250	0	0	0	15	89	434
CURRENT		0	0	22	0	1	164	0	12	147	89	434
FUTURE	P5	0	0	13	50	133	0	0	0	30	10	236
CURRENT		0	0	0	0	2	3	0	0	221	10	236
FUTURE	P6	18	0	194	0	75	0	0	36	19	73	414
CURRENT		2	0	0	0	8	156	0	3	173	73	414
FUTURE	P7	6	0	211	0	90	0	0	55	24	61	446
CURRENT		2	0	32	0	3	56	0	53	240	61	446
FUTURE	P8	0	0	158	11	26	0	0	0	34	20	251
CURRENT		0	0	24	0	56	34	0	0	117	20	251
FUTURE	P9	14	0	35	35	174	0	0	54	701	13	1027
CURRENT		12	0	0	0	71	92	0	43	796	13	1027
FUTURE	MV1	0	0	21	1	39	0	0	0	20	0	82
CURRENT		0	0	21	0	6	2	0	0	53	0	82
FUTURE	MV2	8	0	8	0	387	0	0	0	3	4	409
CURRENT		0	0	8	0	78	103	0	0	216	4	409
FUTURE	MV3	0	0	0	0	350	0	0	2	14	28	395
CURRENT		0	0	0	0	48	34	0	16	255	28	380

Table 2 Land Use (cont'd)

Land Use	Catchment	C	MF	H	MD	LD-G	20 AC/DU	25 AC/DU	GRASS	FOREST	WETLAND
FUTURE	W1	0.0%	0.0%	0.0%	0.0%	77.8%	0.0%	0.0%	18.7%	0.6%	2.9%
CURRENT		0.0%	0.0%	0.0%	0.0%	17.7%	19.5%	0.0%	21.1%	38.7%	2.9%
FUTURE	W2	0.0%	0.0%	0.0%	0.0%	19.8%	0.0%	0.0%	75.3%	0.7%	4.1%
CURRENT		0.0%	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	64.5%	29.1%	4.1%
FUTURE	W2a	0.0%	0.0%	0.0%	0.0%	91.6%	0.0%	0.0%	4.1%	4.1%	0.2%
CURRENT		0.0%	0.0%	0.0%	0.0%	22.4%	17.3%	0.0%	18.5%	41.6%	0.2%
FUTURE	W3	0.0%	0.0%	0.0%	0.0%	82.1%	0.0%	0.0%	0.7%	4.3%	12.9%
CURRENT		0.0%	0.0%	0.0%	0.0%	6.9%	8.3%	0.0%	3.0%	68.9%	12.9%
FUTURE	W4	0.0%	0.0%	0.0%	0.0%	61.8%	0.0%	0.0%	0.0%	12.0%	26.2%
CURRENT		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	73.8%	26.2%
FUTURE	T1	1.5%	0.0%	0.8%	0.0%	94.0%	0.0%	0.0%	0.0%	2.3%	1.4%
CURRENT		1.3%	0.0%	0.8%	0.0%	24.9%	39.0%	0.0%	0.0%	32.7%	1.4%
FUTURE	T2	9.8%	0.0%	16.4%	0.0%	61.6%	0.0%	0.0%	0.5%	7.6%	4.0%
CURRENT		5.9%	0.0%	10.7%	0.0%	0.5%	13.7%	0.0%	14.9%	50.3%	4.0%
FUTURE	T2a	6.9%	0.0%	2.3%	0.0%	78.4%	0.0%	0.0%	0.4%	3.4%	8.7%
CURRENT		2.4%	0.0%	1.6%	0.0%	19.9%	20.0%	0.0%	12.9%	34.5%	8.7%
FUTURE	T3	0.8%	0.0%	0.0%	2.3%	84.7%	0.0%	0.0%	1.1%	2.5%	8.6%
CURRENT		0.4%	0.0%	0.0%	0.0%	23.7%	26.9%	0.0%	6.2%	34.2%	8.6%
FUTURE	T4	1.1%	0.0%	4.0%	3.5%	87.7%	0.0%	0.0%	0.1%	1.3%	2.2%
CURRENT		0.0%	0.0%	3.9%	0.0%	27.4%	10.0%	0.0%	3.4%	53.1%	2.2%
FUTURE	T5	0.0%	0.0%	0.0%	0.0%	84.9%	0.0%	0.0%	0.2%	3.9%	11.0%
CURRENT		0.0%	0.0%	0.0%	0.0%	18.7%	27.3%	0.0%	5.0%	37.9%	11.0%
FUTURE	T6	0.0%	0.0%	0.0%	0.0%	99.7%	0.0%	0.0%	0.0%	0.0%	0.3%
CURRENT		0.0%	0.0%	0.0%	0.0%	13.1%	76.4%	0.0%	1.4%	8.7%	0.3%
FUTURE	T7	0.0%	0.0%	0.0%	0.0%	96.8%	0.0%	0.0%	0.9%	1.9%	0.4%
CURRENT		0.0%	0.0%	0.0%	0.0%	22.3%	36.0%	0.0%	3.5%	37.8%	0.4%
FUTURE	P1	0.0%	0.0%	0.0%	0.0%	90.0%	0.0%	0.0%	1.5%	7.1%	1.3%
CURRENT		0.0%	0.0%	0.0%	0.0%	15.0%	21.3%	0.0%	6.6%	55.8%	1.3%
FUTURE	P2	8.2%	0.0%	0.0%	0.1%	73.9%	0.0%	0.0%	3.1%	4.0%	10.7%
CURRENT		0.0%	0.0%	0.0%	0.0%	20.3%	11.2%	0.0%	10.7%	47.1%	10.7%
FUTURE	P3	0.0%	0.0%	0.0%	0.0%	55.9%	0.0%	0.0%	0.2%	6.1%	37.8%
CURRENT		0.0%	0.0%	0.0%	0.0%	3.6%	15.7%	0.0%	13.3%	29.6%	37.8%
FUTURE	P4	0.0%	0.0%	9.9%	8.8%	57.4%	0.0%	0.0%	0.0%	3.5%	20.4%
CURRENT		0.0%	0.0%	5.1%	0.0%	0.3%	37.8%	0.0%	2.6%	33.8%	20.4%
FUTURE	P5	0.0%	0.0%	5.6%	21.2%	56.2%	0.0%	0.0%	0.0%	12.6%	4.3%
CURRENT		0.0%	0.0%	0.0%	0.0%	0.7%	1.2%	0.0%	0.0%	93.8%	4.3%
FUTURE	P6	4.3%	0.0%	46.9%	0.0%	18.0%	0.0%	0.0%	8.6%	4.6%	17.5%
CURRENT		0.5%	0.0%	0.0%	0.0%	1.9%	37.6%	0.0%	0.6%	41.8%	17.5%
FUTURE	P7	1.3%	0.0%	47.2%	0.0%	20.2%	0.0%	0.0%	12.4%	5.3%	13.6%
CURRENT		0.5%	0.0%	7.1%	0.0%	0.7%	12.5%	0.0%	11.9%	53.7%	13.6%
FUTURE	P8	0.0%	0.0%	63.2%	4.5%	10.6%	0.0%	0.0%	0.0%	13.7%	8.1%
CURRENT		0.0%	0.0%	9.4%	0.0%	22.2%	13.5%	0.0%	0.0%	46.9%	8.1%
FUTURE	P9	1.4%	0.0%	3.4%	3.4%	17.0%	0.0%	0.0%	5.3%	68.2%	1.3%
CURRENT		1.2%	0.0%	0.0%	0.0%	6.9%	9.0%	0.0%	4.2%	77.5%	1.3%
FUTURE	MV1	0.0%	0.0%	25.8%	1.6%	48.2%	0.0%	0.0%	0.0%	24.4%	0.0%
CURRENT		0.0%	0.0%	25.8%	0.0%	7.3%	2.7%	0.0%	0.0%	64.2%	0.0%
FUTURE	MV2	1.9%	0.0%	1.9%	0.0%	94.7%	0.0%	0.0%	0.0%	0.7%	0.9%
CURRENT		0.0%	0.0%	1.9%	0.0%	19.1%	25.2%	0.0%	0.0%	52.9%	0.9%
FUTURE	MV3	0.0%	0.0%	0.0%	0.0%	88.7%	0.0%	0.0%	0.6%	3.6%	7.1%
CURRENT		0.0%	0.0%	0.0%	0.0%	12.6%	8.9%	0.0%	4.2%	67.0%	7.4%

Table 2 Land Use (cont)

Land Use	Catchment	C	MF	H	MD	LD-G	20 AC/DU	25 AC/DU	GRASS	FOREST	WETLAND	TOTAL
FUTURE	R1	170	0	175	0	623	0	0	0	40	0	1007
CURRENT		60	0	32	0	6	76	0	56	778	0	1007
FUTURE	R2	4	0	0	0	153	0	0	48	259	5	469
CURRENT		1	0	0	0	19	9	0	44	391	5	469
FUTURE	R3	11	0	0	1	2128	0	0	284	1119	30	3572
CURRENT		0	0	0	0	131	536	0	215	2660	30	3572
FUTURE	R4	2	0	0	0	149	0	0	3	247	0	400
CURRENT		0	0	0	0	12	1	0	9	379	0	400
FUTURE	R5	6	0	0	1	64	0	0	0	49	2	123
CURRENT		6	0	0	0	4	29	0	0	82	2	123
FUTURE	R6	3	0	40	71	114	0	0	7	2	52	289
CURRENT		3	0	40	0	0	95	0	3	96	52	289
FUTURE	R7	12	0	0	14	230	0	0	72	1058	46	1431
CURRENT		12	0	0	0	7	79	0	54	1233	46	1431
FUTURE	R8	0	0	0	52	41	0	0	21	838	154	1106
CURRENT		0	0	0	0	0	0	0	0	952	154	1106
FUTURE	WL1	0	0	1	0	286	0	0	53	708	10	1057
CURRENT		0	0	0	0	16	138	0	44	849	10	1057
FUTURE	WL1a	0	0	41	0	389	0	0	0	112	26	567
CURRENT		0	0	39	0	158	88	0	5	251	26	567
FUTURE	WL2	0	0	0	0	0	0	0	0	2355	226	2581
CURRENT		0	0	0	0	0	0	0	0	2355	226	2581

Table 2 Land Use (cont'd)

Land Use	Catchment	C	MF	H	MD	LD-G	20 AC/DU	25 AC/DU	GRASS	FOREST	WETLAND
FUTURE	R1	16.8%	0.0%	17.4%	0.0%	61.8%	0.0%	0.0%	0.0%	4.0%	0.0%
CURRENT		6.0%	0.0%	3.2%	0.0%	0.6%	7.5%	0.0%	5.5%	77.2%	0.0%
FUTURE	R2	0.9%	0.0%	0.0%	0.0%	32.5%	0.0%	0.0%	10.3%	55.1%	1.1%
CURRENT		0.2%	0.0%	0.0%	0.0%	4.1%	1.8%	0.0%	9.4%	83.3%	1.1%
FUTURE	R3	0.3%	0.0%	0.0%	0.0%	59.6%	0.0%	0.0%	7.9%	31.3%	0.8%
CURRENT		0.0%	0.0%	0.0%	0.0%	3.7%	15.0%	0.0%	6.0%	74.5%	0.8%
FUTURE	R4	0.4%	0.0%	0.0%	0.0%	37.1%	0.0%	0.0%	0.9%	61.6%	0.0%
CURRENT		0.0%	0.0%	0.0%	0.0%	3.0%	0.2%	0.0%	2.2%	94.5%	0.0%
FUTURE	R5	5.0%	0.0%	0.0%	0.8%	52.3%	0.0%	0.0%	0.0%	39.9%	2.0%
CURRENT		5.0%	0.0%	0.0%	0.0%	3.3%	23.4%	0.0%	0.0%	66.3%	2.0%
FUTURE	R6	1.2%	0.0%	13.7%	24.6%	39.4%	0.0%	0.0%	2.5%	0.7%	17.9%
CURRENT		1.2%	0.0%	13.7%	0.0%	0.0%	32.8%	0.0%	1.2%	33.2%	17.9%
FUTURE	R7	0.8%	0.0%	0.0%	0.9%	16.1%	0.0%	0.0%	5.1%	73.9%	3.2%
CURRENT		0.8%	0.0%	0.0%	0.0%	0.5%	5.5%	0.0%	3.8%	86.2%	3.2%
FUTURE	R8	0.0%	0.0%	0.0%	4.7%	3.7%	0.0%	0.0%	1.9%	75.8%	13.9%
CURRENT		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	86.1%	13.9%
FUTURE	WL1	0.0%	0.0%	0.0%	0.0%	27.0%	0.0%	0.0%	5.0%	67.0%	1.0%
CURRENT		0.0%	0.0%	0.0%	0.0%	1.5%	13.0%	0.0%	4.2%	80.3%	1.0%
FUTURE	WL1a	0.0%	0.0%	7.1%	0.0%	68.5%	0.0%	0.0%	0.0%	19.7%	4.7%
CURRENT		0.0%	0.0%	6.8%	0.0%	27.9%	15.5%	0.0%	0.8%	44.3%	4.7%
FUTURE	WL2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	91.3%	8.7%
CURRENT		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	91.3%	8.7%

Table 3 Flood Quantile Estimates for Each Catchment

GINGER CREEK

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
B- 3	8	12	16	22	27	33
B- 2	14	23	30	40	50	61
B- 1	17	26	35	47	58	70
Current						
B- 3	31	42	50	61	70	79
B- 2	53	73	87	107	122	137
B- 1	61	84	101	123	140	158
Future (with R/D mitigation)						
B- 3	30	41	49	59	68	76
B- 2	54	74	87	106	120	136
B- 1	63	85	101	123	140	157
Future (**without** R/D mitigation)						
B- 3	31	43	51	62	71	80
B- 2	60	81	96	117	133	150
B- 1	69	93	111	134	152	172

MAPLEWOOD CREEK

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
MW- 3	12	19	24	30	35	40
MW- 2	7	12	15	19	23	26
MW- 1	21	33	42	54	63	72
Current						
MW- 3	26	36	43	52	60	67
MW- 2	22	29	34	40	45	50
MW- 1	51	69	81	98	111	125
Future (with R/D mitigation)						
MW- 3	33	41	47	55	61	67
MW- 2	28	35	40	47	52	57
MW- 1	65	82	94	109	121	133
Future (**without** R/D mitigation)						
MW- 3	53	67	78	91	102	113
MW- 2	41	52	59	69	77	85
MW- 1	98	125	143	168	187	207

Table 3 (cont)

MOLASSES CREEK

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
F- 4						
F- 3						
F- 2	31	48	62	82	99	117
F- 1	35	55	72	96	118	141
Current						
F- 4	40	55	66	80	91	102
F- 3	61	84	99	119	134	150
F- 2	78	107	126	152	172	192
F- 1	94	130	155	186	210	234
Future (with R/D mitigation)						
F- 4	41	54	62	74	83	93
F- 3	63	83	96	114	127	141
F- 2	82	108	125	149	166	185
F- 1	99	132	154	183	205	227
Future (**without** R/D mitigation)						
F- 4	57	75	88	104	117	131
F- 3	84	109	127	151	169	188
F- 2	110	144	168	199	224	249
F- 1	130	171	200	238	268	299

MADSEN CREEK

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
M- 5						
M- 4						
M- 3	28	44	58	79	97	118
M- 6	14	21	26	34	41	48
M- 2	48	75	96	127	153	182
M- 1 Hi Flo						
M- 1 Lo Flo						
Current						
M- 5	37	50	58	70	78	87
M- 4	33	47	57	70	81	92
M- 3	91	125	149	180	204	228
M- 6	30	42	50	60	68	76
M- 2	131	182	217	262	297	333
M- 1 Hi Flo	116	168	205	253	291	329
M- 1 Lo Flo	31	37	40	45	48	52
Future (with R/D mitigation)						
M- 5	9	51	60	71	79	87
M- 4	32	46	55	68	79	90
M- 3	94	129	152	183	206	231

Table 3 (cont)

M-6	37	51	61	74	84	94
M-2	145	199	236	284	321	360
M-1 Hi Flo	130	186	225	278	319	362
M-1 Lo Flo	32	38	42	46	50	53
Future (**without** R/D mitigation)						
M-5	43	57	66	78	87	96
M-4	34	48	57	71	81	92
M-3	100	136	161	193	217	242
M-6	38	53	62	75	86	96
M-2	156	213	251	302	341	382
M-1 Hi Flo	142	201	242	297	340	384
M-1 Lo Flo	36	42	46	51	55	59

ORTING HILL

Forested	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
J-2	18	28	37	49	60	72
J-1	29	44	56	74	90	108
Current						
J-2	30	43	51	62	71	79
J-1	54	77	93	114	130	147
Future (with R/D mitigation)						
J-2	22	32	40	52	62	73
J-1	52	73	89	112	131	151
Future (**without** R/D mitigation)						
J-2	43	57	66	77	86	94
J-1	88	117	136	160	177	195

SUMMERFIELD

Forested	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SU-1	5	8	9	12	14	16
Current						
SU-1	8	11	13	15	17	19
Future (with R/D mitigation)						
SU-1	11	14	17	21	24	28
Future (**without** R/D mitigation)						
SU-1	13	17	20	25	28	32

Table 3 (cont)

CEDAR GROVE

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
CG- 5	14	19	23	28	32	36
CG- 4						
CG- 2	16	22	27	32	37	41
CG- 3						
CG- 1						
CG OUTLET	39	54	65	79	90	101
Current						
CG- 5	22	29	34	41	46	51
CG- 4	10	13	15	18	21	23
CG- 2	22	29	34	41	45	50
CG- 3	35	46	55	65	74	82
CG- 1	24	32	38	45	50	55
CG OUTLET	58	78	92	110	123	137
Future (with R/D mitigation)						
CG- 5	21	27	32	38	44	49
CG- 4	10	13	15	18	21	24
CG- 2	22	30	35	43	49	56
CG- 3	35	46	54	64	72	81
CG- 1	25	34	40	49	56	63
CG OUTLET	60	79	93	112	128	144
Future (without R/D mitigation)						
CG- 5	32	41	48	56	63	70
CG- 4	11	15	17	21	24	27
CG- 2	33	43	51	61	69	78
CG- 3	49	63	73	87	98	109
CG- 1	36	47	56	67	77	87
CG OUTLET	84	110	129	154	174	196

CEDAR HILLS

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
CH- 3						
CH- 2						
CH- 1	6	8	9	11	11	12
Current						
CH- 3	18	26	32	38	43	47
CH- 2	5	7	8	9	10	11
CH- 1	8	11	13	15	16	18
Future (with R/D mitigation)						
CH- 3	21	30	36	42	47	51
CH- 2	6	7	9	10	11	12
CH- 1	11	15	18	21	24	28

Table 3 (cont)

Future (without R/D mitigation)						
CH- 3	22	30	36	42	47	51
CH- 2	6	7	9	10	11	12
CH- 1	11	15	18	21	24	28

WEBSTER LAKE

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
WEB LK						
FRA LK						
W- 2A						
W- 2 PIT						
W- 1	5	6	7	8	8	8
Current						
WEB LK	1	1	1	1	2	2
FRA LK	3	4	5	6	6	7
W- 2A	5	7	8	10	11	12
W- 2 PIT	4	5	6	6	7	8
W- 1	5	7	8	9	10	11
Future (with R/D mitigation)						
WEB LK	1	1	1	2	2	2
FRA LK	4	5	6	6	7	8
W- 2A	7	9	11	13	15	17
W- 2 PIT	4	6	6	7	8	8
W- 1	7	9	10	12	14	15
Future (without R/D mitigation)						
WEB LK	1	1	1	2	2	2
FRA LK	4	5	6	6	7	8
W- 2A	7	9	11	13	15	17
W- 2 PIT	4	6	6	7	8	8
W- 1	7	9	10	12	14	15

TAYLOR CREEK

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
T- 4	7	10	12	14	16	17
T- 3	51	68	80	94	104	115
T- 2A	76	102	119	139	154	168
T- 2	80	108	126	147	163	178
T- 1	84	113	132	154	171	186
T- 7	9	12	14	17	19	21
T- 6	1	2	2	3	3	4
T- 5	22	29	34	41	45	50
T- OUTLET	105	142	166	195	216	236

Table 3 (cont)

<u>Current</u>						
T- 4	9	13	15	17	19	21
T- 3	64	87	101	118	130	141
T- 2A	96	130	150	173	188	202
T- 2	103	139	160	184	200	215
T- 1	108	145	167	191	208	223
T- 7	11	16	18	21	24	26
T- 6	2	3	3	4	4	5
T- 5	26	36	42	50	55	60
T- OUTLET	134	181	209	241	262	282
<u>Future (with R/D mitigation)</u>						
T- 4	12	17	20	24	27	30
T- 3	71	101	122	151	174	199
T- 2A	105	146	176	215	245	278
T- 2	111	155	186	227	259	293
T- 1	116	161	192	234	267	301
T- 7	17	24	29	36	42	48
T- 6	3	4	6	8	10	12
T- 5	34	49	59	74	86	100
T- OUTLET	150	209	251	308	353	400
<u>Future (**without** R/D mitigation)</u>						
T- 4	12	17	20	24	27	30
T- 3	71	101	122	151	174	199
T- 2A	105	146	176	215	245	278
T- 2	111	155	186	227	259	293
T- 1	116	161	192	234	267	301
T- 7	17	24	29	36	42	48
T- 6	3	4	6	8	10	12
T- 5	34	49	59	74	86	100
T- OUTLET	150	209	251	308	353	400

PETERSON LAKE

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
P- 7						
P- 6						
P- 5						
P- 4						
P- 3						
P- 9						
P- 8						
P- 2						
P- 1	86	141	180	231	270	309

Table 3 (cont)

<u>Current</u>						
P- 7	9	17	25	37	48	61
P- 6	6	10	13	20	27	36
P- 5	14	21	27	36	43	51
P- 4	5	7	8	9	11	12
P- 3	10	14	16	20	23	26
P- 9	16	25	31	38	44	49
P- 8	60	91	115	149	176	206
P- 2	77	131	170	224	266	309
P- 1	105	171	218	281	329	377
<u>Future (with R/D mitigation)</u>						
P- 7	17	28	35	44	50	55
P- 6	9	15	22	33	44	58
P- 5	24	34	43	54	64	74
P- 4	6	8	9	11	12	13
P- 3	11	16	19	22	25	28
P- 9	51	77	94	116	132	148
P- 8	62	91	109	132	149	165
P- 2	107	162	194	229	252	272
P- 1	151	221	268	329	374	419
<u>Future (**without** R/D mitigation)</u>						
P- 7	20	35	44	55	63	70
P- 6	9	16	23	37	51	71
P- 5	28	41	51	66	79	93
P- 4	6	8	9	11	12	14
P- 3	11	16	19	22	25	28
P- 9	26	35	41	48	54	59
P- 8	79	115	139	169	192	214
P- 2	133	195	232	274	301	326
P- 1	176	258	311	377	424	471

DORRE DON

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
MV- 3	8	14	20	28	35	43
MV- 2	15	24	30	38	45	52
MV- 1	23	38	49	65	78	91
<u>Current</u>						
MV- 3	11	18	24	32	40	48
MV- 2	23	34	41	51	58	66
MV- 1	34	53	66	85	99	115

<u>Future (with R/D mitigation)</u>
MV- 3 no mitigation from detention projected
MV- 2
MV- 1

Table 3 (cont)

Future (**without** R/D mitigation)						
MV- 3	19	29	35	44	52	59
MV- 2	39	54	65	78	88	99
MV- 1	59	84	102	126	145	164

ROCK CREEK

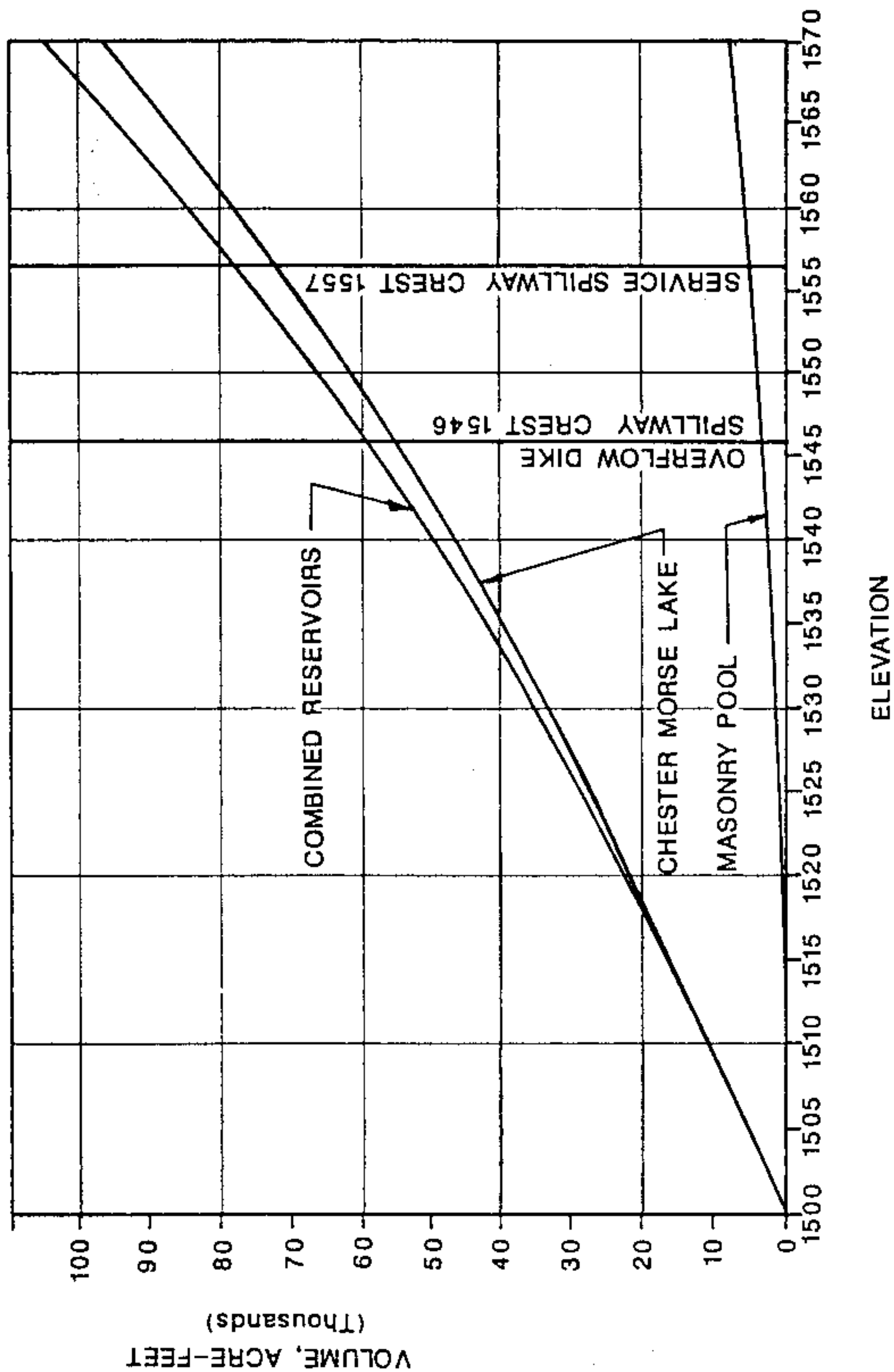
Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
R- 8 (Lake 12)	13	20	25	34	41	48
R- 7	23	36	44	61	73	85
R- 6 (Retreat Lk)	5	8	9	13	16	19
R- 5	6	9	10	15	18	22
R- 4	31	49	59	82	99	115
R- 3	28	45	55	77	92	107
R- 2	60	97	117	164	196	228
R- 1	70	112	136	190	227	264
Current						
R- 8 (Lake 12)	15	24	29	40	48	56
R- 7	26	42	51	71	85	99
R- 6 (Retreat Lk)	5	9	11	15	18	22
R- 5	6	10	12	17	21	26
R- 4	35	56	68	96	115	134
R- 3	32	52	64	89	107	125
R- 2	69	112	136	190	228	266
R- 1	80	130	158	221	264	308
Future (with R/D mitigation)						
R- 8 (Lake 12)	22	37	46	67	82	97
R- 7	38	65	82	119	146	173
R- 6 (Retreat Lk)	8	14	17	26	32	38
R- 5	9	16	19	29	37	45
R- 4	51	88	111	161	197	235
R- 3	46	81	103	150	184	218
R- 2	101	175	220	319	391	465
R- 1	117	203	256	371	453	538
Future (**without** R/D mitigation)						
R- 8 (Lake 12)	23	39	48	70	86	103
R- 7	41	69	86	125	153	183
R- 6 (Retreat Lk)	9	14	18	27	33	40
R- 5	10	16	20	31	38	47
R- 4	55	93	116	169	207	247
R- 3	49	86	108	157	193	229
R- 2	108	185	231	335	411	490
R- 1	125	214	268	389	475	566

Table 3 (cont)

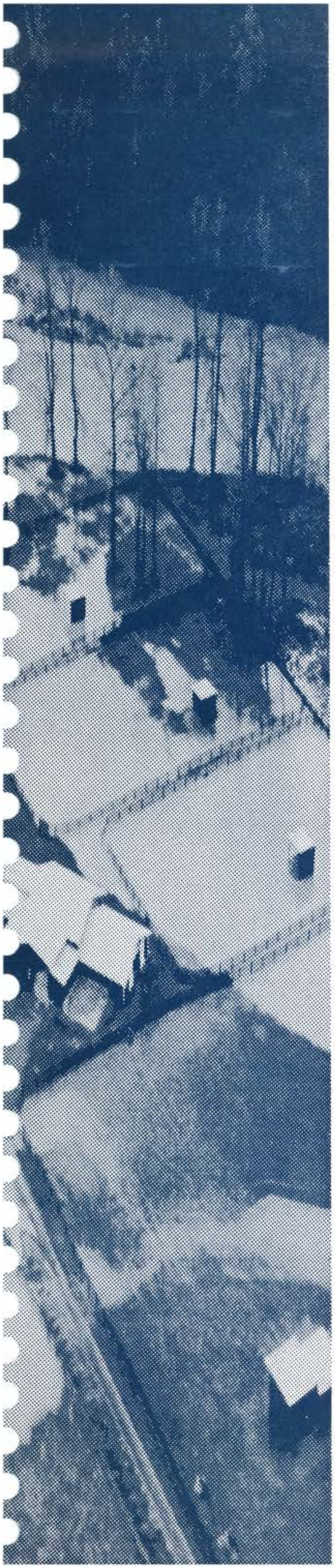
WALSH LAKE DIVERSION DITCH

Forested	2- yr	5- yr	10- yr	25- yr	50- yr	100- yr
WALSH- 2	assumed same as current					
WALSH- 1	under long term forest cover					
Current						
WALSH- 2	82	98	108	119	127	135
WALSH- 1	79	94	103	113	120	127
Future (with R/D mitigation)						
WALSH- 2	assumed same as current					
WALSH- 1	under long term forest cover					
Future (**without** R/D mitigation)						
WALSH- 2	assumed same as current					
WALSH- 1	under long term forest cover					

Figure 1



RESERVOIR CAPACITY CURVES



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Flooding

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Chapter 4: Flooding

4.1 INTRODUCTION

As commonly used, the term "flooding" has implied an unusual occurrence accompanied by damage. Instead, flooding is one of the cyclic, predictable processes that takes place in rivers: every river system floods, given the proper topographic and hydrologic conditions. Flooding by itself is not necessarily hazardous, but it becomes a problem when it threatens human life or when it excessively damages significant structures, roads, or other artificial objects in its path.

Damage to natural elements such as spawning gravel beds and rearing areas can also occur. Flooding at natural magnitudes and return periods is an essential condition of life for salmon evolved in river, estuary, and floodplain habitats. Flooding allows an exchange of nutrients and other materials between areas within and outside a river's banks. Flooding allows the river to change its configuration to more efficiently resist the changing forces acting on it, thereby providing a more stable environment during the periods between floods. See *Chapter 5: Erosion and Deposition* and *Chapter 7: Aquatic Habitat* for further discussion of these effects and of how the buffering action of the natural river system moderates damage from flooding.

Flooding in the Cedar River Basin takes two forms. Local, small-scale flooding is usually caused by short-lived extreme precipitation events; increased runoff, often the result of new development upstream; and inadequate capacities in individual drainage structures, channels, and pipes. It affects fewer properties and inflicts less significant damage than does regional flooding. Regional, larger-scale flooding affects numerous properties and causes significant damage. It is associated with systemic or basinwide conditions such as extreme precipitation, sediment deposition, channel migration, and bank and levee failure.

Generally, regional flooding is found along the Cedar River's mainstem, while local flooding is more common in the tributary subbasins on the plateaus surrounding the Cedar River valley.

TRIBUTARIES

Flooding problems in tributaries away from the mainstem of the Cedar River are generally traced to 1) damaged, insufficiently maintained, or undersized roadside ditches or culverts crossing under roads or driveways; 2) reduced channel capacity caused by an accretion of sediment or other material; 3) increased discharges caused by the increase in impervious area and by the destruction of natural wetland detention as development proceeds through the subbasin; or, 4) structures being built in locations such as wetlands and closed depressions, where surface drainage is naturally poor.

The effects of tributary flooding range from minor problems such as yard and landscape damage to widespread soil erosion, slope movement, and damage to homes and other structures. While tributary flooding is seldom directly life-threatening, it can threaten public health and safety by preventing access to emergency sites by fire and medical services. Even in the absence of direct flood damage, repeated occurrences of soil saturation can cause long-term effects such as foundation settlement, road damage, and environmental changes. Finally, by inundating septic systems and by causing the erosion and deposition of silts and other sediment, tributary flooding can degrade the quality of surface water, groundwater, and fish and wildlife habitat throughout the Basin Planning Area (BPA).

MAINSTEM

Flooding in the Cedar River valley is typically initiated by the combined effects of steady rains, rising temperatures, and melting snowpack on the western slopes of the Cascade Range. Once adequate snowpack has accumulated, warm temperatures and rain can produce lowland flooding any time from late fall through spring.

The pattern of flooding in the Cedar River Basin is affected by topography and historic development. In the Upper Basin, where the river flows through the narrow steep valleys of the City of Seattle watershed, the effects of flooding are minimal. Flooding has damaged some riverside homes in the middle basin above Maple Valley but is usually most serious in the Lower Basin, between Maple Valley and the City of Renton. Most of the development in the Cedar River valley outside Renton is located along this portion of the narrow floodplain that forms the valley floor. As a result, residential developments near, Elliot, Cedar Grove, and Maple Valley have been subject to repeated flooding.

In the Renton Reach, however, flood damage until recently has been minor because the artificial channel created to redirect the Cedar River into Lake Washington historically has been dredged to contain flood flows. Between the mouth of the Cedar River and RM 2.0, channel capacity has been restricted by the deposition of sediment that has accumulated over the years since regular maintenance dredging was discontinued in the early 1980s (NHC, 1992). During high river stages, this section of the Cedar River is growing more flood-prone. The City of Renton and the Corps of Engineers are investigating the effect of dredging this reach.

While backwater effects from a sediment delta in Lake Washington near the mouth of the Cedar River may contribute to this problem, a recent study has shown little evidence that removing the delta alone would significantly reduce flooding in the lowest reaches of the river (Renton, 1992a) .

4.2 DATA SOURCES, ANALYSIS METHODS, AND CRITERIA

DATA SOURCES

Information regarding flood damage was gathered from many sources, including records of complaints made to King County SWM's Drainage Investigation and Regulation (DIR) and Facilities Maintenance Units (see the Appendix following this chapter), King County Roads Division, King County's Draft Flood Hazard Reduction Plan (KCSMWb, 1991), City of Renton Stormwater Utility, Washington State Department of Transportation (WSDOT), U.S. Army Corps of Engineers (COE) Seattle District Office, Federal Emergency Management Agency (FEMA), City of Seattle Water Department (SWD), and the general public.

SWM staff engineers and technicians walked most of the tributaries and the portions of the mainstem protected by levees and revetments.[1] Information was compiled at stream crossings, channel constrictions, and other locations where flooding problems were known or suspected. Photos and data sheets were compiled describing the physical configuration of each location, and these data were used to estimate the flow capacity at each point studied.

ANALYSIS METHODS

Local Flooding Problems

The capacities of culverts were estimated at locations identified as either known or potential flooding problems. This was done using standard highway engineering design methods, whereby the maximum discharge that can be passed by a culvert is estimated given the culvert's size, material, condition, and physical configuration and maximum water depth at its inlet and outlet. The capacities of open conveyances, such as roadside

[1] A "levee" is an artificially elevated portion of the riverbank, built to contain rising floodwaters. A "dike" is a large levee, often associated with tidal waters. A "revetment" is an artificially protected or armored portion of the riverbank, typically a rock-lined face, that helps prevent erosion but does not provide protection from overtopping. Most of the levees on the Cedar River have armored faces and also function as revetments.

systems and private channels, where past problems had been identified were estimated using the Manning equation.

Regional Flooding Problems: HEC-2 Floodplain Model

Description: The floodplain of the Cedar River mainstem was modeled from its mouth to Noble, a distance of approximately 19 miles. The hydraulic model used in this study is the US Army Corps of Engineers HEC-2 Water Surface Profile computer program (COE, 1984). Using discharges generated by the HSPF model as input conditions, HEC-2 computes water surface elevations and other hydraulic parameters for stream reaches whose cross sections have been surveyed and coded into the model. (For further information on the HSPF model, see *Chapter 3: Surface Water Hydrology.*) The effects of bridges, culverts, weirs, levees, and dams on the water surface are also computed by coding in the geometry of these hydraulic structures.

Data for setting up the floodplain model consist largely of stream cross sections and estimates of Manning's "n", a coefficient representing resistance to flow. Additional data can come from topographic mapping and from field notes and photographs of vegetation and bank conditions. Flow resistance is estimated using various methods, such as values tabulated by Chow (1959) and Righellis (1988), or comparisons with photographs of channels of known resistance values. Alternatively, "n" may be found by solving the Manning equation when discharge, water-surface elevation, energy gradient, and cross sections are all known. With few exceptions, this study used the "n" values incorporated in the data files received from COE and NHC.

The principal use of the HEC-2 program is to determine water surface elevations of the river for various discharges. The output from the program can also be useful in studying sediment transport and habitat, and in setting up the stage-discharge-volume-area relationships ("F-tables") needed for channel routing in the HSPF model. Ninety-five different parameters may be calculated including flow velocities, water surface elevation, river cross sectional area of flow, and the horizontal extent of the floodplain for a given discharge.

Data Sources: The HEC-2 application used in this study was compiled by combining input data developed by the COE Seattle District office for use in their *Section 205 Cedar River Flood Damage Reduction Feasibility Study* (COE, 1990), with data developed by Northwest Hydraulic Consultants (NHC) for their February 1992 *Lower Cedar River HEC-2 Model and Evaluation of Flood Relief Alternatives* (NHC, 1992).

For the COE application, 64 cross sections were developed from photogrammetric survey data gathered from flights made in November 1989; ground survey subsequently performed by City of Seattle crews provided data for ten more cross sections and for additional detail within the channel at all other cross sections (Angelo, 1992; Erlandson, 1992; Dodge, 1992). The resulting model, which analyzed the mainstem from its mouth to approximately RM 17.3, was calibrated by the COE against high water marks from the December 1975 flood (Angelo, 1992).

NHC's data, including only the lowest 2.1 miles of the Cedar River, was developed from survey performed in 1991. This application was calibrated by NHC using known high water marks, video tapes, and still photos from the November 25, 1990, flood.

A third set of data was developed by SWM staff to extend the model from RM 17.3 through RM 19.1, the upstream-most significantly developed area in the BPA. No additional survey work was done; these additions to the original data were made based on site visits and on the COE aerial survey maps. Because this data is less accurate than data gathered from a ground survey, the floodplain modeled in this upper reach will probably be less accurate than the floodplain modeled for the reaches of the Cedar River below RM 17.3.

Calibration: A HEC-2 application is calibrated by adjusting input data for each cross section until the water surface elevations calculated for given historical discharges approximate the elevations observed in the field during the corresponding events. Records from December 3, 1975, and November 10 and 25, 1990, were used to calibrate the application used in this analysis.

Estimates of discharges are made based on readings taken at staff gages placed at intervals along the river. The accuracy of these estimates depends on several variables, including the accuracy both of the observations and of the estimate of the river's stage/discharge relationship at each gage location. Stage/discharge relationships can change with the river's changing configuration, especially as a result of high-flow events.

There is no firm agreement on the river's peak discharge during the November 1990 flood; the USGS gage located downstream from the Bronson Way bridge in Renton (RM 0.4) malfunctioned during the storm. Discharge estimates based on high water marks observed nearby vary, and the actual peak discharge for November 25, 1990, will probably never be known with certainty. The application used by this analysis was calibrated using 12,000 cfs to approximate this flood event.

For the remainder of the calibration, Basin Planning staff used the COE's recorded estimates of 8,800 cfs and 3,780 cfs, respectively, for the December 3, 1975, and November 10, 1990, discharges. The water surface elevations used for calibration were observed at 16 King County staff gage locations by the COE Seattle District Hydraulics Section on December 3 and 4, 1975; November 15, 1990; and December 5 and 6, 1990.

HEC-2 is not fully accurate under the best of conditions. As a one-dimensional, steady-state backwater model, it cannot account for unsteady (time-varying) flows due to channel branching, surges, lateral flows, or the effects of overbank storage. Results also can be affected by the accuracy of input survey data, the distances between cross sections, and assumptions regarding the intensities and timing of flows. Changes in the channel above RM 2.0 caused by the November 1990 flood (see *Chapter 5: Erosion and Deposition*) were not accounted for in this calibration. Current cross section data, which would require additional survey, and revised high-flow observations are needed to bring this model of the Cedar River fully up to date.

For the three sets of gage data, the average differences between the observed elevations and water surface elevations calculated during this calibration were approximately one foot (see the Appendix following this chapter). At the worst location (Station5332, downstream from the Logan Street bridge), the result of this calibration was approximately 3.6 feet lower than the observed condition. The remainder of the calibration was within approximately 3 feet of observed conditions.

Conditions Analyzed: Mainstem discharge values at Renton were estimated for various land-use conditions and exceedence levels. See *Chapter 3: Surface Water Hydrology* for an explanation of the assumptions associated with each land development condition and flood return period. The concept of "return period" for peak discharges is somewhat misleading when applied to the Cedar River, because these discharges are so strongly dependent on the operation of Masonry Dam. As explained in *Chapter 3*, these discharges and return periods were estimated using the SEAFM and HSPF computer models, which simulate the dam's operation.

Estimated discharge peaks under future land-use conditions were from 1/2% to 8% greater than peaks estimated under current conditions. Because these increases did not yield significant differences in the estimated size of the floodplain, modeling was performed using only current condition values.

The 10-year, 25-year, and 100-year mainstem peak discharges were modeled. These values were estimated to be 6,100 cfs, 8,000 cfs, and 11,100 cfs, respectively, at Renton. For each peak discharge, a series of progressively reduced values were estimated for selected points upstream. This allowed the HEC-2 model to reflect the small contributions to flood peaks made by the Cedar River's tributaries and valley subcatchments within the BPA.

The November 25, 1990, flood, representing the maximum observed event, was also modeled. The purpose was to compare County records of the extent of flooding and damage caused by this event to the projected effects caused by the 100-year flood.

Tributary subbasins were not modeled using HEC-2 because records of flooding complaints suggested most problems in the tributary subbasins were caused by localized drainage conditions rather than by the systemic backwater flooding HEC-2 was developed to analyze.

CRITERIA FOR IDENTIFYING SIGNIFICANT FLOODING PROBLEMS

The *King County Flood Hazard Reduction Plan* (KCSWMb, 1991) and previous SWM basin plans (KCSWMc, 1992), have developed systems for ranking flooding problems in order of significance. Cedar River Basin Plan staff, in conjunction with the Technical Advisory Committee and Watershed Management Committee, elected to use the following criteria for identifying significant flooding problems.

These criteria were applied to the entire range of flooding problems observed in the Basin Planning Area (all observed problems are listed in the Appendix following this chapter and in *Appendix A*). The flooding problems identified as significant by the following criteria are described in the following sections of this chapter (and are marked with asterisks in *Appendix A*).

Flooding problems will be prioritized in order by the following criteria:

Extremely Significant: Imminent threat to human life due to swift-moving and deep water during flooding up to and including the 100-year event.

Very Significant: Frequently[2] repeated flood damage to structures occupied by humans, including single and multifamily housing; institutions such as schools, hospitals, and libraries; commercial or industrial buildings. Frequently repeated damage to, or service interruption on, arterial roads or bridges, or on roads providing sole access to occupied structures. Frequently repeated damage to Regionally Significant Resource Areas.

Significant: Threat of significant[3] damage from less frequent flood events to structures listed under "Very Significant." Frequently repeated damage to Locally Significant Resource Areas. Threat of damage to Regionally Significant Resource Areas during less frequent events. Frequently repeated damage to areas with high recreational value.

Less Significant: Damage to areas that do not have occupied structures. Threat of damage to Locally Significant Resource Areas from less frequent events. Threat of damage from less frequent events to areas with recreational value.

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[2] A "frequent" event is defined here as one occurring at up to a 10-year return period

[3] "Significant" is defined here as representing 10% of the value of the damaged property.

4.3 RENTON REACH (RM 0.0–1.6)

GENERAL CHARACTER

The Renton Reach extends south-southeast from the Cedar River's mouth, at the south end of Lake Washington, to the I-405 bridge (see Map 17 in *Appendix B*). Most of its length is a channel dug early in the century to re-route the Cedar River into Lake Washington from its former course into the Duwamish River by way of the Black River (Chrzastowski, 1983). The portion of the Cedar River Basin located inside the Renton city limits is almost completely developed into either commercial, industrial, or high-density residential uses.

This lowest reach of the Cedar River is also the flattest, with both the widest floodplain and the gentlest channel gradient found in the basin. These characteristics contribute to sediment deposition and repeated flooding. Until the early 1980s this reach of channel was dredged on a regular basis. Since maintenance dredging was discontinued, sediment has been accumulating here. Bottom depths at some locations are as much as seven feet shallower than when dredging was regularly undertaken (NHC, 1992), though the average decrease in depth due to sedimentation is about 1 foot. See *Chapter 2: Geology and Groundwater* and *Chapter 5: Erosion and Deposition.*

SIGNIFICANT FLOODING PROBLEMS

Boeing (RM 0.0–1.0)

Along the lowest mile of the Cedar River the Renton Municipal Airport borders the left bank,[4] and the Boeing Commercial Aircraft plant borders the right. Several elements combine to influence flooding in this reach: water elevation in Lake Washington, controlled by the Corps of Engineers' (COE's) operation of the Hiram Chittendon Locks, has an effect in the lowest few thousand feet; an extensive sediment delta that has formed at the mouth of the river; the reduced capacity of the lowest reach of the Cedar River caused by sediment deposits in the channel; and extensive filling and construction on the historic floodplain.

Current Conditions: Under current conditions, the Municipal Airport is the location most prone to flooding: the left bank near the South Boeing bridge overtops during the 2-year event; at the 5-year event water begins to impinge on some of the hangars; the 25-year flood covers approximately the southern one-quarter and the central drainage swale of

[4]All right and left bank designations are made assuming the observer is facing downstream.

the airport, leaving only some westernmost buildings and about 5000 feet of the central runway above the water surface; the 100-year flood covers about 10% additional area (NHC, 1992).

Water currently begins to overtop the right bank near the Boeing plant at about the 15-year discharge.

Future Conditions: The future 25-year and 100-year events alone would not cause an appreciable increase in flooded area in this reach. If this reach is not dredged in the future, however, the resulting accumulation of sediment will continue to reduce the channel's capacity and will likely increase the frequency of flooding in this reach.

November 1990: Damage in all of Renton was approximately $5 million during the flood (NHC, 1992); most downtown bridges were contacted by floodwaters; the Municipal Airport was prevented from operating; no major damage was incurred at the Boeing plant, although economic losses were suffered due to an interruption of production caused by the flood.

4.4 LOWER CEDAR RIVER MAINSTEM (RM 1.6–16.2)

GENERAL CHARACTER

The lower mainstem of the Cedar River extends eastward from the I-405 bridge to approximately RM 9.0, where it turns southeasterly upstream to the SR-18 bridge in Maple Valley (RM 14.7), for a total distance of about 13 miles (see Map 18 in *Appendix B*). Land use in this portion of the valley consists mainly of wooded or grassed open space, non-commercial farms, and low-density residential development, with commercial and medium and high-density residential uses concentrated in the lowest reaches. A few isolated areas of concentrated development are found along its length. Some of these are the Maplewood community (RM 3.4–4.2), Maple Valley, and the Riverbend and Rainbow Bend Mobile Home Parks (RM 7.0 and 11.2, respectively).

The Cedar River is contained in its valley by high, steep walls. In many places the river is bordered by either roads (SR-169 and Jones Road, in particular) or an abandoned railroad fill, or both. Early maps and aerial photos show the river historically has meandered within its valley, as is expected of a relatively low-gradient river flowing through erodible material. Although this meandering has been reduced by the moderating effect of the Masonry Dam and constrained by levees and revetments, it is expected to continue in the future as nature brings its forces to bear over time.

Flooding effects from discharges projected under the future-mitigated and future-unmitigated conditions differ very little from those seen under current conditions. This reflects the minor contribution made by the Basin Planning Area's tributaries during high discharges, and the very large contribution made by the Seattle's watershed. Since no significant development is planned to take place inside the watershed boundary, no increase in runoff is expected from it in the future; therefore only the relatively minor increases from the tributaries will impact future discharges. See *Chapter 3: Surface Water Hydrology* for a more detailed explanation of current and future conditions.

SIGNIFICANT FLOODING PROBLEMS

Stoneway Gravel (RM 2.0)

The Stoneway gravel processing site is located on the right bank[5] of the Cedar River between the river and SR-169.

Current/Future Conditions: About 10% of the Stoneway gravel processing site is inundated by the 25-year flood, while one-third of the site is covered by the 100-year flood.

Riviera Apartments (RM 2.2)

The Riviera Apartment complex is located on the right bank of the Cedar River immediately upstream of the Stoneway site. The building closest to the river is 70 feet from the bank.

Current/Future Conditions: This site appears to be safe from the 25-year flood, but the two buildings nearest the river are damaged during the 100-year event.

Elliot Bridge (RM 5.0)

The Elliot Bridge levee is located on the left bank of the Cedar River immediately upstream of the Elliot (149th Avenue SE/lower Jones Road) Bridge. Five homes are located within 100 feet of the river, downstream of the bridge.

Current/Future Conditions: Downstream from the bridge, two homes on the left bank and three on the right are at risk of damage during both the 10-year and 25-year floods.

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[5] All right and left bank designations are made assuming the observer is facing downstream.

On the left bank, upstream from the bridge, two more homes are subject to damage during the 25-year flood, and an additional 5 during the 100-year flood, due to backwater flooding from the area downstream. Several others, while not subject to damage, would likely be isolated by floodwaters.

November 1990: The two homes on the left bank downstream of the bridge were flooded to depths of over three feet. Another home on the left bank, located farther from the river, suffered property flooding but was not damaged.

Lower Jones Road (RM 5.3-6.5)

Approximately 25 homes are located along the right bank of the Cedar River in this reach, many within 50 feet of the river. The area between the left bank and the SR-169/railroad fill is almost entirely given to open space, which is not significantly damaged by flooding.

Current/Future Conditions: Twenty homes on the right bank are likely to be impacted during the 25-year flood, and additional 20 during the 100-year flood. Some have experienced ground subsidence, washouts, and the loss of bank armoring in the past. Jones Road west of 154th Place SE would also be flooded.

November 1990: Over twenty homes located on the right bank of the river were damaged or threatened by flooding. Flood flows eroded the rubble and concrete levees, and overtopped and damaged Jones Road.

Brassfield/Maxwell/Guth Levee (RM 6.8)

This levee is located on the right bank of the Cedar River opposite the Riverbend Mobile Home Park.

Current/Future Conditions: The levee provides 100-year protection for the homes behind it. However, one home downstream of the levee is within the 100-year floodplain.

Ricardi Revetment (RM 7.4)

The Ricardi Revetment is located on the right bank of the Cedar River just upstream of the Riverbend Mobile Home Park.

Current/Future Conditions: The HEC-2 model indicates two homes located within this tight, right-bank bend, about 60 feet from the river, would be isolated but not damaged by the 100-year flood.

November 1990: These homes were severely damaged by fast, deep flows.

WPA/Cedar Mountain Levee (RM 10.6)

This levee is located on an inside bend on the left bank, opposite the Rainbow Bend Mobile Home Park. There are six homes situated between the river and the old Burlington Northern railroad fill.

Current/Future Conditions: While none of these homes is threatened by the 25-year flood, all six are within the 100-year floodplain.

Cedar Grove/Rainbow Bend Mobile Home Park (RM 11.2)

The Rainbow Bend Mobile Home Park is located above the right bank of the Cedar River, with the nearest few units approximately 200 feet from the river. Upstream, six homes are situated behind a levee on the right bank and two homes are on the left bank, immediately downstream of Cedar Grove Road.

Current/Future Conditions: All of the approximately 55 mobile homes and four of the six permanent homes in this reach are identified as being within the 10-year floodplain. The 100-year event would likely damage an additional one of the six permanent homes. Flood flows have repeatedly overtopped and damaged this levee, causing significant damage to County roads and to the private residences. Access to these homes also is prevented during flooding, making evacuation of residents difficult.

November 1990: Several of the permanent structures and nearly all the mobile homes were damaged.

Cedar Grove Road (RM 11.4-12.2)

This area contains approximately 15 homes in the wide flat area situated between the MacDonald levee, on the left bank of the Cedar River, and the SR-169/railroad corridor farther to the west. Cedar Grove Road, a main arterial, crosses the river at the downstream end of the reach. A pipe carrying leachate from the Cedar Hills landfill to a Metro main is buried under the road.

Current/Future Conditions: The HEC-2 model indicates Cedar Grove Road and most of the homes in this area are at risk of damage from the 10-year, 25-year and 100-year floods, primarily from backwater effects (water flowing around the downstream end of the levee) rather than from overtopping of the levee.

November 1990: Flooding damaged the McDonald levee, several homes, and Cedar Grove Road; it also threatened the landfill leachate line under the road. The levee has been partially repaired.

Byers Bend (RM 12.4)

The Byers Bend levee is on the left bank of the Cedar River, about one mile upstream from the Cedar Grove Road bridge. The river curves through 180 degrees and back in this reach, and exerts strong erosive forces against the banks. Momentum has caused water to overtop the levee even when the HEC-2 model indicates it should be safe.

Current/Future Conditions: Flooding appears to isolate but not directly damage the homes in this area during the 25-year event. Southeast 192nd Street and SE 188th Street, providing the sole access to about a dozen homes, are impassable during this flood. Approximately thirty homes are within the 100-year floodplain.

November 1990: Backwater and water overtopping this levee damaged roads, homes, and the levee itself, which has since been repaired.

Jan Road/SE 197th Place (RM 13.0)

This is a lightly developed area located on the right bank between the Cedar River and Maxwell Road (225th Avenue SE) to the east.

Current/Future Conditions: A combination of backwater and overbank flows creates a flood corridor connecting the Jan Road bend with Byers Bend. One home is within the 10-year floodplain and another two are within the 25-year floodplain. SE 197th Place, a sole-access private road, would be impassable during the larger flood. Flows from the Cedar River would probably be compounded by flows from Taylor Creek, which joins the Cedar River immediately above RM 13.0. During the 100-year event, an additional four homes would be flooded.

November 1990: Flood flows left the channel above Jan Road and damaged residences and roadways.

Rhode (RM 13.6)

This area, located on the left bank between the Cedar River and 218th Place SE and the railroad fill, is residentially developed at low to medium density.

Current/Future Conditions: Two homes would be damaged during the 10-year flood. One more home is located within the 25-year floodplain, and an additional 18 are within the 100-year floodplain.

November 1990: On the left bank, several residences and two roads were damaged by water and sediment deposited during the flood.

SR-169 Bridge/Lower Bain Road (RM 13.8-14.7)

This is the reach of the Cedar River located west of SR-169, in the Maple Valley area. It is developed near the highways but much less so along the river.

Current Conditions: The 10-year flood would damage nine homes east of the river; the 25-year floodplain encompasses an additional seven homes on the east side and nine on the west side or the Cedar River. An additional 14 homes are within the 100-year floodplain.

November 1990: Several homes were damaged during this event.

4.5 LOWER CEDAR RIVER SUBBASINS

The Cedar River's tributaries typically display a three-part profile with a steep middle section between two low-gradient sections. They originate on the gently sloping plateaus above the Cedar River, enter steep ravines to drop down the valley wall, and finally flow across the low-gradient valley floor to meet the Cedar River (Maps 13-18). In cases where development on the plateau has increased the sediment load or where increased discharges have promoted incision of the steeper reaches, the resulting sediment deposition in the lower reaches reduces channel conveyance, occasionally causing flooding.

TRIBUTARIES 0300A, 0301, and TRIBUTARY "RM 2.7"

General Character

These subbasins encompass one square mile of land situated south of the Cedar River and southeast of Renton at approximately Cedar River RM 2.5 (see Map 19 in *Appendix B*). They are highly developed, with about 78% of their land use characterized as high-density residential (3 to 7 units/acre). The plateau forming the majority of the subbasin is drained down the face of a high, steep slope to the Cedar River via three small creeks.

Tributary 0300A joins the Cedar River from the south at approximately RM 2.4. The upper reach drains the Cascade Vista and Cascade Hills subdivisions. The middle reach runs through the Maplewood district of the City of Renton, and the lower reach drops through a steep, erosion-prone ravine to join the Cedar River behind the Riviera Apartments at about Cedar River RM 2.3.

Tributary 0301 parallels Tributary 0300A to the east, joining the Cedar River at RM 2.6. It drains a fairly small area composed of about 15% single family residential and the remainder wetland and ravine. No flooding problems have been reported in this subbasin.

The tributary referred to here as "Tributary RM 2.7", located north of SE 5th Street, flows south to join the Cedar River at RM 2.7. It has not been analyzed separately other than to be walked and to have had a search for records of complaints; based on this information, there are no significant flooding problems.

Significant Flooding Problems

None of the current or future flooding conditions identified in this subbasin meet the criteria established for high priority consideration. The minor flooding problems that have been identified are listed in the Appendix following this chapter and in *Appendix A*.

MAPLEWOOD CREEK SUBBASIN: TRIBUTARIES 0302, 0303, AND 0303A

General Character

Maplewood Creek drains approximately 1.7 square miles located directly north of the Cedar River. It joins the mainstem at RM 3.3 (see Map 20 in *Appendix B*). The upper two-thirds of the subbasin is extensively developed, with about 60% of the total subbasin area devoted to commercial, multifamily, or high- or low-density residential land uses. The remainder is considered forested, grassland, or wetland for hydrological purposes.

Tributary 0302, the west fork of Maplewood Creek, flows through the Castlewood, Fernwood, Heather Downs, and Maplewood Heights subdivisions. Tributary 0303 flows south through Puget Colony Homes, and joins Tributary 0302 at RM 0.9. Both tributaries originate north of SE 128th Street but most of the area that apparently originally contributed to Tributary 0303 now flows into Tributary 0302.

Significant Flooding Problems

Current Conditions: Tributary 0303, RM 0.8: The Puget Colony Homes subdivision has experienced several instances of flooded roads and residences in the last ten years. An enclosed drainage system running largely on private property is incapable of handling existing runoff exceeding the two-year return period discharge. Portions of the area upstream of this neighborhood were originally wetland, but now are filled. The resultant loss of storage volume has probably exacerbated this problem. SWM's December 1990 "Yahn Drainage Study — Phase II" addressed this issue and concluded that some small improvement could be gained by enlarging a small detention facility, located north of SE 132nd Street at the (unimproved) 140th Avenue SE right-of-way, but that any significant changes could damage the remaining wetlands and contribute to the erosion seen downstream.

Tributary 0303A, RM 0.4: A culvert carrying Tributary 0303A under SE 132nd Street is inadequate for discharges in excess of those generated by a two-year event. Its backed up water regularly floods the SE 132nd Street/146th Avenue SE intersection, preventing access to homes to the east. Overflow from this problem enters the Tributary 0307 subbasin.

Future Conditions: If unmitigated, the flows in Maplewood Creek would be expected to increase significantly as the subbasin becomes fully developed. Under these conditions the future two-year return flow would approximately equal the current 25-year flow. Without mitigation, existing drainage and flooding problems throughout the subbasin are expected to worsen as a result.

Tributary 0303, RM 1.0: The area upstream from Puget Colony Homes seems likely to experience large increases in discharges as expected development proceeds. Any increase in discharges will cause flooding to occur more frequently. If conveyance is improved through Puget Colony to reduce flooding there, erosion farther downstream in Tributary 0303 would likely be increased.

Tributary 0303A: The flooding at the SE 132nd Street/146th Avenue SE intersection will worsen as upstream development continues. Increasing the capacity of this crossing would also increase the discharge in Tributary 0303 and contribute somewhat to the erosion there.

ORTING HILL SUBBASIN: TRIBUTARY 0307

General Character

This tributary drains about one square mile. It joins the Cedar River from the north at RM 5.6 (see Map 20 in *Appendix B*). Approximately 40% of the land is forested, with the remainder split nearly evenly between high- and low- density residential development. The majority of this subbasin is gently sloping plateau north of the Cedar River, but the last half mile drops steeply down the valley wall to the river.

Overflows from a culvert carrying Tributary 0303A under SE 132nd Street enter the upstream end of this system during flows larger than the two-year discharge.

Significant Flooding Problems

Current Conditions: There is no significant flooding in this subbasin, but erosion due to peak events is a problem, especially in the undeveloped area north of the Maplewood subdivision where the creek is crossed by unculverted dirt roads. This eroded material eventually is deposited in the lower reaches, degrading their habitat value and reducing the lower system's capacity.

The lowest reach of this creek, at the base of Orting Hill ravine, was directed through a 36-inch concrete pipe system in 1989 to prevent damage to SE Jones Road. High discharges, combined with sediment and debris blocking the entrance, caused some flooding problems during the January 1990 storm when runoff left the channel, crossed 154th Place SE, and damaged private yards and flooded one home. The County later repaired the damaged system and there have been no further flooding problems, although there have been complaints that sediment is being deposited in the short reach of open channel near SE Jones Road.

A closed system draining SE 142nd Place (Orting Hill Road) and a housing development farther east daylights at RM 0.8, at the top of the deep, steep-sided ravine carrying this tributary. This system failed during the November 1990 storms, sending a wedge of hillside and several lengths of corrugated metal pipe into the ravine. This slope failure oversteepened the slope next to the road shoulder and threatened to undermine the road. County Road crews dumped several truckloads of large rock over the bank, temporarily stabilizing the system. This reach of creek is also experiencing erosion and landsliding of its banks.

County SWM and Roads Divisions have built a retaining wall at the toe of the slope intended to stabilize the creek sides in the Orting Hill ravine.

Future Conditions: The system failures that caused problems in the past have been repaired. Future storm flows, if unmitigated, could increase by about 50% over the current condition, but no significant new problems are anticipated in this subbasin.

MOLASSES CREEK SUBBASIN: TRIBUTARIES 0304 and 0304A

General Character

Molasses Creek drains approximately 1.8 square miles south of the Maplewood district (see Map 21 in *Appendix B*). It joins the Cedar River at RM 4.0. The largest single land use in this subbasin is high-density residential at 32%, followed by 26% forested, and 20% grass/pastureland. The residential land use is concentrated in the middle and upper reaches; the lowest 3,000 feet of the creek flows through the steep, forested slope that borders the Cedar River valley on the south. The area near the confluence with the Cedar River has experienced severe erosion and landslide problems; however, these conditions do not appear to be directly related to discharges in the creek.

Significant Flooding Problems

Current Conditions: The majority of drainage complaints in this subbasin concern seepage in the sloping areas overlooking Maplewood; runoff from the Seattle Water Department right-of-way in the Fairwood area; and poor drainage in the area surrounding Wetlands 22 and 23, at the upper end of the system. There have also been a number of complaints about maintenance and adequacy of road culverts and drainage ditches throughout the system.

RM 1.0: Water currently ponds between 132nd and 133rd Place SE in an inadequately-sized detention area behind an access road on the Seattle Water Department (SWD) right-of-way south of SE Fairwood Blvd during 25-year and larger flows. One house experienced 6 inches of water over its first floor during both the January and November 1990 storms. Another house, with a one foot higher floor elevation, is threatened. Both were built with finished floor elevations lower than the minimum specified on the plat.

RM 1.8: The culvert crossing under SE 180th Street appears to have adequate capacity for up to a five-year flow. During larger discharges the road would flood, preventing access to homes to the west.

RM 2.0: 140th Avenue SE crossing spans Wetland 22. The low in the road and the surrounding properties experience flooding approximately annually. This crossing has an estimated capacity of 26 cfs, or about a 5-year discharge.

Future Conditions: Without mitigation, storm discharges are expected to increase significantly as this subbasin continues to develop (see *Chapter 3: Surface Water Hydrology*). The following areas in particular are anticipated to experience significant flooding.

RM 1.0: Local flooding behind the SWD right-of-way is expected to become more frequent if development continues to increase without mitigation. SWM has concluded a study of this problem and has recommended an interim solution that would increase detention storage and lower a catchbasin inlet to reduce the likelihood of flooding during large events.

RM 1.8: If future upstream development is unmitigated, this situation is likely to get worse as flows increase in intensity and frequency.

RM 2.0: Most of the area above the 140th Avenue SE crossing of Wetland 22 is currently undeveloped; if unmitigated, future flows will be significantly higher, causing deeper and more frequent flooding.

MADSEN CREEK SUBBASIN: TRIBUTARIES 0305 AND 0306

General Character

The Madsen Creek subbasin drains approximately 2.2 square miles on the Fairwood plateau, a highly urbanized community located south of the Cedar River and east of Renton (see Map 22 in *Appendix B*). This subbasin is largely developed as single-family residential housing encompassing a golf course. This subbasin is characterized by moderate to severe erosion in the middle channels, and by significant sediment deposition below. Sediment deposited in the lower reaches reduces the carrying capacity of the channels, resulting in local flooding in these areas. The middle reach of Madsen Creek, above Madsen RM 0.8, is situated in a deep ravine with a steep bed gradient.

In an effort to reduce water quality and sedimentation problems caused by high rates of erosion in the middle reaches of this basin, Tributary 0305, the main branch of Madsen Creek, was modified by King County in 1974 by the addition of a sediment detention pond at RM 0.8. High flows were segregated by means of a weir and leave the pond flowing directly north, through three 57 by 38 inch corrugated metal pipe arches (CMPAs) under SR-169, to join the mainstem at RM 5.3, just east of the Lower Jones Road (Elliott) Bridge. Low flows were routed to the east, then north to SR-169 where they head west and cross under the high flow channel through three 35-inch by 24-inch corrugated metal pipe arches, then through a 72-inch box culvert under the highway, then northwest to join the Cedar River at RM 5.1.

Both Tributaries 0305 and 0306 show numerous instances of the erosion and deposition described above, with Tributary 0305, the main branch of Madsen Creek, being the most severe. Tributary 0306A appears to be in relatively good condition.

Historical Problems

The sediment detention pond at RM 0.8 was built by King County in 1974 to intercept sediment from the eroded portions of the upper creek. Uprooted trees and other material from upstream created a blockage that caused it to overflow and flood the Wonderland Mobile Home Park during the January 1990 storm. The pond has since been repaired and appears to be functioning safely now. There is still concern about the low-flow outlet channel being subject to fine sediment that passes through the pond.

An 8- inch METRO sewer line running from Tributary 0306, RM 0.1, through Tributary 0305 was exposed in several locations and damaged in the upper ravine during the January and November 1990 storms, when major landslides occurred in the channel. Two 10- inch, high- pressure gas lines (installed in 1956) that cross the creek above the 0305/0306 confluance were exposed during the November event. These problems were temporarily stabilized in 1992 by a project undertaken by METROand King County. This project encountered a number of difficulties due to weather and contractor inexperience that resulted in delays, a break in the sewer pipe, and erosion and other damage to the stream. Some mitigation work that was not completed remains to be done in 1993 to finish this project.

Significant Flooding Problems

Current Conditions: All tributaries, in plateau areas: There have been numerous complaints about water ponding in yards and crawlspaces. This reflects the fact that many of the homes in the Fairwood area, which were built in the 1960s and 1970s, were sited on poorly drained lots. Site investigations performed by SWM staff suggest many of these lots may be filled wetlands.

Current Activity: King County and Metro are negotiating further work to be done along the erosion- damaged reachs of Tributaries 0305 and 0306.

As part of the "SR-169 196th Avenue SE/Jones Road to Maplewood Golf Course" widening project, WSDOT plans to replace the pipes and box culvert conveying Madsen Creek under SR-169. The design of the new crossing is not final as of this writing.

Future Conditions: Flooding is not expected to increase significantly in these subbasins, and no significant additional problems are anticipated in the future.

CEDAR GROVE SUBBASIN: TRIBUTARIES 0308 THROUGH 0310

General Character

Tributaries 0308A, 0309, and 0310, which join the Cedar River at approximately RM 7.2, have been designated the "Cedar Grove" subbasins (see Map 23 in *Appendix B*). Together they drain 1.1 square miles of plateau north of the Cedar River mainstem. The majority of this area is hill and valley topography, comprising several parallel flow paths that join at about RM 0.2, before dropping down the steep valley wall to the Cedar River.

High-density residential and forested land uses each comprise approximately 40% of the subbasin's area. Another 17% is given to low-density residential or industrial use with grass/pastureland and wetlands making up about 30% of the remainder.

SWM has received no complaints indicating significant flooding problems in Tributary 0308. Tributary 0308A also seems to be in relatively good condition. Tributary 0309 is suffering reduced conveyance caused by silt deposition and by lack of maintenance of ditches and culverts. Tributary 0310 has significant deposits of large sediment in the channel, especially in its lowest reach.

Significant Flooding Problems

Current Conditions: None of the flooding problems identified in this subbasin meet the criteria established for high priority consideration. The minor flooding problems that have been identified are listed in the Appendix following this chapter and in *Appendix A*.

Future Conditions: Future-unmitigated development would increase storm flows by approximately 50% over current conditions, but no significant problems are foreseen as a result.

SUMMERFIELD SUBBASIN: TRIBUTARIES 0311, 0312, 0313

General Character

These three creeks drain an area of about one square mile located south of the Cedar River between RM 6.2 and 6.8 (see Map 22 in *Appendix B*). Whereas the majority of the area is very steep and undeveloped, the lowest reach of Tributary 0311 flows through the Summerfield subdivision.

Historical Problems

Tributary 0311, RM 0.1: This site has been subject to landsliding and erosion for many years. During the January 1990 storm, SE 156th Street was flooded and many nearby homes in the Summerfield subdivision were damaged by a mudslide. This occurred when a detention pond receiving runoff from the Fairwood district to the south overtopped, causing the hillside to erode and slide. King County built a tightline system to convey some of the discharge from the Fairwood District to the foot of the hill and across SR-169 to the Cedar River. They also enlarged and otherwise improved an existing sediment pond in the Summerfield subdivision. The pond is probably too small for effective reduction of long-term sediment delivery to the Cedar River, but the tightline should help reduce the risk of future slides and also should reduce the amount of sediment entering the Cedar River system (which may have exceeded a few thousand cubic yards during the 1990 mudslide).

Tributary 0313, RM 0.2: Several units in the Valleyview Mobile Home Park received slide and debris damage during the January 1990 storm, and flooding during the November 1990 storm.

Significant Flooding Problems

Current Conditions: Tributary 0311, RM 0.1: King County is continuing to improve the drainage through the east portion of Summerfield to a 25-year level of protection by installing a new 24-inch drain pipe parallel to the existing system in 161st Avenue SE.

Future Conditions: Tributary 0313, RM 0.2: This channel and the adjacent hillsides are unstable, and the current erosion problems are likely to continue.

If future development is unmitigated, these subbasins will experience a 50% increase in significant discharge peaks. This increase is anticipated to exacerbate current problems and is likely to create new ones as well.

CEDAR HILLS SUBBASINS: TRIBUTARIES 0314, 0315, 0316

General Character

These three small streams drain portions of the "Cedar Hills" catchment, located between the Cedar Grove Road and Upper Jones Road intersections with SR-169 (see Map 24 in *Appendix B*).

Significant Flooding Problems

Current Conditions: Although these areas contain the Cedar Hills landfill, Stoneway quarry, and Cedar Grove Composting facility, they are largely undeveloped, and none has any record of flooding problems.

Future Conditions: No separate analyses of current and future runoff volumes was performed for these subbasins. No future flooding problems are expected.

WEBSTER LAKE SUBBASINS: TRIBUTARIES 0317, 0318, 0319

General Character

These subbasins include Webster and Francis Lakes. They meet the Cedar River at RM 12.1 and drain approximately 0.9 square miles of low-density residential land (see Map 24 in *Appendix B*).

Significant Flooding Problems

Future Conditions: Discharges in this subbasin are relatively small. Even if, as projected, they increase by about 50%, the total flows are still small enough to cause no significant new flooding problems in the subbasin.

4.6 MIDDLE CEDAR RIVER MAINSTEM (RM 16.2–23.4)

GENERAL CHARACTER

The Middle Mainstem of the Cedar River extends from the Cedar River's confluence with Tributary 0336, above Maple Valley, to the USGS gaging station above Landsburg in the SWD watershed (see Map 25 in *Appendix B*). This area is forested and lightly developed for the most part, with the exception of the Dorre Don and Noble/Arcadia residential neighborhoods at RM 16.0 and 18.0, respectively. Like most of the mainstem, the principal flooding problems reflect the conflict between the migrating nature of the river and development within the historical floodplain.

SIGNIFICANT FLOODING PROBLEMS

Lower Dorre Don (RM 16.4)

Dorre Don is a high-density residential development built on an inside bend on the right bank[6] of the mainstem, containing some 25 homes. Approximately 20 of these are located immediately adjacent to the river on its right bank. The low-density residential area immediately downstream of Dorre Don is included in this analysis.

Current/Future Conditions: The 10-year event floods Lower Dorre Don Way and the 19 homes nearest the river, as well as four homes downstream. This intensity of flooding can also prevent access to many homes. The 100-year floodplain includes one additional home. The County has received numerous requests to replace material washed from this levee but has not done so do date.

November 1990: Many homes and Lower Dorre Don Way were damaged by flooding, erosion, and debris during the flood.

Orchard Grove (RM 17.1)

This neighborhood is just upstream from Dorre Don and is also built on an inside right bank curve. It contains approximately 40 homes, with 25 located along the Cedar River's right bank.

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[6] All right and left bank designations are made assuming the observer is facing downstream.

Current/Future Conditions: Two homes are within the 10-year floodplain. Five more homes experience damage from flooding at the 25-year level. Backwater flows from larger floods overtop the bank at its downstream end, scouring the bank. A total of thirteen homes behind the levee suffer flooding damage during the 100-year event, and access to approximately 14 homes is prevented by flood flows.

November 1990: Five homes were damaged by flooding.

Noble/Arcadia (RM 18.1-19.0)

These areas consist of residential developments located on a series of tight bends on the river. As noted in the *Analysis Methods* section, water surface calculations for the following areas were based on cross-section data taken from topographic maps, and could be less accurate than elevations calculated for the rest of the mainstem.

Current/Future Conditions: On the left bank, one home is within the estimated 25-year floodplain and four more are within the estimated 100-year floodplain at RM 18.1. Four homes at RM 18.4, immediately downstream of the Arcadia-Noble levee, are within the 100-year floodplain (none within the 25-year floodplain). At RM 18.8, four homes are within the 25-year floodplain and three more are within the 100-year floodplain. On the right bank, four homes at RM 19.0, just downstream of the Petorak-Wadhams levee, are within the 25-year floodplain, with an additional four within the 100-year floodplain.

November 1990: Flooding, erosion, and deposition of material damaged three homes in this area. SWM Drainage Investigation and Regulation Unit received reports of erosion damage to the right bank at RM 18.2.

4.7 PETERSON CREEK SUBBASIN

PETERSON LAKE: TRIBUTARIES 0328 THROUGH 0334

General Character

The Peterson Lake Subbasin is located between the Fairwood and Maple Valley communities. Its tributaries drain approximately 6.3 square miles including the Spring (also called "Otter") Lake and Lake Desire watersheds (see Map 26 in *Appendix B*). Over half of the area is classified as forested, with another quarter developed as low-density residential. Nine percent of the subbasin is classified as wetland. While this subbasin is among the largest in the Cedar River Basin, it is also one of the least developed. In addition, this basin benefits from the moderating effects of its many wetlands and lakes, which act as multiple detention ponds to reduce runoff peaks.

Tributaries 0328 and 0328A: This catchment includes Spring Lake. Tributaries 0328 and 0328A have not been significantly affected by storm water runoff, though there are instances of severe erosion and in some locations the streams contain large quantities of silt and sediment. Peterson Lake is a part of this drainage system; its level is controlled by an ecology-block weir.

Tributary 0328B: This catchment includes Lake Desire. Water leaving the lake flows under an unpaved road through a 30 inch CMP. This outlet channel flows throught a County- owned open- space parcel.

Tributaries 0329-0334: These small tributaries drain into Peterson Creek from the north. These catchments are mostly undeveloped.

Significant Flooding Problems

Current Conditions: Tributary 0328B, RM 1.7: The residents of Lake Desire have complained of frequent road flooding over East and North Lake Desire Drives SE. This flooding is reportedly caused by two problems: 1) these areas are underlain by deep peat deposits that cause the road to subside; and, 2) the lake's outlet pipe and channel are inadequately maintained, and the resultant reduced capacity causes the lake level to rise. Neither report has been varified at this time. Exiting flows sometimes overtop the maintenance road, causing erosion and sedimentation. In addition, some areas around the lake drain through its surrounding wetlands rather than through well-developed drainage courses, and the nearby yards sometimes flood.

Future Conditions: Tributary 0328B, RM 1.7: Road flooding of East Lake Desire Drive SE and North Lake Desire Drive SE is not expected to change significantly.

4.8 TAYLOR CREEK SUBBASIN

TAYLOR CREEK: TRIBUTARIES 0320 THROUGH 0327

General Character

Taylor Creek, also known as Downs Creek, joins the Cedar River at RM 13.0. Its two forks, which together are approximately eight miles long, drain 5.2 square miles east of Maple Valley (see Map 27 in *Appendix B*). The terrain is generally rolling to hilly, with slopes averaging from 1.5 to 25%. Nearly half of the land in the Taylor Creek basin is in low-density residential use, with another third remaining as second-growth forest.

Taylor Creek has, over recent geological time, cut steep, moderately deep ravines into the native glacial soils. There is anecdotal evidence that it (at least intermittently) flowed directly to the Cedar River approximately along the SR-18 alignment, but maps from the late 1800s show it following its current alignment.

Significant Flooding Problems

Current Conditions: Unlike most of the Cedar River's tributaries, Taylor Creek experiences both local and regional flooding.

Local: According to SWM Drainage Investigation and Regulation Unit records, there are two local flooding problems in this subbasin. Both are ditches on private property and do not qualify as significant under the adopted criteria.

Tributary 0326, RM 0.8: The crossing at 262nd Avenue SE and SE 208th Street experienced erosion damage from high discharges during the January and November storms of 1990.

Regional: Two locations have been sites of regional flooding, both on Tributary 0320: at RM 1.2, above the concrete box culvert under SR-18; and the reach from RM 0.4 to RM 0.6, along Maxwell Road SE and 225th Avenue SE.

Tributary 0320, RM 0.4-0.6: The Maxwell Road reach of the creek overtops its banks almost yearly. One homeowner has reported water filling his heat ducts to a height just below his floorboards; others claim saturated soils resulting from flooding have allowed their house foundations to settle and crack. Maxwell Road SE and SE 206th Street flood, preventing access to several homes. Most driveway crossings are small bridges; however, two large culverts exist along this reach. The lower one, a damaged 54-inch diameter concrete pipe at RM 0.5, appears to add to the flooding problem upstream by restricting discharges larger than the 2-year event.

Tributary 0320, RM 1.2: The box culvert under SR-18 begins to cause flooding damage during the 20-year discharge. Its internal area is reduced by internal baffles installed to facilitate the passage of fish. In addition, a large debris barrier increases entrance losses during high discharges, reducing the capacity still further. The resulting system performs as though it were about 40% smaller than its nominal size; hence, it requires approximately ten feet of head to pass 180 cfs of flow, or about the 20-year storm. Above this discharge the impounded water begins to overtop the surrounding high ground and sluice a new path around the culvert, under the SR-18 overpass, and along Maxwell Road SE until it again enters Taylor Creek at about RM 1.0. The overflow carries with it material eroded from the road shoulder and the railroad fill along its way. This material is then deposited in the Maxwell Road reach, reducing channel capacity and causing the flooding of private property and of Maxwell Road SE itself.

Current Activity: In 1991, King County SWM retained Entranco Engineers to begin studying the Taylor Creek basin and to develop long-term and interim solutions to these problems. Interim solutions have included informing residents on how to floodproof and sandbag their homes, and a preliminary plan for an interim dredging of the Maxwell Road reach of the creek. Possible long-term and interim solutions to the flooding problem in the area are currently being developed for inclusion in the Cedar River Basin Plan.

Future Conditions
Local: Without mitigation, the local flooding in the Taylor Creek Subbasin is expected to become more frequent as runoff discharge increases approximately 25% due to continued development.

Regional: Tributary 0320, RM 0.4-0.8: The flooding along Maxwell Road will worsen if no mitigation is undertaken as development in the basin increases. Also, as part of WSDOT's planned improvements to SR-18, the capacity of the existing crossing carrying Taylor Creek under the highway will be improved (see below), reducing the moderating effect of the undersized box culvert. This will allow more flow through to this reach and, if not mitigated, will cause still more severe flooding.

Tributary 0320, RM 1.2: The capacity of the crossing under SR-18 is expected to be improved in 2001 as part of WSDOT's improvements to SR-18. The flooding problem will be reduced at this location but downstream discharges will be higher, making flooding more severe, when the culvert's current moderating influence is lost.

4.9 MIDDLE CEDAR RIVER SUBBASINS

DORRE DON SUBBASIN: TRIBUTARIES 0336 AND 0337

General Character

This subbasin (see Map 25 in *Appendix B*) exhibits the land configuration typical of the middle Cedar River Basin: flat, often poorly-drained highlands bounded by the river valley below. Unlike most of the tributaries in the Cedar River Basin, however, this channel does not traverse any single steep slope face on its way to the river.

This is one of the least developed subbasins in the Basin Planning Area, with only 35% of its 1.3 square miles developed, and fully 60% remaining forested. About one-fourth of the developed area is in the Dorre Don community, near the confluence of Tributary 0336 and the Cedar River, at RM 16.2, with the remainder spread throughout the highlands.

Significant Flooding Problems

Current Conditions: Aside from flooding associated with the mainstem in this area, none of the flooding problems identified in this subbasin meet the criteria established for high priority consideration. The minor flooding problems that have been identified are listed in the Appendix following this chapter and in *Appendix A*, and flooding problems associated with the mainstem are addressed in the *Middle Cedar River Mainstem* section.

Future Conditions: The majority of future development in this subbasin is anticipated to be single family homes on large parcels. Because land developed at this density is not required to include storm detention, future-unmitigated runoff discharges from this subbasin are estimated to be approximately 50% larger than those experienced under current conditions. Although SWM analysis has not identified any locations likely to become significant flooding problems under future conditions, new problems may begin as development and storm flows increase.

WALSH LAKE DIVERSION DITCH: TRIBUTARY O341

General Character

The Walsh Lake Diversion Ditch, Tributary 0341, is an artificially constructed canal that drains a long, narrow, largely undeveloped basin 6.6 square miles in area. Only about 10% of this basin is developed, almost entirely as low-density residential, with 90% remaining as forest, grass/pastureland, or wetland.

Significant Flooding Problems

Current Conditions: Of the relatively few flooding complaints received by SWM DI from this area, none relate to the diversion ditch itself.

Future Conditions: Only minor increases in runoff are projected in the Walsh Lake subbasin. No significant increase in flooding or related damages are expected.

4.10 ROCK CREEK SUBBASIN

ROCK CREEK: TRIBUTARIES 0338 and 0339

General Character

Rock Creek drains the 11.1 square miles located generally south of Cedar River RM 21.0, and joins the river at RM 18.1 (see Map 28 in *Appendix B*). This is the longest of the tributaries in the BPA, as well as one of the least developed basins under study, with 77% of its land remaining forested and only about 13% given to development of any kind.

Significant Flooding Problems

Current Conditions: None of the flooding problems identified in this subbasin meet the criteria established for high priority consideration. The minor flooding problems that have been identified are listed in the Appendix following this chapter and in *Appendix A*.

Future Conditions: As described above for the Dorre Don subbasin, future runoff discharges may create flooding problems as continuing unmitigated development and causes storm flows to increase.

4.11 KEY FINDINGS

MAINSTEM

★ Although flood discharge peaks are characterized in this analysis by return periods as thought they occurred in an uncontrolled system (e.g., "25-year flood event"), this terminology can be misleading because discharges in the mainstem of the Cedar River are strongly dependent on the operation of Masonry Dam.

★ More than 100 residences are situated within the 10-year floodplain at eight locations: RM 5.2, RM 11.2, RM 11.4, RM 13.0, RM 13.6, RM 13.8, RM 16.4, and RM 17.1. Most of these areas are subject to fast, deep flood flows during the 100-year event, and are therefore classified as "Extremely Significant Problems."

★ An additional 47 homes are outside the 10-year floodplain but within the 25-year floodplain; a total of 177 homes are within the 100-year floodplain.

★ Although flooding problems at the Renton Municipal Airport, at the Boeing Commercial Aircraft Plant, and in portions of Renton's downtown commercial and civic areas are characterized as "very significant" in this document, the significance of these problems could be considered elevated further because of their far-reaching economic and social impacts.

★ No significant change in mainstem flooding is anticipated in the future because future flows are anticipated to be only slightly greater than current flows.

TRIBUTARIES

★ Nearly all local flooding problems within the Cedar River Basin are located in the flat, poorly drained headwater areas of the tributaries. Of these, most currently present little or no threat of significant damage.

★ Puget Colony Homes, on the east fork of Maplewood Creek (Tributary 0303), is subject to frequent flooding caused by an inadequate drainage system and increased runoff from upstream development.

★ Taylor Creek currently experiences frequent, widespread flooding along Maxwell Road SE. This problem is considered "Very Significant" to the degree that it limits access to numerous homes, and is expected to become more widespread as flood discharges increase by an anticipated 25%.

★ If unmitigated, flooding problems are likely to develop in the Rock Creek and Dorre Don subbasins as anticipated future flood discharges increase by approximately 50% above current amounts.

FLOODING REFERENCES

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Flooding Appendix

CEDAR RIVER DRAINAGE INVESTIGATION COMPLAINTS (Through 1991)

Cedar River Basin Complaint File
Sorted by tributary

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
85-0217	02/13/85	0089C	21016	184th Av SE	Neighbor's pond floods his property
91-1147	11/14/91	0299	14506	165th Pl SE	Water ponds in front yard
91-1144	11/13/91	0299	14325	165th Pl SE	Neighbors tightlined ditch w/ 4" pipe-now floods
91-1000	09/17/91	0299	158xx	SE 136th St	Unmaintained road ditch overflows onto propert
91-0955	08/27/91	0299	16855	194th Av SE	Field runoff backs up at fire station
91-0634	04/25/91	0299	18917	SE 168th St	Water standing in ditch & yard
91-0564	04/16/91	0299	18605	SE Renton-MV Rd	Rd & hill runoff flood saloon parking
91-0530	04/08/91	0299	16448	SE Jones Rd	Ravine erosion deposited on his property
91-0422	03/25/91	0299	16448	SE Jones Rd	Ravine erosion deposited on his property
91-0367	03/13/91	0299	24119	SE 238th St	Will owners get bank stabilization help?
91-0350	03/11/91	0299	18233	SE Renton-MV Rd	Increasing runoff-hillside erosion
91-0336	03/07/91	0299	19257	218th Av SE	Cedar R. levee broke-wahsed away rock
91-0322	03/04/91	0299	16418	SE 145th St	Plugged drain floods his property
91-0239	02/20/91	0299	14833	SE Jones Pl	Clearing & grading around Elliot bridge
91-0223	02/20/91	0299	14833	SE Jones Pl	Road runoff floods her property
91-0213	02/19/91	0299	15240	160th Pl SE	Home flooded from area runoff & Cedar R.
91-0188	02/19/91	0299	164xx	SE 143rd Pl	Bad pipe joint in Serena Park R/D system
91-0175	02/14/91	0299	16861	SE Jones Rd	Cedar River flooded - wants dike raised
91-0135	02/05/91	0299	22811	SE 225th St	Flood washed away Cedar R. bank rock
91-0071	01/18/91	0299	19209	218th Av SE	Dike across Cedar being raised-will flood her
91-0064	01/18/91	0299	16426	SE 145th St	Old R/D pond needs maintenance
91-0045	01/14/91	0299	13125	SE 151st St	Erosion on Cedar R. bank-want advice
91-0013	01/07/91	0299	15631	SE Jones Rd	Cedar River washed out bulkhead & deck
90-1710	12/30/90	0299	17065	SE Jones Rd	Cedar River overtopped dike & flooded property
90-1709	12/30/90	0299	23109	Lower Dorre Don Way SE	Cedar R. revetment needs repair
90-1707	12/19/90	0299	17410	SE Renton-MV Rd	Cedar R. revetment needs repair
90-1699	12/18/90	0299	24434	249th Av SE	Cedar River bank eroded in storm
90-1684	12/20/90	0299	17055	SE Jones Rd	Cedar River revetment needs repair
90-1675	12/20/90	0299	17410	SE Renton-MV Rd	Cedar R. revetment needs repair
90-1673	12/20/90	0299	14908	SE Jones Rd	Cedar River bank eroded in storm
90-1667	12/19/90	0299	23050	231st Pl SE	Cedar River bank eroded in storm
90-1660	12/19/90	0299	24631	250th Av SE	Cedar River levee eroded in storm
90-1659	12/19/90	0299	203xx	218th Pl SE	Cedar R. levee overtopped or breached
90-1658	12/19/90	0299	20836	SE 184th St	Dike needs fixing to prevent flooding
90-1656	12/19/90	0299	20301	218th Pl SE	Cedar River dikes overtopped
90-1655	12/19/90	0299	23621	Dorre Don Way SE	Cedar R. revetment broken-flooding homes
90-1649	12/19/90	0299	25531	SE 218th St	Cedar River Flooding
90-1648	12/19/90	0299	22712	228th Av SE	Cedar River bank eroding-house threatened?
90-1625	12/11/90	0299	15633	SE Jones Rd	Cedar River washed away bulkhead
90-1621	12/10/90	0299	19209	218th Av SE	Erosion on Cedar River bank
90-1611	12/05/90	0299	19225	SE 170th St	Development has increased runoff
90-1591	12/04/90	0299	18001	SE Renton-MV Rd	Neighbor's runoff deposits sediment
90-1570	11/26/90	0299	17215	SE Jones Rd	Cedar River overtopped levee
90-1551	11/28/90	0299	15018	132nd Av SE	Homes flooded in storm-no drainage system
90-1542	11/27/90	0299	16448	SE Jones Rd	Stream overtopped channel and flooded road
90-1519	11/26/90	0299	24434	249th Av SE	Levee across Cedar caused flooding
90-1443	11/01/90	0299	22840	SE 230th Pl	Dirty gravel pit runoff to Cedar River
90-1381	10/15/90	0299	19406	SE 174th St	R/D pond inadequate for new development?
90-1354	10/02/90	0299	19614	221st Av SE	Large area cleared-levee lowered?
90-1343	09/29/90	0299	14920	163rd Ct SE	Contractor damaged storm line - has been fixed
90-1320	09/25/90	0299	25101	SE Renton-MV Rd	Development increased erosion & runoff
90-1280	09/07/90	0299	14926	165th Pl SE	Road drainage flows onto property
90-1273	09/04/90	0299	18825	SE Renton-MV Rd	Storm eroded hillside
90-1255	08/31/90	0299	18854	SE 168th St	County road ditches need improvement
90-1240	08/24/90	0299	25504	SE 253rd Pl	Pond berm needed backfilling - Done
90-1228	08/20/90	0299	24835	SE 239th St	Ditch needs cleaning

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
90-1209	08/16/90	0299	17065	SE Jones Rd	Plugged culvert causes deep pool in yard
90-1170	06/26/90	0299	13203	SE 151st St	Question of riverbank ownership
90-1101	07/05/90	0299	16516	SE 149th St	Wants to build an addition on an easement
90-1089	06/29/90	0299	17427	195th Pl SE	Citizens concerned R/D inadequate
90-1041	06/08/90	0299	164xx	196th Av SE	Bluff eroding into Cedar River
90-1029	06/05/90	0299	25427	SE 240th St	Neighbor added paving-increased runoff
90-1023	06/04/90	0299	15408	SE Jones Rd	Land cleared to Cedar River
90-0953	05/07/90	0299	218xx	SE Bain Rd (last home)	Unknown pipes to Cedar River-WQ prob?
90-0939	05/01/90	0299	17427	195th Pl SE	Citizens concerned R/D inadequate
90-0931	04/30/90	0299	16423	SE 135th St	Water drains to property
90-0802	02/22/90	0299	16655	196th Av SE	Spring flow increased during storm
90-0748	03/15/90	0299	15023	SE Jones Rd	CCF 12989-Home flooded in storm
90-0702	02/27/90	0299	15059	SE Jones Rd	claim # 12933-Home flooded in storm
90-0504	01/30/90	0299	17105	SE 149th St	Channel filled by neighbor causes yard to flood
90-0401	01/19/90	0299	16861	SE Jones Rd	Clearing on hillside causing erosion
90-0272	01/09/90	0299	24305	252nd Av SE	Road ditch floods needs cleaning
90-0152	01/09/90	0299	17653	SE Jones Rd	Cedar River flooding property
89-0867	12/27/89	0299	13802	160th Av SE	Clogged ditches caused flooding-CCF #12735
89-0525	08/10/89	0299	17065	SE Jones Rd	Plugged culvert causes flooding
89-0479	07/21/89	0299	233xx	SE 225th St	Buyer wanted drainage info
89-0344	05/09/89	0299	22505	Dorre Don Way SE	Unhappy w/ Cedar River rip-rap job
89-0306	04/04/89	0299	19040	216th Av SE	Neighbor cleared Cedar River bank
89-0257	04/19/89	0299	22509	Dorre Don Way SE	Unhappy w/ Cedar River rip-rap job
89-0252	04/17/89	0299	13601	SE Renton-MV Rd	Slide on Cedar River-KC offered help
89-0211	04/04/89	0299	20002	SE 185th Pl	Owner wants to drain pond properly
89-0086	02/24/89	0299	14820	154th Pl SE	Neighbor installed interceptor drain
89-0034	01/18/89	0299	22215	Dorre Don Way SE (across	Garbage, clearing, earthwork
89-0020	01/12/89	0299	134xx	168th Av SE	Fill deposited on KC drainage easement
89-0008	01/05/89	0299	22111	217th Av SE	Road drain too small, floods
88-0783	12/15/88	0299	12941	SE 159th St	Water bubbles up on sidewalk-ice forms
88-0567	09/01/88	0299	18600	SE 162nd St (Lot 38)	Drainage easement eroding see 88-063
88-0391	06/02/88	0299	190xx	SE Jones Rd	Fill in drainage & pond created
88-0377	05/24/88	0299	14250	161st Av SE	Wants KC to fence an R/D pond
88-0330	05/09/88	0299	134xx	168th Av SE	Residents piped channel within KC easement
88-0315	05/04/88	0299	13601	SE Renton-MV Rd	Further erosion in slide area
88-0261	04/14/88	0299	16807	SE Jones Rd	Neighbor blocking stream
88-0216	04/05/88	0299	14831	196th Av SE	Grading has disrupted drainage-floods
88-0208	04/01/88	0299	14638	196th Av SE	Grading has disrupted drainage-floods
88-0175	03/22/88	0299	18446	SE 162nd St	Drainage easement eroding-see 88-063
88-0146	03/08/88	0299	18001	SE Renton-MV Rd	Private drainage system inadquate
88-0091	02/11/88	0299?	21626	215th Pl SE	Neighbor's dam flooding property
88-0063	01/29/88	0299	18446	SE 162nd St	Easement eroded-owner will pipe it
87-0991	10/05/87	0299	19348	Byres Rd	Clearing/grading on Cedar River
87-0910	08/26/87	0299	16861	SE Jones Rd	New development is causing stream to back up
87-0593	04/22/87	0299	16822	SE 136th St	Private drainage easment not draining properly
87-0504	03/25/87	0299	17225	SE Renton-MV Rd	Erosion depositing from above him
87-0461	03/08/87	0299	158xx	SE Jones Rd (pit)	Erosion & flooding from gravel pit
87-0392	03/02/87	0299	16448	SE Jones Rd (across from)	Logging on Cedar River
87-0249	12/30/86	0299	19237	SE Renton-MV Rd	Hillside eroding & pasture flooding
87-0201	02/03/87	0299	16916	SE Renton-MV Rd	Illegal fill causing silt problems
87-0182	01/22/87	0299	16916	SE Renton-MV Rd	Illegal fill causing drainage problems
87-0112	12/31/86	0299	20243	SE Renton-MV Rd	Neighbor grading for mobile home placement
86-1297	12/22/86	0299?	22135	217th Av SE	Stream backs up at culvert onto property
86-1216	11/26/86	0299	17105	SE 149th St	Owner filled yard and covered storm drain
86-1163	11/24/86	0299	17105	SE 149th St	Yard floods in storm
86-1158	11/24/86	0299	15059	SE Jones Rd	Neighbor filled-now she floods
86-1117	11/13/86	0299	16861	SE Jones Rd	Debris dumped in Cedar River floodplain

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
86-0840	08/31/86	0299	20053	SE Renton-MV Rd	Extensive grading-no drainage impact?
86-0812	08/08/86	0299	15421	SE Jones Rd	Cedar River bank eroding
86-0745	07/29/86	0299	15059	SE Jones Rd	Neighbor filling on Cedar River
86-0732	07/17/86	0299	218xx	SE Bain Rd (end of road)	Someone digging near Cedar R - okay
86-0651	06/27/86	0299	15115	SE Jones Rd	Ravine filled, changing drainage
86-0644	06/25/86	0299	184xx	SE Renton-MV Rd	Junkyard filling in natural drainage swale
86-0641	06/23/86	0299	17225	SE Renton-MV Rd	Neighbor cutting into hillside
86-0446	04/21/86	0299	20006	SE Jones Rd	Pit discharge eroding property
86-0378	03/17/86	0299	13129	160th Av SE	Ditch filled by neighbor causing road to flood
86-0372	03/13/86	0299	15817	SE Jones Rd	Mobile home in Cedar River floodplain
86-0371	03/13/86	0299	15817	SE Jones Rd	Mobile home in Cedar River floodplain
86-0330	03/10/86	0299	17000	196th Av SE	Stream changed course in storm
86-0226	02/10/86	0299	18043	SE Renton-MV Rd	Uphill development-increased erosion & flood
86-01C7	01/18/86	0299	14504	166th Pl SE	Plugged culvert caused flooding
86-0103	01/02/86	0299	14220	164th Av SE	Drainage from new home will cause flooding
85-1215	12/03/85	0299	22728	Upper Dorre Don Way SE	Property on bluff cleared of trees
85-0741	07/19/85	0299	22628	Dorre Don Ct SE (above)	Development atop bluff above Cedar R.
85-0710	07/10/85	0299	15035	SE Jones Rd (across river)	Neighbor working in river-erosion on his side
85-0422	04/12/85	0299	19647	SE Renton-MV Rd	Private ditches need cleaning;logging?
85-0312	02/27/85	0299	22840	SE 230th Pl	Pit excavation increased runoff-well threatened
84-1025	10/12/84	0299	13425	160th Av SE	Crawlspace of three houses flood regularly
84-0911	09/10/84	0299	15845	SE 143rd St	Low yard-inadequate drainage
84-0904	09/05/84	0299	15635	SE Jones Rd	Concrete put on Cedar bank-her bank eroding
A	07/03/84	0299	148xx	SE 145th Pl	New home drainage inadequate
B	06/29/83	0299	16017	188th Av SE	Bluff erosion threatens home
D	07/06/83	0299	221xx	SE 214th St	Fill in depresion in floodplain
D	04/28/83	0299	13227	SE 151st St	Slide in Cedar causes flooding
F	10/10/83	0299	187xx	SE Renton-MV Rd	Small drainage causes flood
G	03/15/82	0299	19237	SE Renton-MV Rd	Ravine erodes-fills stream-floods
G	08/15/84	0299	20029	SE 152nd St	Gravel pit w/ erosion & runoff problems
G	07/23/82	0299	22108	SE 197th Pl	Neighbor has backed up water
G	09/21/83	0299	15064	SE Renton-MV Rd	Neighbor filled Cedar River side channel
H	02/22/82	0299	14243	SE 146th St	Backyard on bluff settling & cracking
H	04/06/83	0299	15823	130th Pl SE	R/D pond not fenced & plugged
H	07/23/84	0299	21918	SE 207th St	Wants to discuss Cedar R. flooding solutions
J	05/11/82	0299	17100	SE 149th St	Fill placed along road ROW
J	01/06/83	0299	22111	217th Av SE	Inadequate culvert-road floods
M	02/14/83	0299	17000	196th Av SE	Stream flooding & causing erosion on bluff
M	02/03/83	0299	21909	SE 207th St	Neighbor cleared & graded Cedar bank
N	04/24/84	0299	214xx	Bain Rd SE	Owner draining steep hillside springs
N		0299	250xx	SE 243rd St (no file)	Slide slid
R	02/24/82	0299	24416	SE 246th St	Fill near Cedar R. blocks drainage
S	10/28/83	0299	19221	SE Jones Rd	Stream flooding & may erode revetment
S	02/25/82	0299	13612	160th Av SE	Low lying property-poor drainage
S	01/25/82	0299	16426	SE 145th St	New Development causing flooding problems
T	01/31/84	0299	24305	252nd Av SE	Worried c. slide possibility
V	04/20/83	0299	140xx	SE Renton-MV Rd	Water from pit & 140th floods him
V	03/10/84	0299		SE 225th St (left bank Cedar	Property cleared-overflow blocked
W	03/12/84	0299	18043	SE Renton-MV Rd	Hillside erosion deposited on land
Y	05/11/84	0299	19029	SE Renton-MV Rd	Hillside runoff brings sand & silt
91-0429	03/27/91	0299DD	26531	SE 237th St	Entrance to Maplewood Estates flooding
90-1173	07/31/90	0299DD	28023	SE 231st St	Poor drainage in the area
87-0879	08/17/87	0299DD	26813	SE 236th St	After upstream logging, creek erosion
M	12/11/81	0299DD	27120	SE 236th St	Road settling
91-1100	10/21/91	0300A	12512	SE 164th Pl	Roadway CB overflows and floods basement

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
91-0725	05/29/91	0300A	12020	SE 157th Pl	Private pond smells of sewage
91-0170	02/12/91	0300A	12109	SE 164th St	Water in basement
90-1433	10/29/90	0300A	15750	116th Av SE	Yard doesn't drain well - always wet
90-1126	07/18/90	0300A	12431	SE 160th St	Ditch behind lot needs maintenance
90-0529	02/01/90	0300A	12512	SE 166th St	Drain system plugged - yard wet
90-0485	01/29/90	0300A	12376	SE 160th St	Catch basin failing, flooding
90-0445	01/23/90	0300A	12020	SE 157th Pl	Private pond smells of sewage
88-0221	04/06/88	0300A	11833	SE 164th St	Pumping muddy water onto roadway
88-0069	01/29/88	0300A	15750	116th Av SE	Private ditch needs maintenance
87-1162	12/10/87	0300A	12615	SE 164th St	Area drainage pipes are clogged or damaged
87-0433	03/12/87	0300A	12716	SE 164th St	Water under house - installed sump pump
86-0427	04/01/86	0300A	12003	SE 160th St	Wants to tightline ditch behind lot
85-0745	08/09/85	0300A	12646	SE 165th St	Drainage system may need cleaning
85-0705	06/27/85	0300A	16835	125th Av SE	Neighbor draining water to her yard
C	01/27/82	0300A	15779	119th Pl SE	Soggy, settling yard
M	05/05/83	0300A	16618	127th Av SE	Water under house
P	06/21/84	0300A	11613	SE 164th St	Yard floods
V	06/07/82	0300A	11702	SE 157th St	Soggy yard from neighbor's drain
91-0883	07/17/91	0302	13732	SE 141st St	Wants info on "The Orchards" development
91-0106	01/22/91	0302	966	Bremerton Ct NE	Drainage ditch overtops & floods her
90-1623	12/10/90	0302	13611	SE 116th St	R/D pond overtopped and flooded road in storm
90-1135	07/20/90	0302	13713	SE 144th St	Neighbor drains pool over ravine bank
90-1020	06/04/90	0302	13732	SE 141st St	Neighbor drains pool over ravine bank
90-0512	01/31/90	0302	138xx	SE 136th St	Culvert discharge eroding ravine
89-0602	09/19/89	0302	13448	SE 141st St	Roadway runoff washing away driveway rock
89-0318	05/11/89	0302	138xx	SE 118th St	County wetland tract cleared
89-0135	03/13/89	0302	956	Anacortes Ct NE	Clearing & grading blocked drainage
88-0369	05/24/88	0302	12003	138th Pl SE	Runoff from new construction
87-0658	05/11/87	0302	955	Anacortes Ct NE	Wetland filling diverted water
87-0456	03/16/87	0302	170	Whitman Ct NE	Fill violation causing diversion and flooding
87-0108	01/02/87	0302	13419	SE 141st St	Uphill construction increasing runoff & sediment
86-0304	03/04/86	0302	13812	SE 121st St	Plugged drain caused ponding in yard
84-1110	11/19/84	0302	130xx	SE 128th St	Wetland drained-impacts downstream pond
M	05/18/83	0302	132xx	SE Renton-MV Rd	Upstream development causing flooding
91-0946	08/23/91	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
91-0888	08/06/91	0303	14306	144th Av SE	Wants wetland above Puget Colony restored
91-0885	08/06/91	0303	13405	142nd Av SE	Road ditches in Puget Colony need cleaning
91-0868	07/31/91	0303	14010	SE 134th St	Wants to open storm line in Puget Colony
91-0777	05/22/91	0303	14103	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
91-0739	06/10/91	0303	14103	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
91-0732	06/05/91	0303	14024	SE 133rd St	Inadequate storm line btwn SE 134th & SE 135t
91-0723	05/22/91	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
91-0715	05/13/91	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
91-0712	05/20/91	0303	14103	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
91-0682	05/09/91	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
91-0657	05/03/91	0303	14306	144th Av SE	WQ/Flooding problems in Puget Colony Homes
91-0655	05/03/91	0303	132xx	140th Av SE	Flooded septic drainfields in Puget Colony
91-0650	05/02/91	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
91-0315	03/04/91	0303	14011	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
91-0246	02/21/91	0303	14013	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
91-0098	01/25/91	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
91-0081	01/25/91	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
90-1539	11/27/90	0303	14231	SE 138th St	Possible erosion of ravine banks
90-1511	11/27/90	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
90-1464	11/13/90	0303	12413	142nd Av SE	Culvert plugged on 142nd Av SE

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
90-1184	08/02/90	0303	14306	144th Av SE	Increased stream erosion due to development
90-0587	02/12/90	0303	14306	144th Av SE	Increased stream erosion due to development
90-0388	01/17/90	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
90-0374	01/16/90	0303	13909	SE 139th St	Erosion and landslides in ravine
90-0352	01/16/90	0303	14231	SE 138th St	Erosion and landslides in ravine
89-0636	10/02/89	0303	14103	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
89-0472	07/19/89	0303	14105	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
89-0200	03/29/89	0303	13120	138th Av SE	Sinkhole in yard
89-0113	03/06/89	0303	13852	SE 128th St	Sheet flow from road floods property
89-0084	02/22/89	0303	11833	142nd Av SE	Neighbor raised pond-now causes flooding
89-0036	01/19/89	0303	14003	SE 132nd St	Construction debris left at construction site
88-0713	11/04/88	0303	140xx	SE 128th St	Someone filled and blocked roadway ditch
88-0280	04/20/88	0303	14106	SE 135th St	Failed storm line between SE 134th & SE 135th
88-0229	04/07/88	0303	14231	SE 138th St	Owners want to culvert & fill ravine
87-0787	07/06/87	0303	12808	138th Av SE	Drainage concerns over new development
87-0463	03/04/87	0303	13025	138th Av SE	Downstream filling blocking drainage system
87-0445	03/09/87	0303	13837	SE 128th St	Neighbor's fill blocking drainage course
87-0405	03/04/87	0303	13025	138th Av SE	Downstream filling blocking drainage system
86-0707	07/07/86	0303	13837	SE 128th St	Neighbor's fill blocking drainage course
86-03A4	03/28/86	0303	128xx	138th Av SE	Silted drainage system
86-01D9	01/21/86	0303	14011	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
85-1010	10/10/85	0303	14100	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
85-0402	03/19/85	0303	14017	SE 139th St	Wants flow control structure on outfall into ravin
84-1015	09/27/84	0303	13836	SE 131st St	WQ/Flooding problems in Puget Colony Homes
84-1005	09/18/84	0303	14100	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
84-0935	09/28/84	0303	14011	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
84-0918	09/17/84	0303	13843	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
A	06/11/82	0303	14005	SE 133rd St	WQ/Flooding problems in Puget Colony Homes
B	01/16/84	0303	13843	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
D	01/27/83	0303	12808	138th Av SE	Downstream filling blocking drainage system
G	09/17/81	0303	14306	144th Av SE	Increased stream erosion due to development
L	01/20/81	0303	13832	SE 131st St	WQ/Flooding problems in Puget Colony Homes
Y	01/18/82	0303	14100	SE 132nd St	WQ/Flooding problems in Puget Colony Homes
90-0226	01/09/90	0303A	14607	SE 128th St	Road runoff washing gravel into ditch
C	02/16/83	0303A	13224	144th Av SE	Pipe installed in county R-O-W
91-1121	10/21/91	0304	16507	133rd Pl SE	Creek flooded home in 2 major storms
91-1022	09/25/91	0304	18012	140th Av SE	Flooded last 4 yrs from adjacent property
91-0966	08/30/91	0304	18112	145th Av SE	Slight driveway erosion
91-0770	06/24/91	0304	13531	SE 163rd St	Seepage from neighboring lot
91-0451	04/02/91	0304	13405	SE 163rd St	Yard runoff causing sidewalk/road damage
91-0345	03/10/91	0304	14031	SE 159th Pl	Seepage from lot draining over sidewalk
91-0242	02/22/91	0304	14414	SE 192nd St	Road runoff floods yard (CCF#291-27)
91-0180	02/16/91	0304	17070	140th Av SE	Plugged drainage system in golf course
91-0174	02/14/91	0304	14030	SE 187th St	Natural drainage course on property
91-0155	02/06/91	0304	14043	SE 159th Pl	Seepage from lot draining over sidewalk
91-0080	01/11/91	0304	14037	SE 159th Pl	Uncontrolled seepage from adjacent lot
91-0043	01/14/91	0304	14207	SE 170th St	Plugged CB grate caused flooding
91-0023	01/11/91	0304	15805	140th Ct SE	Sediment on road from new construction
90-1602	12/07/90	0304	15805	140th Ct SE	Sediment on road from new construction
90-1571	11/26/90	0304	14227	SE 162nd Pl	Water in garage - seeps?
90-1505	11/09/90	0304	16524	132nd Pl SE	Question about the 100 year floodplain
90-1473	11/14/90	0304	18203	140th Av SE	12" roadway system is inadequate
90-1447	11/08/90	0304	14421	SE 183rd St	Open roadside ditch flooding
90-1326	09/26/90	0304	13405	SE 163rd St	Yard wet by county drainage easement
90-1321	09/26/90	0304	13405	SE 163rd St	Yard wet by county drainage easement

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90-1299	09/14/90	0304	14414	SE 192nd St	Road runoff floods yard (CCF#291-27)
90-1187	08/01/90	0304	13932	SE 155th Pl	Water under house - Claim #13430
90-1111	07/11/90	0304	16507	133rd Pl SE	SWD access road blocking drainage path
90-1048	06/12/90	0304	14705	SE 183rd St	New development causing erosion
90-0969	05/11/90	0304	16507	133rd Pl SE	SWD access road blocking drainage path
90-0853	04/06/90	0304	13405	SE 163rd St	Seepage flowing across sidewalk
90-0769	03/19/90	0304	13932	SE 155th Pl	CB overflows onto property
90-0611	02/13/90	0304	18110	143rd Av SE	Neighbor's fill changed drainage course
90-0535	02/02/90	0304	13017	SE 171st Pl	Orange substance in water behind school
90-0233	01/09/90	0304	14414	SE 192nd St	Road runoff floods yard (CCF#291-27)
90-0057	01/09/90	0304	13811	SE Fairwood Blvd	Runoff from SWD access road flooded yard
89-0803	12/04/89	0304	14414	SE 192nd St	Road runoff floods yard (CCF#291-27)
89-0635	10/03/89	0304	14301	SE 164th St	Water from neighbor behind lot
89-0611	09/25/89	0304	13967	SE 156th St	No erosion control on new lot
89-0437	06/28/89	0304	152xx	140th Way SE	Info needed on R/D pond
89-0400	06/15/89	0304	13405	SE 163rd St	Yard wet by county drainage easement
89-0357	05/30/89	0304	13941	SE 158th St	Pond cleared & house built
89-0261	04/18/89	0304	18012	140th Av SE	Lot doesn't drain well
89-0256	04/19/89	0304	14625	SE 183rd St	Wants ditch & culvert on street
89-0190	03/27/89	0304	14301	SE 164th St	Water from neighbor behind lot
89-0164	03/17/89	0304	16130	133rd Pl SE	Inadequate drainage on lot
89-0128	03/13/89	0304	13405	SE 163rd St	Drainage causing sidewalk to buckle
89-0081	02/22/89	0304	16513	133rd Pl SE	KC drainage easement ponding water
88-0800	12/30/88	0304	14421	SE 183rd St	Inadequate erosion control on adjacent lot
88-0756	11/28/88	0304	14414	SE 192nd St	Road runoff floods yard (CCF#291-27)
88-0635	10/05/88	0304	182xx	145th Av SE	Open roadside ditch flooding
88-0379	05/26/88	0304	13929	SE 155th Pl	Inadequate erosion control on adjacent lot
88-0259	04/14/88	0304	15657	140th Pl SE	Inadequate lot drainage
88-0237	04/11/88	0304	13967	SE 156th St	Inadequate lot drainage
88-0172	03/21/88	0304	14414	SE 192nd St	Neighbor cleared low swampy area
88-0166	03/16/88	0304	13241	SE 162nd Pl	Questions about a private drainage system
88-0082	02/05/88	0304	140xx	SE Petrovitsky Rd	Inquiry about Fairwood drainage study
87-1183	12/17/87	0304	134xx	SE Petrovitsky Rd	Access to drainage system blocked
87-1159	12/10/87	0304	14410	SE Petrovitsky Rd	Bldg flooded by Fairwood shopping center
87-1133	12/03/87	0304	16510	133rd Pl SE	SWD access road blocking drainage path
87-1100	11/20/87	0304	16510	133rd Pl SE	SWD access road blocking drainage path
87-0808	07/08/87	0304	179xx	145th Av SE	DI report recommends channel upgrade
87-0793	07/08/87	0304	18161	145th Av SE	Intersection always floods
87-0780	07/06/87	0304	14414	SE 192nd St	Road runoff floods yard (CCF#291-27)
87-0736	06/12/87	0304	179xx	145th Av SE	Roadside ditches too small
87-0654	05/12/87	0304	17005	130th Av SE	Inadequate lot drainage
87-0344	12/02/86	0304	132xx	SE 164th St	30" culvert plugged w/ debris
87-0122	12/29/86	0304	13236	SE 161st Pl	Water flowing over sidewalk
86-01D1	01/18/86	0304	144xx	SE 176th St	Fairwood Park R/D pond needs maintenance
86-0154	01/18/86	0304	16513	133rd Pl SE	Plugged trash rack in stream caused flooding
85-1038	10/28/85	0304	144xx	SE 183rd St	Roadway ditch needs improvement
85-0530	05/13/85	0304	14121	SE 177th St	Detention pond needs maintenance
C	03/28/84	0304	18005	145th Av SE	Neighbor filled yard, now flooding
H	10/18/83	0304	16305	134th Av SE	Sidewalk always wet
L	01/28/83	0304	16203	140th Pl SE	Yard floods
W	02/18/82	0304	13214	SE 166th Pl	Wants addition raised above floodplain
91-0718	05/24/91	0305	16073	SE 172nd Pl	Standing water in backyard
91-0305	03/04/91	0305	16230	SE 175th Pl	Plugged pipe in easement floods yard
90-1081	06/21/90	0305	15250	Pine Dr (Wonderland MHP)	Mud flow at mobile home park CCF 13175
90-1060	06/12/90	0305	15283	Birch Dr (Wonderland MHP)	Mud flow at mobile home park CCF 13175
90-0995	05/22/90	0305	14937	SE Renton-MV Rd	Mud flow at mobile home park CCF 13176

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90-0994	05/22/90	0305	14645	SE Renton-MV Rd	Mud flow at mobile home park CCF 13175
90-0779	03/21/90	0305	16073	SE 172nd Pl	Runoff collects in backyard
90-0727	03/12/90	0305	14708	SE 165th Pl	Severe erosion in ravine
90-0707	03/05/90	0305	16420	148th Av SE	Severe erosion in ravine
90-0692	02/28/90	0305	15277	Birch Dr (Wonderland MHP)	Mud flow at mobile home park CCF 13175
90-0686	03/01/90	0305	14716	SE 165th Pl	Yard slipping into ravine. See 90-707
90-0638	02/19/90	0305	15273	Birch Dr (Wonderland MHP)	Mud flow at mobile home park CCF 13175
90-0599	02/08/90	0305	15271	Birch Dr (Wonderland MHP)	Mud flow at mobile home park CCF 13175
90-0590	02/12/90	0305	14933	SE Jones Rd	Madsen Ck or Cedar River flooding yard
90-0578	02/07/90	0305	14700	SE 165th Pl	Bank erosion in greenbelt
90-0449	01/24/90	0305	14943	SE Jones Rd	Madsen Ck depositing sediment in yard
88-0376	05/24/88	0305	17119	163rd Pl SE	Adjacent roofdrains draining to her lot
86-1005	10/06/86	0305	16558	162nd Pl SE	Neighbor discharging runoff above rockery
86-03A5	04/20/86	0305	17633	162nd Pl SE	Neighbor dumping debris in R/D pond
86-0322	03/11/86	0305	16021	SE 167th Pl	Neighbor discharging runoff toward his house
86-0190	01/18/86	0305	16033	SE Fairwood Blvd	R/D pond needs maintenance
86-0189	01/18/86	0305	16033	SE Fairwood Blvd	R/D pond needs maintenance
84-1216	12/18/84	0305	16635	157th Av SE	Asked if a drywell is required on the lot
D	04/11/84	0305	16502	161st Av SE	Neighbor's runoff floods his lot
E	01/06/83	0305	14827	SE Jones Rd	Madsen Creek overflow channel full of silt
M	01/27/84	0305	16917	163rd Pl SE	Plugged CB causing erosion
91-0331	03/05/91	0306	17114	156th Av SE	Neighbor's runoff flooding yard. See 91-0116.
91-0221	02/20/91	0306	16961	157th Av SE	Water ponding in yard-due to debris?
91-0116	01/29/91	0306	17151	158th Ct SE	Boyers runoff floods neighbor
90-1315	09/20/90	0306	17443	158th Av SE	Neighbor built retaining wall & filled
90-0933	04/30/90	0306	17026	154th Pl SE	Stream bank erosion
90-0902	04/24/90	0306	17407	155th Av SE	Streambank eroding
90-0505	01/30/90	0306	17536	157th Pl SE	Stream crossing in park pathway overflowing
89-0457	07/07/89	0306	17029	154th Pl SE	Debris in stream causing erosion and flooding
89-0260	04/19/89	0306	17400	156th Pl SE	Yard drains do not drain properly
88-0652	10/13/88	0306	17218	154th Ct SE	Concerned about bank erosion in stream
88-0288	04/21/88	0306	15934	SE 176th Pl	Standing water in yard
88-0210	04/04/88	0306	151xx	SE Fairwood Blvd	Plugged catch basin caused washout
88-0206	04/01/88	0306	17022	154th Pl SE	Curb drainage pools in driveway
87-0962	09/21/87	0306	17833	163rd Pl SE	Catch basins full of sediment
87-0732	06/15/87	0306	18207	159th Ct SE	Roof drainage flows across sidewalk
87-0691	05/14/87	0306	15934	SE 176th Pl	Standing water in yard
87-0470	03/17/87	0306	17926	158th Pl SE	Pipeline construction left standing water
87-0309	02/19/87	0306	15946	SE 176th Pl	Roof drainage flowing across sidewalk
87-0159	01/07/87	0306	16954	151st Av SE	Plugged stream crossing causing erosion
87-0127	01/15/87	0306	18220	160th Av SE	Wetland floods yard
86-1195	11/24/86	0306	18220	160th Av SE	Wetland floods crawl space
86-0605	06/05/86	0306	17218	154th Ct SE	Stream crossing outfall causing erosion
85-0412	04/05/85	0306	15612	SE Fairwood Blvd	Standing water in yard
R	01/25/83	0306	17425	161st Av SE	Back yard floods
S	02/14/84	0306	15417	SE 176th Pl	Neighbor's runoff floods lot
91-0091	01/24/91	0306A	18232	155th Pl SE	Water in crawl space-poor lot drainage
90-1214	08/17/90	0306A	155xx	SE 183rd Dr (Lots 13 & 14)	Private fence on KC drainage easement
90-0135	01/09/90	0306A	17124	151st Av SE	Storm eroded county maintained road
89-0232	04/10/89	0306A	17515	151st Av SE	Runoff coming from rock wall
87-0592	04/21/87	0306A	18215	153rd Av SE	Wetland made into a park floods
87-0420	03/04/87	0306A	18231	154th Pl SE	Water in crawl space
87-0351	11/26/86	0306A	146xx	SE 176th St	R/D pond spillway causes flooding
86-0753	07/29/86	0306A	15351	SE 183rd Dr	Spring under new home-pump to road
85-1115	11/07/85	0306A	154xx	SE 183rd Dr	Construction causing muddy roads

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
85-0818	08/22/85	0306A	18221	153rd Av SE	Water ponding under house & in yard
85-0342	03/12/85	0306A	18215	153rd Av SE	Concerned about unfinished detention pond
C	04/05/83	0306A	15325	SE 178th St	Neighbor's sidewalk blocks runoff
F	03/07/83	0306A	15319	SE 178th St	Neighbor's runoff eroding yard
S	10/16/84	0306A	18215	153rd Av SE	Property on old wetland floods
91-0954	08/27/91	0307	15606	SE 143rd St	Undersized culvert floods property
91-0812	07/10/91	0307	14639	SE 132nd St	Roadway ditches inadequate to handle the flow
91-0750	06/17/91	0307	13016	156th Av SE	Neighbor's fill causing increased runoff
91-0688	04/26/91	0307	15243	SE 132nd St	Road runoff floods yard-erodes shoulder
91-0005	01/05/91	0307	15240	SE 142nd Pl	Storm system outlets may be eroding ravine
90-1509	11/26/90	0307	142xx	154th Pl SE	Road embankment eroded exposing culvert
90-1503	11/26/90	0307	15219	SE Jones Rd	Sediment/debris blocks channel
90-0956	05/07/90	0307	15226	SE Jones Rd	See CCF #13138
90-0793	03/23/90	0307	15035	SE Jones Rd	See CCF #13019
90-0556	02/06/90	0307	13323	146th Av SE	Natural drainage floods property
90-0518	02/01/90	0307	15225	SE Jones Rd	See CCF #12839
90-0318	01/12/90	0307	15225	SE Jones Rd	Failed system diverted muddy water onto his lot
90-0209	01/10/90	0307	14639	SE 132nd St	Roadway ditch needs maintenance
87-0328	02/11/87	0307	13323	146th Av SE	KC drainage system outlets onto his property
87-0255	02/09/87	0307	14639	SE 132nd St	Muddy horse pasture potential health threat
86-0739	07/23/86	0307	13323	146th Av SE	Sub-standard drainage system causes flooding
86-0437	04/25/86	0307	15252	SE 142nd Pl	Wants to tightline drainage channel on his lot
T	09/12/83	0307	15243	SE 132nd St	Neighbor filled drainage ditch with gravel
90-1356	10/04/90	0308	17045	SE 134th St	Dirt & debris pile by pond
89-0264	03/30/89	0308	173xx	SE 136th St	Fill encroaching on drainage swale
89-0052	01/27/89	0308	13834	171st Av SE	Lot doesn't drain well
T	10/12/83	0308A	14063	171st Av SE	Swale floods-want county to clean it
90-1420	10/24/90	0309	17371	SE 133rd St	Clogged, crushed culvert
90-0392	01/18/90	0309	17343	SE 133rd St	Inadequate drainage on lot and road
90-0316	01/12/90	0309	13845	177th Av SE	Inadequate road drainage floods home
90-0074	01/09/90	0309	17356	SE 135th St	Road runoff flooding property
89-0490	07/27/89	0309	134xx	175th Av SE	Neighbor's driveway culverts small
87-0357	11/21/86	0309	17509	SE 136th St	Illegal swale piping caused erosion
87-0311	02/23/87	0309	13859	177th Av SE	Flooding along 177th Av SE
91-0942	08/22/91	0310	14515	183rd Av SE	No street drainage system-debris in yard
91-0871	07/31/91	0310	18256	SE 144th Pl	Road runoff eroding & flooding yards
91-0245	02/21/91	0310	14220	183rd Av SE	Development diverted water-home floods
91-0145	02/05/91	0310	18325	SE 140th St	Road runoff drains to his property-soggy
90-1380	10/11/90	0310	17817	SE Jones Rd	See Claim #13625
90-1064	06/18/90	0310	18002	SE 144th St	Road runoff floods property
90-1042	06/08/90	0310	18315	SE 140th St	Neighbor filling natural drainage course
90-1007	05/31/90	0310	17817	SE Jones Rd	Storm eroded creek channel & flooded
90-0820	03/28/90	0310	17817	SE Jones Rd	Storm eroded creek channel & flooded
90-0816	03/27/90	0310	17809	SE 145th St	Private drainage system impacting road
90-0222	01/09/90	0310	14220	183rd Av SE	Water from construction above
89-0553	08/28/89	0310	13205	180th Av SE	Inadequate road drainage-flood-silt
89-0281	04/21/89	0310	17838	SE 146th St	Culvert is too high causing yard to flood
89-0280	04/21/89	0310	14401	178th Av SE	Road culvert blocked & floods property
88-0796	12/27/88	0310	17817	SE Jones Rd	Uphill construction increasing runoff & sediment
88-0755	11/28/88	0310	17817	SE Jones Rd	Uphill construction increasing runoff & sediment
88-0646	10/13/88	0310	14220	183rd Av SE	Neighbor's new drainage system-flood?
88-0415	06/10/88	0310	136xx	182nd Av SE	Purchaser concerned c. lot drainage

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
88-0047	01/26/88	0310	13328	178th Av SE	SE 134th St drains to his property
87-0957	09/17/87	0310	17805	SE Jones Rd	Sediment in creek-fish can't pass
87-0558	04/14/87	0310	18005	SE 147th Pl	New development drains to his property
86-0904	09/04/86	0310	17817	SE Jones Rd	Uphill construction increasing runoff & sediment
86-0706	07/03/86	0310	17817	SE Jones Rd	County stream culvert needs maintenance
86-0645	06/24/86	0310	17653	SE Jones Rd	Stream floods-want to build bridge-built
86-0272	01/31/86	0310	17817	SE Jones Rd	Gravel washed down-creek flooding
86-0228	02/11/86	0310	17805	SE Jones Rd	Stream full of silt
85-0405	04/01/85	0310	13517	180th Av SE	Old upstream fill causing flooding
B	08/25/83	0310	134xx	180th Av SE	Large fill in drainage
W	05/22/83	0310	17817	SE Jones Rd	Jones Rd runoff floods property
91-0152	02/07/91	0311	16405	SE Renton-MV Rd	Mudslide/flooding at Valley View MHP
90-1688	12/20/90	0311	15613	160th Ct SE	Summerfield pond full of silt
90-1687	12/20/90	0311	156xx	161st Av SE	Mud/silt from Summerfield filling DOT ditch
90-1196	08/08/90	0311	16126	SE 156th St	Mud/silt from Valley View MHP
90-1164	07/27/90	0311		Summerfield Tracts	Sidewalks cracked by dump trucks
90-1128	07/16/90	0311	16126	SE 156th St	See CCF #13375
90-0869	04/09/90	0311	15607	160th Ct SE	See Summerfield claim file #13000
90-0776	03/22/90	0311	15900	SE 156th St	See Summerfield claim file #13000
90-0708	03/02/90	0311	15617	160th Ct SE	See Summerfield claim file #13000
90-0654	02/22/90	0311	15604	160th Ct SE	See Summerfield claim file #13000
90-0653	02/22/90	0311	16020	SE 156th St	See Summerfield claim file #13000
90-0622	02/15/90	0311	15613	160th Ct SE	See Summerfield claim file #13000
90-0598	02/08/90	0311	16104	SE 156th St	See Summerfield claim file #13000
90-0589	02/12/90	0311	16405	SE Renton-MV Rd	Mud/silt damage at Valley View MHP
90-0568	02/07/90	0311	15854	SE 156th St	See Summerfield claim file #13000
90-0552	02/06/90	0311	16104	SE 156th St	See Summerfield claim file #13000
90-0490	01/29/90	0311	16405	SE Renton-MV Rd	Mud/silt damage at Valley View MHP
90-0482	01/29/90	0311	16405	SE Renton-MV Rd	Mud/silt damage at Valley View MHP
90-0480	01/30/90	0311	15616	160th Ct SE	See Summerfield claim file #13000
90-0477	01/29/90	0311	15621	160th Ct SE	See Summerfield claim file #13000
90-0476	01/25/90	0311	15620	160th Ct SE	See Summerfield claim file #13000
90-0298	01/11/90	0311	15603	161st Av SE	Summerfield pond overflow caused mudslide
90-0297	01/11/90	0311	16136	SE 156th St	Mud/silt from Valley View MHP
90-0256	01/11/90	0311	16020	SE 156th St	Summerfield pond overflow caused mudslide
90-0208	01/10/90	0311	15604	160th Ct SE	Summerfield pond overflow caused mudslide
90-0137	01/09/90	0311	15616	160th Ct SE	Summerfield pond overflow caused mudslide
90-0136	01/09/90	0311	15610	160th Ct SE	Summerfield pond overflow caused mudslide
90-0100	01/10/90	0311	15617	160th Ct SE	Summerfield pond overflow caused mudslide
88-0156	03/10/88	0311	15900	SE 156th St	Catch basin plugged with silt
F	10/27/81	0311	16221	SE 165th St	Runoff from neighboring lots floods property
90-0787	03/23/90	0314?	206xx	SE 158th St	Ditch & culvert need cleaning
90-1691	12/20/90	0316	20715	SE 180th St	Cedar R. revetment needs repair
90-1657	12/19/90	0316	20401	SE 180th St	Cedar River flooding at Rainbow Bend
88-0684	10/13/88	0316	17744	204th Pl SE	Cedar Grove Mobile Home Park flooding
87-0875	08/14/87	0316	20715	SE 180th St	Cedar Grove Rd runoff floods driveway
S	01/24/84	0316	17400	201st Pl SE	Cedar bank eroding & flood from stream too
91-0660	05/03/91	0316A	228xx	Cedar Grove Rd	Great quantity, poor quality water from landfill
88-0549	08/22/88	0316A?	17836	Cedar Grove Rd	Merlino excavation disrupted aquifer
87-0453	03/13/87	0316A?	17836	Cedar Grove Rd	Stoneway excavation cutoff their stream
86-1038	10/21/86	0316A?	17615	Cedar Grove Rd	Gravel extraction dried up stream
86-0414	04/11/86	0316A?	18006	Cedar Grove Rd	Stoneway diversion washing out road
85-1220	12/17/85	0316A?	18006	Cedar Grove Rd	Swanson's drainage in violation

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
90-0061	01/09/90	0317	18908	Maxwell Rd SE	Maxwell Rd culvert backs up and floods him
87-0697	05/27/87	0317	19441	Maxwell Rd SE	Neighbor filling property w/o permit
84-1029	10/17/84	0317	216xx	SE Lake Francis Rd	Stoneway gravel diversion ditch
91-0418	03/19/91	0319	18438	231st Av SE	Runoff from new road drains to her property
90-1383	10/10/90	0319	18027	234th Av SE	Claim # 13562-property loss due to rezone
90-1382	10/10/90	0319	18027	234th Av SE	Claim # 13562-property loss due to rezone
91-0708	05/21/91	0320	20912	Maxwell Rd SE	Grading near Taylor Creek - not in floodplain
90-1683	12/20/90	0320	23422	SE 217th Pl	Broken R/D storm line - has been fixed??
90-1559	11/30/90	0320	23422	SE 217th Pl	Broken R/D storm line - has been fixed??
90-0618	02/15/90	0320	21208	Maxwell Rd SE	Flooding - CCF #12904
90-0307	01/11/90	0320	20920	Maxwell Rd SE	Taylor Creek flooding property
90-0296	01/11/90	0320	21208	Maxwell Rd SE	Taylor Creek flooding property
90-0158	01/10/89	0320	21010	Maxwell Rd SE	Taylor Creek flooding property
89-0815	12/05/89	0320	21010	Maxwell Rd SE	Taylor Creek flooding property
89-0227	04/06/89	0320	19710	Maxwell Rd SE	Road drainage inadequate-causes flooding
88-0390	06/01/88	0320	21621	255th Pl SE	Standing water behind property
88-0058	01/29/88	0320	25435	SE 219th St	New homes causing standing water on property
88-0046	01/25/88	0320	21235	230th Av SE	Concerned with Taylor Creek flooding problems
87-1113	11/25/87	0320	20920	Maxwell Rd SE	Taylor Creek flooding property
87-0854	08/06/87	0320	20920	Maxwell Rd SE	Silt raising Taylor Creek channel elevation
87-0837	07/28/87	0320	21208	Maxwell Rd SE	Taylor Creek flooding property
86-1228	12/03/86	0320	25425	SE 216th St	Neighbor's new barn causing erosion
86-1167	11/24/86	0320	21208	Maxwell Rd SE	Silt in Taylor Creek
85-0733	08/01/85	0320	21208	Maxwell Rd SE	Taylor Ck Meadows worries d/s residents
85-0211	01/14/85	0320	234xx	SE 216th St	Taylor Ck Meadows worries d/s residents
90-1581	12/03/90	0321	18805	244th Av SE	Neighbor's ditch floods property
85-1206	12/05/85	0321	18805	244th Av SE	Water in crawlspace-sump pump installed
P	01/11/84	0322	23306	SE 209th Pl	Blocked swale causing 236th Av SE to flood
87-1143	12/08/87	0324	24061	SE 216th St	No access to inspect commercial R/D pond
87-0926	09/03/87	0324	21665	244th Av SE	Private drainage system needs maintenance
L	11/03/83	0324	24207	SE 216th St	Road runoff floods property
W	05/05/83	0324	21665	244th Av SE	Private drainage system needs maintenance
91-1031	09/27/91	0326	20616	258th Av SE	Severe erosion in stream channel
90-0983	05/16/90	0326	26058	SE 208th St	Erosion in drainage channel
89-0551	08/25/89	0326	26925	SE 200th St	Concerned that creek is dry
R	01/07/83	0326	26210	SE 224th St	Neighbor's pond causing mild erosion
90-0837	04/02/90	0327	25627	SE 192nd St	Neighbor's clearing causing drainage problem
91-1115	10/28/91	0328	196xx	SE Petrovitsky Rd	Fill dumped near Peterson Creek
91-1006	09/19/91	0328	17918	E Spring Lake Dr SE	Uphill property cleared and filled
91-0891	08/06/91	0328	18113	E Spring Lake Dr SE	Culvert into Spring Lake plugged with sediment
91-0249	02/22/91	0328	18401	W Spring Lake Dr SE	Runoff from County land floods his driveway
90-0228	01/09/90	0328	17917	E Spring Lake Dr SE	Plugged road culverts causing flooding
88-0405	06/06/88	0328	18300	E Spring Lake Dr SE	County road culverts outlet onto his property
H	07/21/81	0328	18515	E Spring Lake Dr SE	Neighbor plans to fill drainage channel
S	08/02/84	0328	18113	E Spring Lake Dr SE	Neighbor's french drain outlets in R/W
S	12/23/81	0328	17966	W Spring Lake Dr SE	Concerned about erosion all around Spring Lak
91-0943	08/22/91	0328A	192xx	196th Av SE	New 6" driveway culvert too small

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
91-1107	10/22/91	0328B	340	Lake Desire Dr N	Sediment and water flows through property
91-0945	08/21/91	0328B	17247	174th Av SE	2 new homes causing their property to flood
91-0572	04/17/91	0328B	233	W Lake Desire Dr SE	Lake Desire high, outlet partially plugged
91-0203	02/19/91	0328B		W Lake Desire Dr SE	Adjacent lots cleared and unstable
90-1271	09/04/90	0328B	156	W Lake Desire Dr SE	Adjacent lot has been cleared to Lake Desire
90-1259	08/31/90	0328B		174th Ave SE	Ditch dug in Lower Cedar Wetland #14
90-1070	06/19/90	0328B	18553	W Lake Desire Dr SE	Neighbor's pond floods property
87-1087	11/13/87	0328B	120	Lake Desire Dr N	Neighbor filled ditch that drains to Lake Desire
87-0947	09/09/87	0328B		Lake Desire	Concerned about construction near Lake Desire
87-0774	07/01/87	0328B	126	Lake Desire Dr N	Lake Desire high, outlet may be blocked
87-0133	01/15/87	0328B	16844	186th Av SE	Roadway drainage floods his property
86-0701	07/02/86	0328B	227	W Lake Desire Dr SE	Neighbor's fill impacting private drainage syste
86-01L5	01/30/86	0328B	124	Lake Desire Dr N	Urbanization causing flooding problems
H	07/22/83	0328B	16859	188th Av SE	Neighbor's runoff causing a soggy yard
91-0968	09/03/91	0328C	17216	SE Petrovitsky Rd	Unmaintained ditch causes basement to flood
91-0791	07/01/91	0328C	17436	SE 196th Dr	Ditch recently dug along his property line
90-1517	11/26/90	0328C	17648	SE 192nd Dr	Neighbor's pond drains onto her property
90-1474	11/14/90	0328C	174xx	SE 196th Dr	Substandard driveway culvert installed
90-1267	09/04/90	0328C	17216	SE Petrovitsky Rd	Unmaintained ditch causes basement to flood
90-1229	08/20/90	0328C	17643	SE 192nd Dr	Wants to tightline drainage channel
90-0753	03/14/90	0328C	19603	SE Lake Youngs Rd	Roadway system outlets onto her property
90-0306	01/11/90	0328C	17415	SE 192nd Dr	Possible illegal 12" culvert
86-11B5	11/25/86	0328C	17210	SE 192nd Dr	8" driveway culvert too small
86-0841	08/07/86	0328C	192xx	172nd Av SE	Private roadway culvert too small
86-0708	07/07/86	0328C	17643	SE 192nd Dr	Culvert inlet too high-causes road to flood
86-01C4	01/18/86	0328C	17643	SE 192nd Dr	Blocked culvert & ditch causing flooding
M	01/10/83	0329	20626	216th Av SE	Neighbor filled wetland and caused landslide
91-0902	08/08/91	0330	20511	208th Av SE	Roadway runoff eroding driveway
89-0061	02/06/89	0331	204xx	208th Av SE	Lot doesn't drain well-want to tighline channel
86-0307	02/21/86	0331	203xx	208th Av SE	Roadway system outlets onto his property
87-0822	07/21/87	0334	20624	SE 192nd St	Roadway system outlets onto his property
91-0702	05/16/91	0334A	20625	SE 192nd St	Roadway ditches don't drain properly
90-1302	09/17/90	0336	22722	244th Av SE	Damaged culvert floods property
89-0697	10/26/89	0336	22722	244th Av SE	Damaged culvert floods property
87-0632	05/04/87	0336	22915	Lower Dorre Don Way SE	Culvert cannot handle larger storms
87-0569	04/15/87	0336	22915	Lower Dorre Don Way SE	Culvert cannot handle larger storms
B		0336	23221	Lower Dorre Don Way SE	Flooding-no file
C	01/12/84	0336	23360	Lower Dorre Don Way SE	Dispute between neighbors over duck pond
H	12/03/82	0336	23014	Lower Dorre Don Way SE	Culvert cannot handle larger storms
W	02/14/84	0336	233xx	Lower Dorre Don Way SE	Dispute between neighbors over duck pond
90-1115	07/11/90	0336A	22612	253rd Av SE	Neighbor changed stream course
90-0503	01/30/90	0336A	22216	257th Av SE	Stream overtopped banks
88-0600	09/26/88	0336A	22830	262nd Av SE	Neighbor's fill diverts runoff onto his lot
88-0022	01/14/88	0336A	26105	SE 225th Pl	Puget Power utility ditch caused a mess
87-0611	04/16/87	0336A	22240	257th Av SE	Inadequate drainage system causes flooding
87-0372	03/02/87	0336A	22830	262nd Av SE	Neighbor diverted runoff onto his lot
86-0531	05/13/86	0336A	22240	257th Av SE	Inadequate drainage system causes flooding
W	08/13/84	0336A	227xx	257th Pl SE	Illegal activity in Lower Cedar wetland #90

COMPLAINT NUMBER	DATE	DRAINAGE BASIN	HOUSE NUMBER	STREET ADDRESS	NATURE OF COMPLAINT
91-0874	07/31/91	0337	28435	SE 224th St	Unmaintained ditch caused home to flood
91-0537	04/11/91	0337	22610	285th Av SE	Undersized culvert causes yards to flood
91-0397	03/20/91	0337	22610	285th Av SE	Undersized culvert causes yards to flood
90-1270	09/05/90	0337	22319	286th Ave SE	Private road needs cross-culvert
90-0106	01/08/90	0337	22319	286th Av SE	Private road needs cross-culvert
88-0493	07/15/88	0337	223xx	244th Av SE	Cross-culvert needs upgrading
88-0404	06/06/88	0337	22205	286th Av SE	Poor lot drainage causes property to flood
86-1213	11/25/86	0337	28515	SE 226th St	Drainage system has chronic problems
86-11A8	11/24/86	0337	22319	286th Av SE	Private road needs cross-culvert
86-0818	08/13/86	0337	28515	SE 226th St	Private drainage easements not maintained
90-1265	08/30/90	0338	26930	262nd Av SE	Drainage onto property with no outlet
90-1252	08/29/90	0338	26900	262nd Av SE	Neighbor diverting spring runoff onto property
90-1251	08/29/90	0338	26918	262nd Av SE	Neighbor diverting spring runoff onto property
90-1250	08/28/90	0338	26918	262nd Av SE	Neighbor diverting spring runoff onto property
P	05/04/84	0338	24703	244th Pl SE	Erosion on Rock Creek bank
91-0720	05/24/91	0339	32128	SE 293rd Pl	Private road ditches plugged with silt
91-0649	05/01/91	0339	31701	SE 291st St	Sediment plugs R/D pond and causes flooding
91-0586	04/19/91	0339	27230	SE Green River Gorge Rd	Water overflows ditch and causes erosion
91-0282	02/26/91	0339	30011	SE Lake Retreat Rd	Debris plugs lake outlet grate and floods yards
90-1520	11/26/90	0339	31701	SE 291st St	Construction causing erosion/sedimentation
90-1413	10/23/90	0339	31701	SE 291st St	Development increasing runoff to R/D facility
90-1306	09/17/90	0339	318xx	SE 291st St	Owner wants to culvert stream
88-0625	10/04/88	0339	27002	SE Ravensdale Pl	Flooding due to unmaintained stream
87-0798	07/08/87	0339	28422	296th Av SE	Plugged culvert needed to be cleaned
88-0535	08/11/88	Issaquah	18249	252nd Av SE (2/3 mi upstrm)	Log road built with no drainage system
89-0099	02/28/89	Lk Kathl	18022	SE 128th St	Water ponding in road drainage ditch
86-0909	09/09/86	Lk Kathl	18102	SE 132nd St	Neighbor filled & redirected runoff
86-0825	08/21/86	Lk Kathl	18102	SE 132nd St	Neighbor filled & redirected runoff
90-1282	09/06/90	Lk McDo	19640	SE 150th St	Road drains to property
90-1151	07/24/90	Lk McDo	19804	SE 150th St	Illegal culvert extension
91-0173	02/14/91	Soos Cr	16623	116th Pl SE	Road drains to his yard-extend rd ditch
90-0304	01/11/90	Soos Cr	16623	116th Pl SE	Water from road flooding property
88-0772	12/08/88	Soos Cr	16548	115th Av SE	Road runoff floods driveway-no culvert
90-0369	01/11/90		?????	Coal Ck & Coal Ck Pkway	Silt & gravel covered boardwalk-ok
89-0453	07/07/89	???	204xx	Sweeney Rd SE	Dam flooding property-Jenkins wetland 2
89-0322	05/16/89	???	218xx	Sweeney Rd SE	Dam causes high water table-Jenkins #2
86-1108	11/03/86	???	?????	Sweeney Rd & 206th	Lake outlet blocked -need culvert
91-0912					
91-0412					
91-0104					
90-0709					
89-0592					
89-0263					
87-0713					
87-0430					
86-1130	11/03/86				
86-0256					
84-1030					

Table 2

HEC-2 Calibration Runs – Output Table
March 16, 1993

(1) SECNO	(2) CUMDS	(3) Q	(4) ELMIN	(5) CWSEL	(6) WSELK	(7) Df 3780	Df 8800	Df 12000
0.001	0	3780	7.4	13.4	13.4	0		
0.001	0	8800	7.4	13.4	13.4		0	
0.001	0	10600	7.4	13.4	13.4			0
5332	5532	3780	16.54	23.05		n/a		
5332	5532	8800	16.54	25.51	25.2		0.31	
5332	5532	10600	16.54	26.08	29.7			-3.62
7483	7673	3780	22.21	27.41	27.49	-0.08		
7483	7673	8800	22.21	30.76			n/a	
7483	7673	10600	22.21	32.41	32.6			-0.19
300	11206	3780	28.5	35.94	35.41	0.53		
300	11206	8800	28.5	40.22	38.5		1.72	
300	11206	12000	28.5	41.5	43.4			-1.9
800	15826	3780	42	50.49	50.84	-0.35		
800	15826	8800	42	55.21	54.7		0.51	
800	15826	12000	42	57.64	58.2			-0.56
1401	22441	3780	64.6	71.61	71.26	0.35		
1401	22441	8800	64.6	74.84	74.1		0.74	
1401	22441	12000	64.6	76.17	76.5			-0.33
2300	31666	3780	99.8	106.64	108.53	-1.89		
2300	31666	8800	99.8	110.47			n/a	
2300	31666	12000	99.8	112.43	114.1			-1.67
2600	36226	3780	121.2	126.84	126.73	0.11		
2600	36226	8800	121.2	129	128.1		0.9	
2600	36226	12000	121.2	129.86	129.2			0.66
3300	42906	3780	149.2	155.77	154.46	1.31		
3300	42906	8800	149.2	158.42	157.1		1.32	
3300	42906	12000	149.2	159.7	158.2			1.5
3400	44866	3780	159.8	166.34	169.11	-2.77		
3400	44866	8800	159.8	169.58			n/a	
3400	44866	12000	159.8	171.25	172.8			-1.55
3800	50526	3780	180.8	186.55	189.47	-2.92		
3800	50526	8800	180.8	189.85	192.6		-2.75	
3800	50526	12000	180.8	191.56	193.7			-2.14

(1) Cross section number
(2) Distance from mouth
(3) Discharge
(4) Minimum elevation in section
(5) Calculated water surface elevation
(6) Observed water surface elevation
(7) Difference between calculated and observed water surfaces

Table 2 (cont)

(1) SECNO	(2) CUMDS	(3) Q	(4) ELMIN	(5) CWSEL	(6) WSELK	Df 3780	(7) Df 8800	Df 12000
4200	58086	3780	209.4	215	212.73	2.27		
4200	58086	8800	209.4	216.8	214.1		2.7	
4200	58086	12000	209.4	217.69	216.1			1.59
4600	62406	3780	224.2	231.09	231.24	-0.15		
4600	62406	8800	224.2	233.03			n/a	
4600	62406	12000	224.2	234.05	233.7			0.35
5100	68586	3780	246.6	255.78	256.04	-0.26		
5100	68586	8800	246.6	259.43	258.7		0.73	
5100	68586	12000	246.6	260.01	259.7			0.31
5600	73506	3780	270.1	276.44	277.46	-1.02		
5600	73506	8800	270.1	279.91	278.2		1.71	
5600	73506	12000	270.1	281.51	280.4			1.11
7100	86786	3780	336.9	345.43	345.66	-0.23		
7100	86786	8800	336.9	348.95	346.9		2.05	
7100	86786	12000	336.9	350.36	348.5			1.86
7400	92406	3780	364.9	374.07	370.99	3.08		
7400	92406	8800	364.9	376.9			n/a	
7400	92406	12000	364.9	377.65	377.2			0.45

Date	1/10/90	1/3/75	11/24/90
Flow (cfs)	3780	8800	12,000
Avg. Difference (ft.)	1.14	0.91	1.25
Median Difference (ft.)	-0.15	0.90	0.06
Maximum Overestimate (ft.)	3.1	2.7	1.9
At station	7400	4200	7100
Maximum Underestimate (ft.)	-2.9	-2.8	-3.6
At station	3800	3800	5332
Range of Over - Underestimate (ft.)	6.0	5.5	5.5

(1) Cross section number
(2) Distance from mouth
(3) Discharge
(4) Minimum elevation in section
(5) Calculated water surface elevation
(6) Observed water surface elevation
(7) Difference between calculated and observed water surfaces

Table 3 HEC- 2 WATER SURFACE PROFILES

Run Date: February 17, 1993- - - Version 4.6.2; May 1991

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	0.001	0	6100	6.00	13.40	Lake Washington
25- Year Current	0.001	0	8000	6.00	13.40	
100- Year Current	0.001	0	11100	6.00	13.40	
10- Year Current	0.01	150	6100	5.70	13.10	
25- Year Current	0.01	150	8000	5.38	12.78	
100- Year Current	0.01	150	11100	6.02	13.42	
10- Year Current	0.1	200	6100	5.43	12.85	
25- Year Current	0.1	200	8000	6.09	13.51	
100- Year Current	0.1	200	11100	7.08	14.50	
10- Year Current	100	300	6100	6.25	14.30	N Boeing Bridge
25- Year Current	100	300	8000	7.26	15.31	RM 0.0
100- Year Current	100	300	11100	8.75	16.80	
10- Year Current	140	340	6090	6.46	14.51	
25- Year Current	140	340	8002	7.45	15.50	
100- Year Current	140	340	11128	8.91	16.96	
10- Year Current	955	1155	6090	6.67	16.42	
25- Year Current	955	1155	8002	7.65	17.40	
100- Year Current	955	1155	11128	9.13	18.88	
10- Year Current	1665	1865	6090	6.17	17.88	
25- Year Current	1665	1865	8002	7.20	18.91	
100- Year Current	1665	1865	11128	8.79	20.50	
10- Year Current	2585	2785	6090	6.41	19.66	
25- Year Current	2585	2785	8002	7.42	20.67	
100- Year Current	2585	2785	11128	8.79	22.04	
10- Year Current	3460	3660	6090	6.75	21.06	
25- Year Current	3460	3660	8002	7.65	21.96	
100- Year Current	3460	3660	11128	8.54	22.85	
10- Year Current	3975	4175	6090	6.99	21.87	
25- Year Current	3975	4175	8002	7.68	22.56	
100- Year Current	3975	4175	11128	8.34	23.22	
10- Year Current	4037	4237	6090	7.79	22.42	S Boeing Bridge
25- Year Current	4037	4237	8002	9.01	23.64	RM 0.8
100- Year Current	4037	4237	11128	10.30	24.93	
10- Year Current	4192	4392	6090	7.48	22.74	
25- Year Current	4192	4392	8002	8.77	24.03	
100- Year Current	4192	4392	11128	10.18	25.44	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	4732	4932	6090	5.97	23.27	
25- Year Current	4732	4932	8002	7.20	24.50	
100- Year Current	4732	4932	11128	8.59	25.89	
10- Year Current	5332	5532	6090	7.88	24.42	
25- Year Current	5332	5532	8002	8.69	25.23	
100- Year Current	5332	5532	11128	9.70	26.24	
10- Year Current	5644	5844	6090	7.61	25.01	
25- Year Current	5644	5844	8002	8.45	25.85	
100- Year Current	5644	5844	11128	9.46	26.86	
10- Year Current	5696	5896	6090	7.55	25.10	Logan Ave
25- Year Current	5696	5896	8002	8.40	25.95	TM 1.1
100- Year Current	5696	5896	11128	9.43	26.98	
10- Year Current	5800	6000	6090	7.68	25.33	
25- Year Current	5800	6000	8002	8.63	26.28	
100- Year Current	5800	6000	11128	11.26	28.91	
10- Year Current	6012	6212	6090	6.95	25.64	
25- Year Current	6012	6212	8002	7.89	26.58	
100- Year Current	6012	6212	11128	10.32	29.01	
10- Year Current	6502	6702	6090	6.98	26.77	Williams Ave
25- Year Current	6502	6702	8002	7.96	27.75	RM 1.2
100- Year Current	6502	6702	11128	9.98	29.77	
10- Year Current	6541	6741	6090	7.26	27.05	
25- Year Current	6541	6741	8002	8.32	28.11	
100- Year Current	6541	6741	11128	10.51	30.30	
10- Year Current	6681	6881	6090	6.97	27.35	
25- Year Current	6681	6881	8002	8.03	28.41	
100- Year Current	6681	6881	11128	10.13	30.51	
10- Year Current	6931	7131	6090	6.70	27.97	Wells Ave
25- Year Current	6931	7131	8002	7.83	29.10	RM 1.3
100- Year Current	6931	7131	11128	9.78	31.05	
10- Year Current	6973	7173	6090	6.87	28.14	
25- Year Current	6973	7173	8002	8.04	29.31	
100- Year Current	6973	7173	11128	11.32	32.59	
10- Year Current	7103	7293	6090	6.87	28.37	
25- Year Current	7103	7293	8002	8.08	29.58	
100- Year Current	7103	7293	11128	11.36	32.86	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	7483	7673	6090	6.85	29.06	
25- Year Current	7483	7673	8002	7.97	30.18	
100- Year Current	7483	7673	11128	10.87	33.08	
10- Year Current	7652	7843	6058	7.18	29.35	
25- Year Current	7652	7843	7966	8.31	30.48	
100- Year Current	7652	7843	11091	11.12	33.29	
10- Year Current	7653	7844	6058	7.03	29.20	Bronson Way
25- Year Current	7653	7844	7966	8.08	30.25	RM 1.5
100- Year Current	7653	7844	11091	10.87	33.04	
10- Year Current	7725	7916	6058	7.40	29.57	
25- Year Current	7725	7916	7966	8.60	30.77	
100- Year Current	7725	7916	11091	11.17	33.34	
10- Year Current	7726	7917	6058	7.69	29.96	
25- Year Current	7726	7917	7966	9.10	31.37	
100- Year Current	7726	7917	11091	11.78	34.05	
10- Year Current	7845	8027	6058	7.71	30.18	Renton Library
25- Year Current	7845	8027	7966	9.09	31.56	RM 1.5
100- Year Current	7845	8027	11091	11.71	34.18	
10- Year Current	8002	8184	6058	7.66	30.35	
25- Year Current	8002	8184	7966	9.05	31.74	
100- Year Current	8002	8184	11091	11.65	34.34	
10- Year Current	8092	8274	6058	7.43	30.37	
25- Year Current	8092	8274	7966	8.77	31.71	
100- Year Current	8092	8274	11091	11.38	34.32	
10- Year Current	8380	8562	6058	9.55	31.22	
25- Year Current	8380	8562	7966	10.80	32.47	
100- Year Current	8380	8562	11091	13.07	34.74	
10- Year Current	8387	8569	6058	9.76	31.43	
25- Year Current	8387	8569	7966	11.05	32.72	
100- Year Current	8387	8569	11091	14.09	35.76	
10- Year Current	8402	8584	6058	9.79	31.46	Houser Way
25- Year Current	8402	8584	7966	11.09	32.76	RM 1.6
100- Year Current	8402	8584	11091	14.12	35.79	
10- Year Current	8436	8618	6058	10.11	31.78	
25- Year Current	8436	8618	7966	11.46	33.13	
100- Year Current	8436	8618	11091	15.40	37.07	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	8476	8658	6058	11.61	31.86	BNRR
25- Year Current	8476	8658	7966	12.93	33.18	RM 1.6
100- Year Current	8476	8658	11091	16.81	37.06	
10- Year Current	8596	8778	6058	9.98	32.28	I- 405
25- Year Current	8596	8778	7966	11.42	33.72	RM 1.6
100- Year Current	8596	8778	11091	15.21	37.51	
10- Year Current	8836	9018	6058	9.55	32.67	
25- Year Current	8836	9018	7966	10.98	34.10	
100- Year Current	8836	9018	11091	14.61	37.73	
10- Year Current	9446	9628	6058	11.16	34.29	
25- Year Current	9446	9628	7966	12.51	35.64	
100- Year Current	9446	9628	11091	15.45	38.58	
10- Year Current	10236	10418	6058	9.72	36.57	
25- Year Current	10236	10418	7966	11.31	38.16	
100- Year Current	10236	10418	11091	13.98	40.83	
10- Year Current	300	11206	6058	9.61	38.11	
25- Year Current	300	11206	7966	11.12	39.62	
100- Year Current	300	11206	11091	13.47	41.97	
10- Year Current	400	12386	6058	11.40	40.60	
25- Year Current	400	12386	7966	12.97	42.17	
100- Year Current	400	12386	11091	15.22	44.42	
10- Year Current	500	13486	5980	7.95	43.55	
25- Year Current	500	13486	7887	9.26	44.86	
100- Year Current	500	13486	11021	11.23	46.83	
10- Year Current	588	14434	5980	8.52	47.32	PedestrianBridge
25- Year Current	588	14434	7887	9.64	48.44	RM 2.7
100- Year Current	588	14434	11021	11.30	50.10	
10- Year Current	600	14446	5980	8.58	47.38	
25- Year Current	600	14446	7887	9.73	48.53	
100- Year Current	600	14446	11021	11.42	50.22	
10- Year Current	700	15166	5980	9.31	49.91	
25- Year Current	700	15166	7887	10.70	51.30	
100- Year Current	700	15166	11021	12.68	53.28	
10- Year Current	701	15306	5980	9.02	49.92	BNRR
25- Year Current	701	15306	7887	10.29	51.19	RM 2.9
100- Year Current	701	15306	11021	12.08	52.98	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	702	15326	5980	9.29	50.19	
25- Year Current	702	15326	7887	10.63	51.53	
100- Year Current	702	15326	11021	12.57	53.47	
10- Year Current	800	15826	5980	10.76	52.76	
25- Year Current	800	15826	7887	12.45	54.45	
100- Year Current	800	15826	11021	14.93	56.93	
10- Year Current	900	16576	5980	9.87	54.37	
25- Year Current	900	16576	7887	11.45	55.95	
100- Year Current	900	16576	11021	13.78	58.28	
10- Year Current	1000	17456	5980	8.85	56.75	
25- Year Current	1000	17456	7887	10.36	58.26	
100- Year Current	1000	17456	11021	12.65	60.55	
10- Year Current	1100	18336	5940	11.17	58.97	
25- Year Current	1100	18336	7847	12.38	60.18	
100- Year Current	1100	18336	10988	14.19	61.99	
10- Year Current	1200	19416	5940	8.61	63.11	
25- Year Current	1200	19416	7847	9.87	64.37	
100- Year Current	1200	19416	10988	11.47	65.97	
10- Year Current	1300	20916	5940	8.04	68.14	
25- Year Current	1300	20916	7847	9.10	69.20	
100- Year Current	1300	20916	10988	10.55	70.65	
10- Year Current	1400	22416	5902	8.54	73.14	SR169
25- Year Current	1400	22416	7820	9.61	74.21	RM 4.2
100- Year Current	1400	22416	10988	10.98	75.58	
10- Year Current	1401	22441	5902	8.66	73.26	
25- Year Current	1401	22441	7820	9.76	74.36	
100- Year Current	1401	22441	10988	11.19	75.79	
10- Year Current	1500	23136	5902	7.69	75.59	
25- Year Current	1500	23136	7820	8.99	76.89	
100- Year Current	1500	23136	10988	10.90	78.80	
10- Year Current	1600	24136	5902	7.08	79.28	
25- Year Current	1600	24136	7820	7.97	80.17	
100- Year Current	1600	24136	10988	9.36	81.56	
10- Year Current	1700	25176	5902	7.16	84.06	
25- Year Current	1700	25176	7820	7.74	84.64	
100- Year Current	1700	25176	10988	9.12	86.02	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	1800	26216	5902	8.73	90.33	
25- Year Current	1800	26216	7820	10.10	91.70	
100- Year Current	1800	26216	10988	11.92	93.52	
10- Year Current	1900	27636	5857	7.31	94.31	
25- Year Current	1900	27636	7786	8.59	95.59	
100- Year Current	1900	27636	10988	10.35	97.35	
10- Year Current	1901	27766	5857	8.92	94.62	Elliot Bridge
25- Year Current	1901	27766	7786	10.11	95.81	RM 5.3
100- Year Current	1901	27766	10988	11.79	97.49	
10- Year Current	1902	27776	5857	8.95	94.65	
25- Year Current	1902	27776	7786	10.18	95.88	
100- Year Current	1902	27776	10988	11.83	97.53	
10- Year Current	1903	27801	5857	9.04	94.74	
25- Year Current	1903	27801	7786	10.27	95.97	
100- Year Current	1903	27801	10988	11.92	97.62	
10- Year Current	1904	27811	5857	9.08	94.78	
25- Year Current	1904	27811	7786	10.32	96.02	
100- Year Current	1904	27811	10988	11.98	97.68	
10- Year Current	2000	28386	5857	7.51	97.41	
25- Year Current	2000	28386	7786	8.45	98.35	
100- Year Current	2000	28386	10988	9.75	99.65	
10- Year Current	2100	29586	5831	8.23	101.73	
25- Year Current	2100	29586	7767	9.47	102.97	
100- Year Current	2100	29586	10989	10.81	104.31	
10- Year Current	2200	30306	5831	7.91	103.71	
25- Year Current	2200	30306	7767	9.32	105.12	
100- Year Current	2200	30306	10989	10.94	106.74	
10- Year Current	2300	31666	5831	8.58	108.38	
25- Year Current	2300	31666	7767	9.98	109.78	
100- Year Current	2300	31666	10989	12.04	111.84	
10- Year Current	2400	32886	5836	7.80	112.60	
25- Year Current	2400	32886	7790	9.02	113.82	
100- Year Current	2400	32886	11046	10.89	115.69	
10- Year Current	2500	34426	5836	8.39	120.09	
25- Year Current	2500	34426	7790	9.08	120.78	
100- Year Current	2500	34426	11046	10.22	121.92	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	2600	36226	5836	6.70	127.90	
25- Year Current	2600	36226	7790	7.46	128.66	
100- Year Current	2600	36226	11046	8.41	129.61	
10- Year Current	2700	36726	5836	6.07	129.97	
25- Year Current	2700	36726	7790	6.72	130.62	
100- Year Current	2700	36726	11046	7.78	131.68	
10- Year Current	2800	37486	5836	10.00	133.60	
25- Year Current	2800	37486	7790	11.11	134.71	
100- Year Current	2800	37486	11046	12.90	136.50	
10- Year Current	2900	38286	5836	7.41	136.41	
25- Year Current	2900	38286	7790	8.44	137.44	
100- Year Current	2900	38286	11046	10.04	139.04	
10- Year Current	3000	40486	5791	9.49	146.89	
25- Year Current	3000	40486	7735	10.59	147.99	
100- Year Current	3000	40486	10976	12.17	149.57	
10- Year Current	3100	41446	5791	7.49	150.99	
25- Year Current	3100	41446	7735	8.57	152.07	
100- Year Current	3100	41446	10976	10.22	153.72	
10- Year Current	3200	42306	5791	10.53	154.53	
25- Year Current	3200	42306	7735	11.36	155.36	
100- Year Current	3200	42306	10976	12.48	156.48	
10- Year Current	3300	42906	5791	7.80	157.00	
25- Year Current	3300	42906	7735	8.75	157.95	
100- Year Current	3300	42906	10976	10.12	159.32	
10- Year Current	3400	44866	5791	8.01	167.81	
25- Year Current	3400	44866	7735	9.19	168.99	
100- Year Current	3400	44866	10976	10.93	170.73	
10- Year Current	3500	46626	5791	8.19	174.79	
25- Year Current	3500	46626	7735	9.34	175.94	
100- Year Current	3500	46626	10976	11.02	177.62	
10- Year Current	3600	48226	5791	7.05	179.85	
25- Year Current	3600	48226	7735	8.06	180.86	
100- Year Current	3600	48226	10976	9.50	182.30	
10- Year Current	3700	49126	5791	8.83	183.13	Jones Rd
25- Year Current	3700	49126	7735	10.06	184.36	RM 9.2
100- Year Current	3700	49126	10976	11.78	186.08	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	3701	49136	5791	8.98	183.28	
25- Year Current	3701	49136	7735	10.31	184.61	
100- Year Current	3701	49136	10976	12.29	186.59	
10- Year Current	3702	49161	5791	9.05	183.35	
25- Year Current	3702	49161	7735	10.38	184.68	
100- Year Current	3702	49161	10976	12.37	186.67	
10- Year Current	3703	49171	5791	9.08	183.38	
25- Year Current	3703	49171	7735	10.44	184.74	
100- Year Current	3703	49171	10976	12.48	186.78	
10- Year Current	3800	50526	5794	7.20	188.00	
25- Year Current	3800	50526	7732	8.43	189.23	
100- Year Current	3800	50526	10956	10.24	191.04	
10- Year Current	3900	52466	5794	8.60	195.40	
25- Year Current	3900	52466	7732	9.46	196.26	
100- Year Current	3900	52466	10956	11.16	197.96	
10- Year Current	4000	54006	5794	6.98	199.98	
25- Year Current	4000	54006	7732	7.49	200.49	
100- Year Current	4000	54006	10956	8.67	201.67	
10- Year Current	4100	56386	5794	5.37	209.17	
25- Year Current	4100	56386	7732	5.99	209.79	
100- Year Current	4100	56386	10956	6.73	210.53	
10- Year Current	4200	58086	5794	6.44	215.84	
25- Year Current	4200	58086	7732	7.07	216.47	
100- Year Current	4200	58086	10956	8.01	217.41	
10- Year Current	4300	58866	5794	6.97	218.67	
25- Year Current	4300	58866	7732	7.66	219.36	
100- Year Current	4300	58866	10956	8.64	220.34	
10- Year Current	4400	59946	5794	11.02	224.02	Cedar Grove Rd
25- Year Current	4400	59946	7732	12.54	225.54	TM 11.3
100- Year Current	4400	59946	10956	12.31	225.31	
10- Year Current	4401	59972	5794	11.18	224.18	
25- Year Current	4401	59972	7732	12.71	225.71	
100- Year Current	4401	59972	10956	12.98	225.98	
10- Year Current	4500	60866	5816	8.68	226.68	
25- Year Current	4500	60866	7773	10.04	228.04	
100- Year Current	4500	60866	11034	11.43	229.43	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	4600	62406	5816	7.74	231.94	
25- Year Current	4600	62406	7773	8.41	232.61	
100- Year Current	4600	62406	11034	9.55	233.75	
10- Year Current	4700	64146	5816	7.81	238.71	
25- Year Current	4700	64146	7773	8.99	239.89	
100- Year Current	4700	64146	11034	10.50	241.40	
10- Year Current	4800	64766	5830	8.17	240.37	
25- Year Current	4800	64766	7789	9.33	241.53	
100- Year Current	4800	64766	11051	10.88	243.08	
10- Year Current	4900	66006	5830	9.48	245.08	
25- Year Current	4900	66006	7789	10.48	246.08	
100- Year Current	4900	66006	11051	11.94	247.54	
10- Year Current	5000	67046	5830	9.41	249.31	
25- Year Current	5000	67046	7789	10.48	250.38	
100- Year Current	5000	67046	11051	11.39	251.29	
10- Year Current	5100	68586	5830	10.87	257.47	
25- Year Current	5100	68586	7789	11.94	258.54	
100- Year Current	5100	68586	11051	12.99	259.59	
10- Year Current	5200	70286	5754	9.04	265.14	
25- Year Current	5200	70286	7725	9.91	266.01	
100- Year Current	5200	70286	11019	11.22	267.32	
10- Year Current	5300	71606	5754	7.63	270.63	
25- Year Current	5300	71606	7725	8.14	271.14	
100- Year Current	5300	71606	11019	8.87	271.87	
10- Year Current	5400	72366	5754	9.75	273.35	
25- Year Current	5400	72366	7725	10.36	273.96	
100- Year Current	5400	72366	11019	11.47	275.07	
10- Year Current	5600	73506	5754	7.84	277.94	SR169
25- Year Current	5600	73506	7725	9.13	279.23	RM 13.8
100- Year Current	5600	73506	11019	10.91	281.01	
10- Year Current	5601	73542	5754	8.02	278.12	
25- Year Current	5601	73542	7725	9.31	279.41	
100- Year Current	5601	73542	11019	11.11	281.21	
10- Year Current	5700	74186	5754	8.77	280.57	
25- Year Current	5700	74186	7725	10.17	281.97	
100- Year Current	5700	74186	11019	12.28	284.08	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	5800	74806	5754	10.30	283.50	
25- Year Current	5800	74806	7725	11.38	284.58	
100- Year Current	5800	74806	11019	13.11	286.31	
10- Year Current	5900	75886	5678	7.65	288.05	
25- Year Current	5900	75886	7615	8.83	289.23	
100- Year Current	5900	75886	10852	10.48	290.88	
10- Year Current	6000	76306	5678	7.49	290.59	
25- Year Current	6000	76306	7615	8.69	291.79	
100- Year Current	6000	76306	10852	10.50	293.60	
10- Year Current	6100	76946	5678	6.09	293.69	
25- Year Current	6100	76946	7615	7.08	294.68	
100- Year Current	6100	76946	10852	8.54	296.14	
10- Year Current	6200	77746	5678	6.92	298.72	
25- Year Current	6200	77746	7615	7.81	299.61	
100- Year Current	6200	77746	10852	9.01	300.81	
10- Year Current	6300	78306	5678	6.20	301.80	
25- Year Current	6300	78306	7615	7.11	302.71	
100- Year Current	6300	78306	10852	7.85	303.45	
10- Year Current	6400	79056	5678	10.65	306.15	SR18
25- Year Current	6400	79056	7615	11.65	307.15	RM 14.9
100- Year Current	6400	79056	10852	13.41	308.91	
10- Year Current	6401	79066	5678	10.62	306.12	
25- Year Current	6401	79066	7615	11.59	307.09	
100- Year Current	6401	79066	10852	13.33	308.83	
10- Year Current	6402	79146	5678	11.06	306.56	
25- Year Current	6402	79146	7615	12.46	307.96	
100- Year Current	6402	79146	10852	14.37	309.87	
10- Year Current	6403	79156	5678	11.24	306.74	
25- Year Current	6403	79156	7615	12.75	308.25	
100- Year Current	6403	79156	10852	14.66	310.16	
10- Year Current	6500	79686	5678	9.87	308.47	SR169
25- Year Current	6500	79686	7615	11.66	310.26	RM 15.0
100- Year Current	6500	79686	10852	13.47	312.07	
10- Year Current	6501	79712	5678	10.00	308.60	
25- Year Current	6501	79712	7615	11.78	310.38	
100- Year Current	6501	79712	10852	13.62	312.22	

Table 3 (cont)

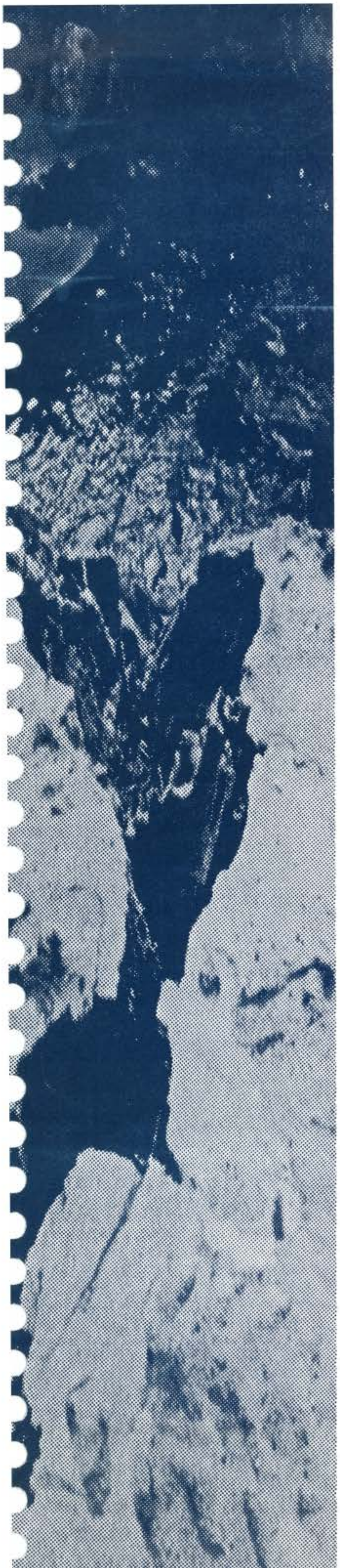
STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	6600	80026	5678	9.65	309.95	BNRR
25- Year Current	6600	80026	7615	11.24	311.54	RM 15.1
100- Year Current	6600	80026	10852	13.17	313.47	
10- Year Current	6601	80047	5678	9.91	310.21	
25- Year Current	6601	80047	7615	11.45	311.75	
100- Year Current	6601	80047	10852	13.40	313.70	
10- Year Current	6700	80746	5678	7.02	313.62	
25- Year Current	6700	80746	7615	8.05	314.65	
100- Year Current	6700	80746	10852	9.65	316.25	
10- Year Current	6800	81266	5678	6.41	316.91	
25- Year Current	6800	81266	7615	7.32	317.82	
100- Year Current	6800	81266	10852	8.67	319.17	
10- Year Current	6900	83266	5678	6.97	329.27	
25- Year Current	6900	83266	7615	7.72	330.02	
100- Year Current	6900	83266	10852	8.82	331.12	
10- Year Current	7000	85266	5678	8.25	339.15	
25- Year Current	7000	85266	7615	9.03	339.93	
100- Year Current	7000	85266	10852	10.10	341.00	
10- Year Current	7100	86786	5654	10.11	347.01	BNRR
25- Year Current	7100	86786	7578	11.44	348.34	RM 16.3
100- Year Current	7100	86786	10785	12.97	349.87	
10- Year Current	7101	86796	5654	10.32	347.22	
25- Year Current	7101	86796	7578	11.57	348.47	
100- Year Current	7101	86796	10785	13.00	349.90	
10- Year Current	7102	86816	5654	10.43	347.33	
25- Year Current	7102	86816	7578	11.68	348.58	
100- Year Current	7102	86816	10785	13.14	350.04	
10- Year Current	7103	86826	5654	10.59	347.49	
25- Year Current	7103	86826	7578	11.89	348.79	
100- Year Current	7103	86826	10785	13.45	350.35	
10- Year Current	7200	87246	5654	11.09	348.59	
25- Year Current	7200	87246	7578	12.24	349.74	
100- Year Current	7200	87246	10785	13.63	351.13	
10- Year Current	7300	88906	5654	8.76	355.96	
25- Year Current	7300	88906	7578	9.98	357.18	
100- Year Current	7300	88906	10785	11.73	358.93	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	7400	92406	5654	10.58	375.48	BNRR
25- Year Current	7400	92406	7578	11.56	376.46	RM 17.2
100- Year Current	7400	92406	10785	12.51	377.41	
10- Year Current	7500	93211	5654	8.15	379.35	
25- Year Current	7500	93211	7578	9.47	380.67	
100- Year Current	7500	93211	10785	10.75	381.95	
10- Year Current	7600	94166	5654	7.45	383.15	
25- Year Current	7600	94166	7578	8.47	384.17	
100- Year Current	7600	94166	10785	10.05	385.75	
10- Year Current	7700	95131	5654	6.13	390.13	
25- Year Current	7700	95131	7578	7.27	391.27	
100- Year Current	7700	95131	10785	8.87	392.87	
10- Year Current	7800	96471	5654	6.29	400.29	
25- Year Current	7800	96471	7578	7.45	401.45	
100- Year Current	7800	96471	10785	8.94	402.94	
10- Year Current	7900	97601	5510	7.31	409.01	
25- Year Current	7900	97601	7407	8.69	410.39	
100- Year Current	7900	97601	10575	10.45	412.15	
10- Year Current	8000	98271	5510	7.56	413.06	
25- Year Current	8000	98271	7407	8.98	414.48	
100- Year Current	8000	98271	10575	11.48	416.98	
10- Year Current	8100	99001	5510	8.77	421.97	
25- Year Current	8100	99001	7407	10.12	423.32	
100- Year Current	8100	99001	10575	11.65	424.85	
10- Year Current	8200	100131	5510	10.34	431.04	
25- Year Current	8200	100131	7407	11.77	432.47	
100- Year Current	8200	100131	10575	13.61	434.31	
10- Year Current	8300	101051	5510	6.76	435.16	
25- Year Current	8300	101051	7407	8.08	436.48	
100- Year Current	8300	101051	10575	9.77	438.17	
10- Year Current	8400	101971	5510	6.43	440.43	
25- Year Current	8400	101971	7407	7.55	441.55	
100- Year Current	8400	101971	10575	9.50	443.50	
10- Year Current	8500	102601	5510	6.00	444.00	
25- Year Current	8500	102601	7407	7.14	445.14	
100- Year Current	8500	102601	10575	8.95	446.95	

Table 3 (cont)

STORM EVENT	Cross Section Number	Dist From Mouth	Flow Rate	Flow Depth	Water Surface Elev	Landmark
10- Year Current	8600	103806	5510	7.19	452.89	
25- Year Current	8600	103806	7407	8.52	454.22	
100- Year Current	8600	103806	10575	10.53	456.23	
10- Year Current	8700	104556	5510	6.32	462.22	
25- Year Current	8700	104556	7407	7.38	463.28	
100- Year Current	8700	104556	10575	8.97	464.87	



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Chapter 5: Erosion and Deposition of Stream and River Channel Sediments

5.1 INTRODUCTION

The topography and geology of the Cedar River Basin affect both the location and magnitude of sediment erosion and deposition processes. These basin characteristics largely determine the degree to which a stream channel will be affected by the hydrologic changes that accompany development.

The Cedar River flows to Lake Washington through a valley that is incised through 200 to 300 feet of glacial sediments (see Map 5 in *Appendix B*). Above the Cedar River valley, these glacial sediments form gently sloping plateaus. The low-gradient streams that flow across these plateaus are unable to erode or transport much sediment, even when stream flows are substantially increased by development. However, when these streams reach the steep valley sides, their velocity and thus sediment transport capacity increases dramatically. If destabilized by flow increases, these steep streams can rapidly cut down through the erodible glacial sediments that underlie the plateau. Upon reaching the valley bottom, most of the sediment carried by these tributary streams drops out on the broad floodplain of the Cedar River, forming alluvial fans. Part of the tributary sediment load enters the Cedar River and is transported intermittently downstream.

The Cedar River has historically been a migrating river that swung back and forth across its floodplain, eroding one bank and redepositing the eroded material on the opposite bank. Rock revetments constructed to prevent bank erosion have reduced the rate of channel migration along much of the river. In many cases the revetments have narrowed the channel and reduced available sites for sediment deposition.

In addition to moving laterally, the bed of the Cedar River moves up and down in response to sediment influx and stream flow. In locations where the river cannot transport all the sediment that is supplied to it from upstream, sediment is deposited and the bed of the river rises. Such is the case in Renton, where the river's slope decreases and sediment deposits have partially filled in the channel. Sediment transported through Renton to the mouth of the river has built an extensive delta in Lake Washington.

Section 5.2 of this chapter describes the methods used to gather and analyze the information presented; *Section 5.3* describes erosion of tributary stream channels; *Section 5.4* describes the mainstem; *Section 5.5* contains the results of a bedload sediment transport modeling of the Cedar River mainstem; and *Section 5.5* lists key findings.

5.2 DATA GATHERING METHODS AND ANALYSIS

TRIBUTARY CHANNELS

Data for this chapter was primarily obtained by field observations by Surface Water Management Division (SWM) staff. All numbered lower mainstem tributaries were walked in 1987 as part of the Basin Reconnaissance Program (King County, 1987). Almost all stream segments with gradients steep enough to have potential erosion problems, or for which erosion- or sediment-related drainage complaints had been filed during 1986-1991, were walked in 1991 or 1992. Field observations included type and severity of erosion problems, depositional zones, grade control structures, geologic substrate, channel dimensions, and bed-material size. On two streams in the basin (0305 and 0300A), monumented channel cross-sections were established in 1988 and resurveyed in two subsequent years to measure short-term changes in width and depth.

Perhaps because of the short time elapsed since the 1990 floods, most moderate to steep channels in the Cedar River Basin are incised and a "bankfull channel," in equilibrium with the prevailing hydrology, was not discernable during the field observations. The few channels that were not obviously incised were substantially larger than would be predicted based on their current discharge, perhaps due to residual effects of the 1990 floods. Hence a hydraulic geometry analysis, in which increases in bankfull width and depth are related to increases in the bankfull discharge (typically the 1.5-year flood discharge), was not attempted. Instead, the analysis concentrated on relating the observed degree of channel instability to three factors: 1) hydrologic changes, 2) channel slope and morphology, and 3) geologic substrate. Hydrologic data were obtained from HSPF model output (*Chapter 3: Surface Water Hydrology*). Average channel slopes were obtained from 25-foot contour interval maps, in some locations supplemented by clinometer measurements in the field. The relationship of channel instability to these factors can be used as a predictive tool to identify locations where discharge increases from future development are likely to cause channel erosion.

CEDAR RIVER MAINSTEM

Data on riverbed and bank materials and floodplain channels were obtained during field studies by SWM Basin Planning staff in 1991 and 1992. Information on revetments and bank erosion problems was compiled from County records and by SWM River Planning staff. Channel migration and historic changes in channel patterns were documented using maps from 1865 and aerial photographs from 1936 to 1989, following the preliminary report of Strieby and Booth (1992). Bedload sediment transport in the Cedar River was modeled using measured sediment size data together with channel geometry and water-surface elevations from the most recent HEC-2 model output. Estimates of sediment deposition and transport rates in the river through Renton and at the delta were also obtained from two studies published in 1992: Northwest Hydraulic Consultants compared channel cross-sections surveyed for 1985 and 1991 flood studies and Harza Northwest compared the observed deposition rates with dredged volumes and the predictions of sediment transport modeling. Depositional trends upstream from Renton were identified by resurveying and comparing channel cross-sections of various dates.

5.3 EROSION AND SEDIMENT DEPOSITION IN TRIBUTARY STREAMS

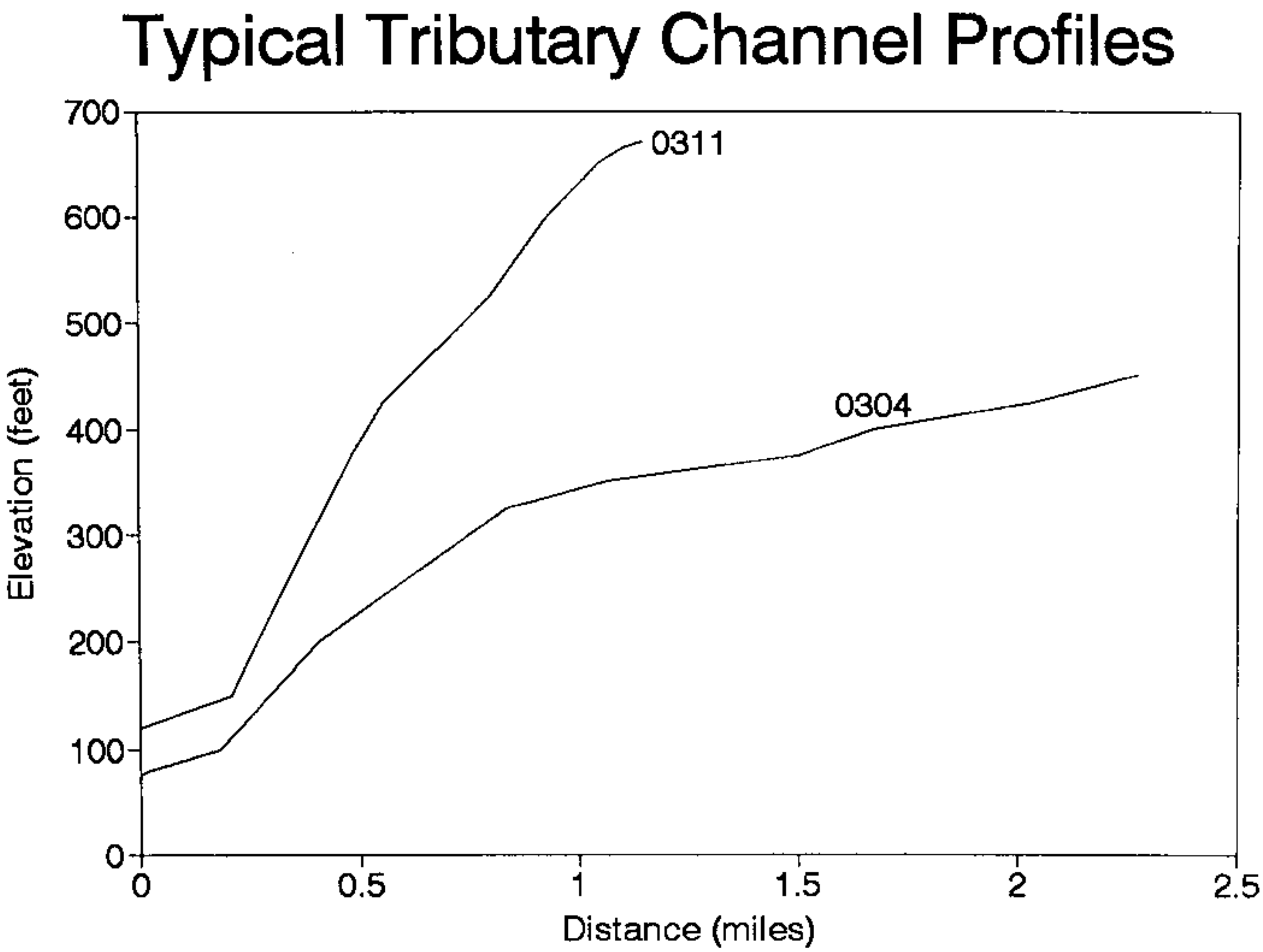
INTRODUCTION

Most erosion problems in the BPA occur in the lower mainstem tributaries that enter the Cedar River downstream from Maple Valley. These tributaries drain relatively impermeable, gently-sloping till uplands that generate substantial amounts of storm runoff. From the uplands, the tributaries descend 200 to 300 feet down the steep sides of the Cedar River valley. In the 14,000 years since deglaciation and the formation of the Cedar River valley, the larger streams have flattened their gradients to as low as 3% by cutting deep ravines that extend as much as a mile into the plateau. The smaller streams are much shorter and steeper, with gradients of 15 to 35%. Despite their steep gradients, it is likely that natural erosion rates were low and that all but the steepest of these channels had densely vegetated, generally stable banks prior to logging and development of the Cedar River Basin.

Most lower Cedar River tributaries have experienced significant increases in the size and frequency of floods capable of moving sediment, resulting in accelerated channel-erosion rates that greatly exceed natural rates. The largest flow increases have occurred in the high-density, developed lower end of the valley. The severity of channel erosion correlates well with these development-induced flow increases (see *Tributary Channel Response to Hydrologic Change*, below) and with the geologic and topographic conditions typical in this part of the BPA. These conditions were recognized prior to preparation of this basin plan and resulted in designation of the "West Cedar River Valley Ridge Critical Drainage Area" in 1989 by King County SWM. This designation imposes enhanced levels of onsite detention for all new development that drains over the steep western sideslopes of the Cedar River valley between Maple Valley and the upper Elliot Bridge (about River Mile (RM) 14.2 through RM 9.8 on the Cedar River mainstem), covering Tributary 0334A and numerous unnumbered drainages and valleys.

Upstream from Maple Valley, channel-erosion problems are rarer and less severe. This is a consequence of less intense urban development, gentler slopes, and moderation of floods and channel erosion by the permeable outwash soils on the upland plateau in this part of the BPA.

Figure 5-1



Typical Tributary Channel Profiles
700
600
500
400
300
200
100
0
Elevation (feet)
0311
0304
0
0.5
1
1.5
2
2.5
Distance (miles)

LOWER CEDAR RIVER TRIBUTARIES

Tributaries to the lower Cedar River downstream of Maple Valley typically display a three-part profile with a steep middle section between two low-gradient sections, as shown in profiles of two typical tributaries (Figure 5-1). The tributaries originate on gently-sloping plateaus above the Cedar River valley, with typical gradients of less than 2%. Near the plateau edge, they enter ravines that rapidly enlarge and steepen downstream once they incise into the erodible sands and clays beneath the capping layer of till. Virtually all channels within the ravines show evidence of some downcutting and accelerated sediment production. These changes have occurred in response to increased flows, and due to a lack of the large woody debris (LWD) that normally stabilizes channels in an undisturbed system. Upon reaching the valley floor, channel gradient drops abruptly and the streams deposit most of their sediment load prior to reaching the Cedar River. This sediment clogs drainage ditches and stream channels and adds to existing alluvial fans. Sediment ponds have been installed at the mouths of many of these channels in an effort to protect residences built on alluvial fans.

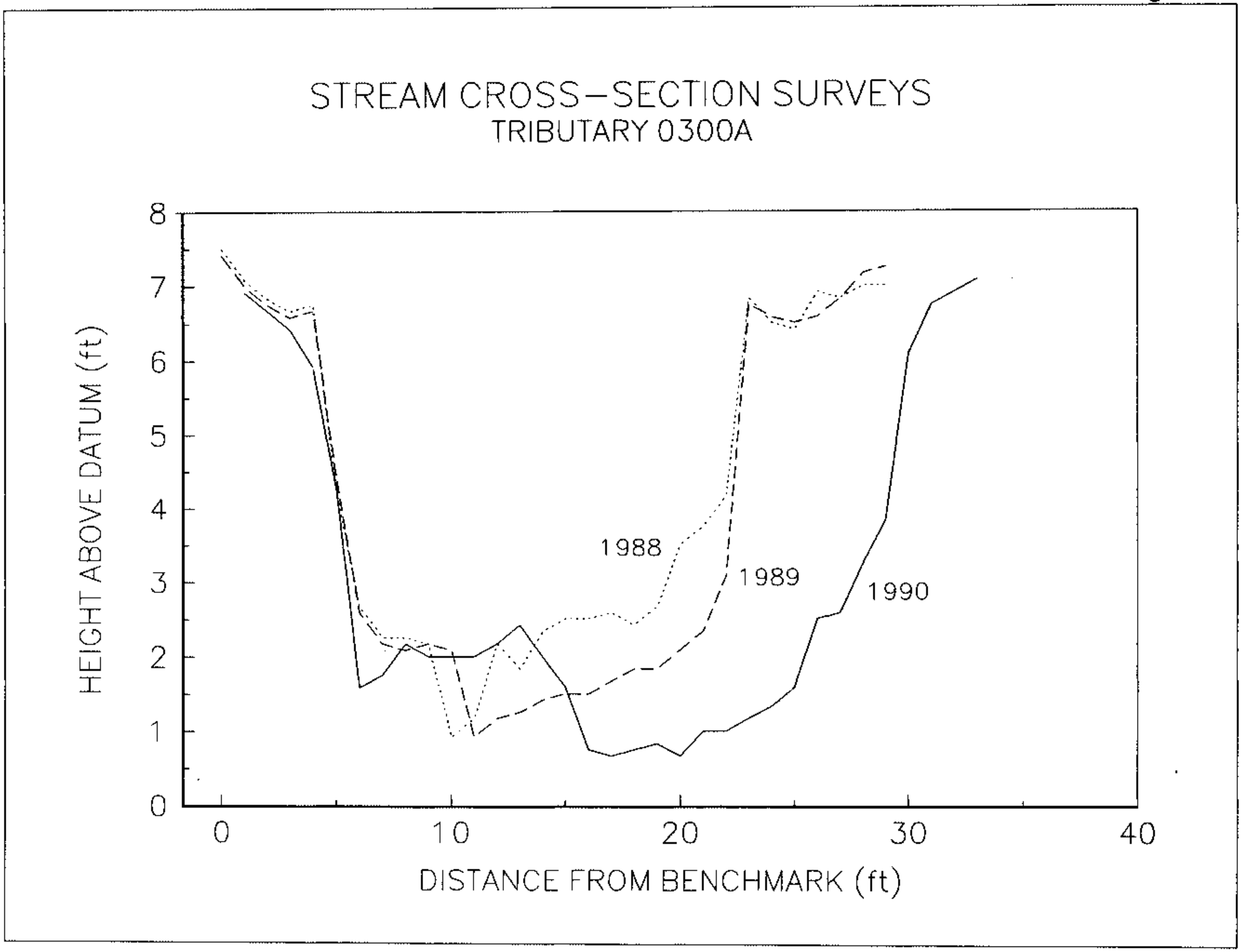
Conditions in the lower Cedar River tributaries are discussed in the remainder of this section. By convention, "right" and "left" in the following descriptions apply to the banks while facing in the direction of water flow (i.e., downstream). Refer to *Appendix A* for a listing of specific problem sites and to *Appendix B* for maps showing locations of the most significant problems.

Small, Steep, Valley-Side Tributaries Downstream of Maple Valley (see Map 18)

These include Tributaries 0301, 0311 (Summerfield Creek), 0312, 0313, 0314, 0315, 0334A, as well as at least 6 unnumbered channels with known erosion problems (see *Appendix A*). These streams, which flow down the steep, forested sides of the Cedar River valley from Renton to Maple Valley, have small drainage areas (less than 150 acres) and hence relatively low discharges, but due to their steep slopes these channels are marginally stable so that even slight increases in runoff from upslope development have caused rapid channel incision and numerous slope failures. Sediment fans at the mouths of many of these tributaries indicate a long history of erosion and sediment deposition,some of it pre-dating human disturbance.

The most severely eroded small tributaries are located on the south valley wall: 0334A, 0311, 0313, and an unnumbered tributary at RM 8.0 (old Indian Coal Mine, behind the former King County shops). Incision and widening (locally in excess of 10 feet) have destabilized the ravine walls and caused numerous landslides along virtually the entire lengths of these four tributaries. In 1990 debris flows occurred on two of these (0311 and 0334A). Large sediment deposits have repeatedly damaged buildings and roads located on the alluvial fans at the mouths of these channels, leading to construction of a sediment basin on 0311 and diversion of drainage into pipelines on 0334A and 0311.

Figure 5-2


STREAM CROSS-SECTION SURVEYS
TRIBUTARY 0300A
HEIGHT ABOVE DATUM (ft)
DISTANCE FROM BENCHMARK (ft)
1988
1989
1990
0
1
2
3
4
5
6
7
8
0
10
20
30
40

Erosion and deposition problems have occurred on most of the other small tributaries listed above on a smaller scale. These eroding tributaries all receive concentrated surface runoff from developments or other drainage alterations in their source areas, except Tributary 0313. Tributary 0313's instability may date back to the 1930s when a debris flow reportedly occurred shortly after the area was logged. Of the numbered channels listed above, only channels 0301, 0312, and 0315 are generally stable, although 0315 has one small, steep fork that is destabilized and eroding. Although 0301 has development in its headwaters, it appears to convey very little flow and is partly underlain by bedrock. The catchments of 0312 and 0315 are largely undeveloped, and 0312 has a relatively gentle slope (9-13%). Judging by the effects of runoff increases on other small steep tributaries, flow increases from future development could destabilize Tributaries 0312 and 0315 as well as numerous other unmapped small channels that descend the slopes of the Cedar River valley. This would lead to additional sediment deposition problems on the valley floor.

Tributary 0300A (Ginger Creek: see Map 19)

Ginger Creek and its neighboring small Tributary (0301) are the only tributaries to the Cedar River that flow over bedrock. Erosion on Ginger Creek is less severe than would be expected given the extremely high-density development in its catchment because half of its drop down to the Cedar River is in the form of bedrock falls. Moderate incision (1 to 4 feet) has occurred where the channel is underlain by till from RM 0.45 to 0.6 and from RM 0.3 to 0.4, and severe incision and widening occur only in a short reach of gravelly pre-Fraser sediments between RM 0.3 and the bedrock falls at RM 0.2. Downstream from the falls, only a few feet of alluvium overlie bedrock, which serves as a grade control and limits incision. Repeated surveys of a cross-section about 100 feet upstream of the mouth of the creek showed eight feet of widening and two feet of downcutting occurred between 1988 and 1990, by which time bedrock was exposed in most of the channel bottom (Figure 5-2). In contrast to other tributaries, sediment from this steep creek does not deposit on an alluvial fan but directly enters the Cedar River, which flows against the valley wall at the creek mouth. For this reason, the creek probably delivers more gravel to the Cedar River than any other tributary downstream of Maple Valley.

Tributary 0302–0303
(Maplewood Creek: see Map 20)

Also extensively developed, the upstream 0.2 miles of the east and west fork ravines of Maplewood Creek show evidence of recent, extensive incision and widening (Figure 5–3). In the downstream part of the west fork (RM 0.9–1.2), extensive landsliding of ravine sidewalls in glaciolacustrine silt and overlying outwash deposits is occurring as banks adjust to past incision. Landsliding probably occurred in this reach prior to development, but has likely been exacerbated by recent downcutting. Maplewood Creek is relatively stable downstream from the east fork confluence, with some depositional zones and only localized bank erosion. Several culverts high on the ravine sides have eroded large gullies that are major localized sources of sediment (Figure 5–4).

Figure 5–3 Photograph of incised reach of Maplewood Creek, RM 1.3.

Most of the coarse sediment from Maplewood Creek is trapped in ponds at RM 0.5 and 0.6, which filled up completely during the November 1990 floods.

Figure 5–4 Photograph of ravine eroded by a daylighted culvert, Maplewood Creek.

Tributary 0304 (Molasses Creek: see Map 21)
Molasses Creek is relatively stable despite its high level of development. Scattered bank erosion and numerous landslide scars on the ravine walls between RM 0.65 and 0.8 are probably a consequence of channel widening in response to past incision. No evidence of recent incision was noted except in the alluvial fan near the mouth of Molasses Creek. Downcutting of the channel appears to have been limited by an abundant supply of coarse sediment from landslides and eroding banks upstream from RM 0.65 and the presence of abundant large woody debris (LWD) in the steepest part of the channel (RM 0.2–0.4).

Tributary 0305–0306 (Madsen Creek: see Map 22)
The mainstem and west fork of Madsen Creek have experienced the most dramatic incision within the basin. Runoff from high-density development of subdivisions in the 1960s and 1980s and installation of a sewer line down the creek in 1974 have contributed to severe destabilization of the channel. In the past 26 years, over 15 feet of downcutting has occurred on the west fork of the creek where two gas lines, formerly buried below the creek bed (Tributary 0306, RM 0.05), are now suspended about 6 to 15 feet in the air (Figure 5-5). The pipelines were first exposed during two large storm events in 1990, when over 10 feet of the downcutting is estimated to have occurred (CH2M Hill, 1991). The incision caused substantial channel widening and numerous landslides on the west fork, threatening the sewer line and a house on the bank. This led to construction in summer 1992 of an emergency channel bypass pipeline. Although incision is presently less severe on the east fork of Madsen Creek than the west fork, a knickpoint (an abrupt, vertical step in the channel profile) near the bottom of the east fork could migrate upstream and destabilize that channel further.

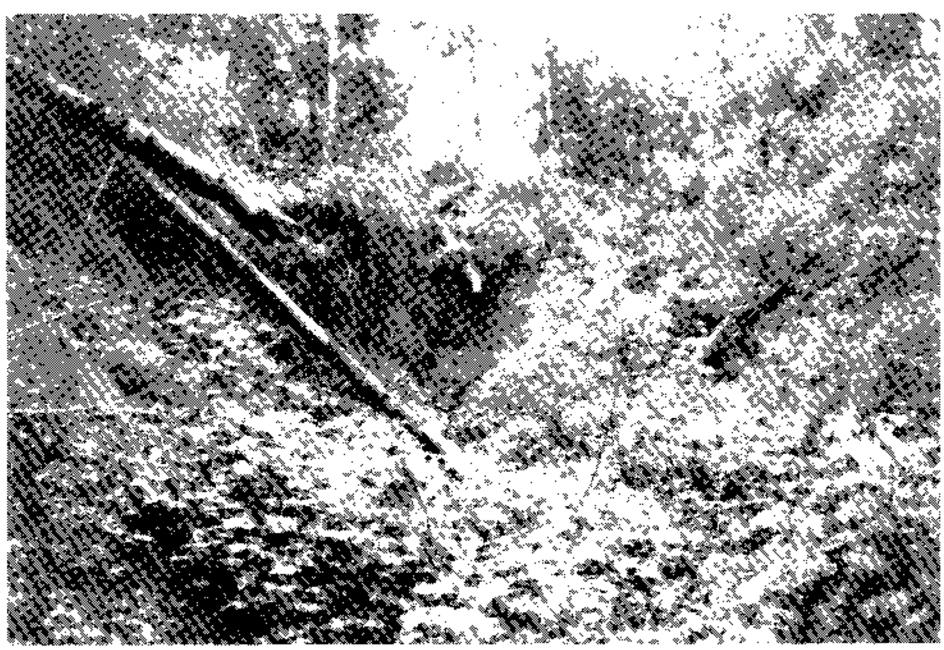
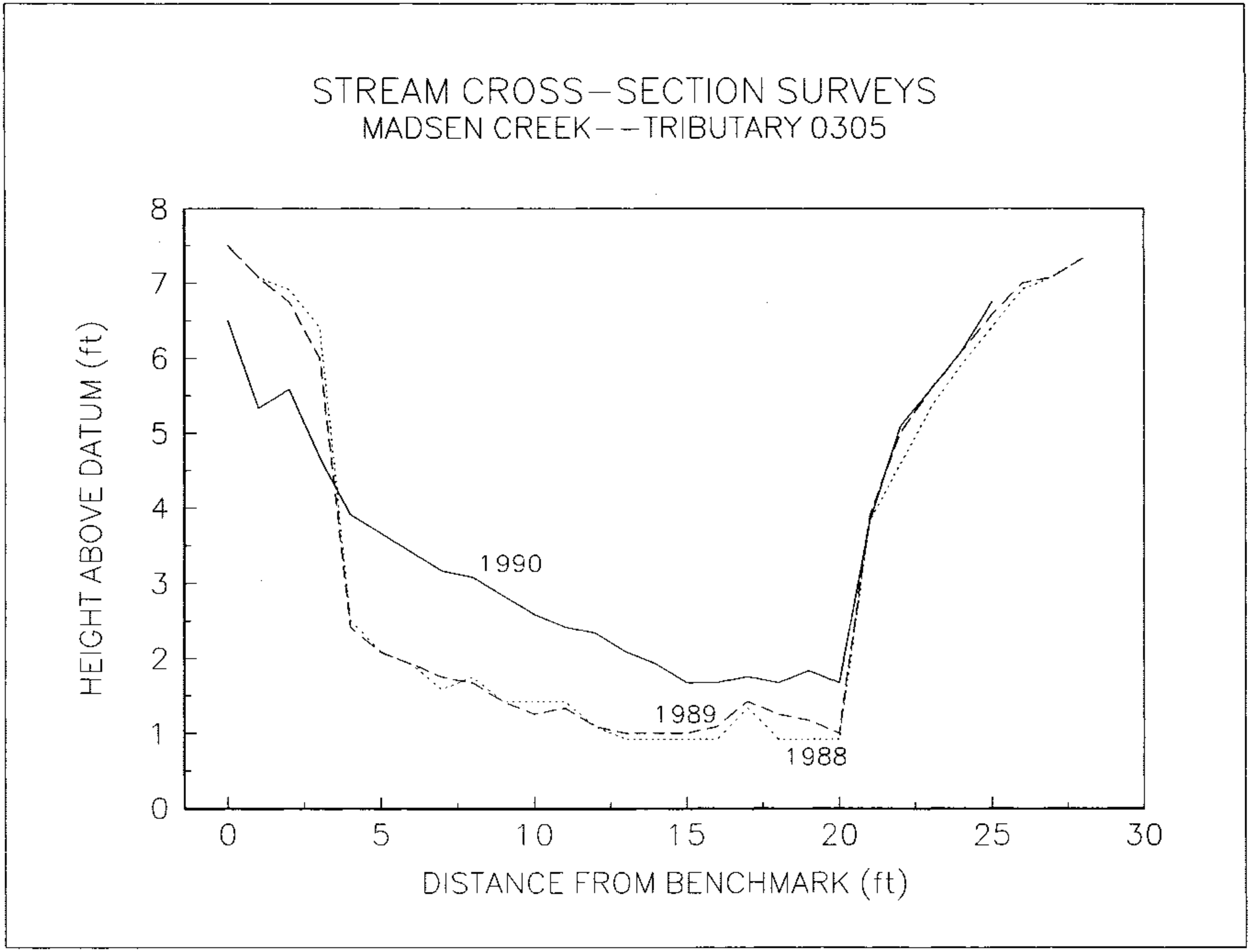


Figure 5-5 Photograph of incised reach of the west fork of Madsen Creek, RM 0.05. The suspended gas pipes were originally buried below the creek bed.

Figure 5-6


STREAM CROSS—SECTION SURVEYS
MADSEN CREEK——TRIBUTARY 0305
HEIGHT ABOVE DATUM (ft)
DISTANCE FROM BENCHMARK (ft)
1990
1989
1988
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30

Downstream from the confluence of the two forks (RM 1.55), Madsen Creek has incised through its floodplain, which is now stranded above the flood level as a 6- to 15-foot-high terrace. The lower Madsen Creek valley is quite wide, incision has occurred largely within the floodplain so that landslides have occurred only in a few locations where the creek impinges on the valley wall. In addition, lateral erosion has exposed and undermined a sewer line in a number of places. Coarse sediment eroded from upstream is deposited in the downstream part of the canyon. At a cross-section established in 1988 approximately 460 feet upstream (RM 0.9) from the sediment pond, the channel was stable in the low-flow water year 1989 but experienced over one foot of aggradation in water year 1990 (Figure 5-6) as well as erosion of one bank. Up to three feet of sediment deposition reportedly occurred in the lower valley and a sediment pond at the mouth of the valley (RM 0.8) filled with sediment during floods of water year 1991. The sediment pond traps gravel and some sand, but passes fine sand and silt downstream. Downstream from the pond, fine sediment from Madsen Creek has, in places, completely filled in a channel designed for fish habitat enhancement. Some fine sediment from Madsen Creek continues downstream and into the Cedar River.

Further channel incision could occur on the mainstem of Madsen Creek if flows are not reduced. If not stabilized, existing knickpoints from past incision will proceed upstream in both forks, exacerbating bank instability. Even if the knickpoints are controlled and further incision is prevented, the oversteepened side slopes of the west fork (Tributary 0306) will retreat back substantially before stabilizing. Accelerated erosion and high rates of sediment production are therefore likely to continue for many years.

Tributary 0307 (see Map 20)

Channel enlargement has undercut the banks of this ravine and contributed to numerous shallow bank failures between RM 0.4 and 0.5; in 1992 a crib wall was constructed at the toe of the left bank (looking downstream) in this area in an attempt to prevent damage to Orting Hill Road. Runoff from culverts along 154th Place SE has caused surface erosion in at least three locations, but this is relatively minor compared to stream-induced landsliding. Sediment and debris have clogged the catch basin at the RM 0.2 culvert inlet and caused flooding of the road during large storms.

Tributaries 0308-0310 (see Map 23)

This steep system is fairly stable, probably due to relatively small flow increases in the subbasin. Although some channel enlargement has taken place, banks are generally stable and well-vegetated. Tributary 0309 shows evidence of one to two feet of incision and contains a short, severely eroding reach with an active knickpoint near RM 0.2. The mainstem channel (0308) is lacking in LWD and pool-riffle structure and appears to be conveying significant amounts of coarse sediment downstream. At the mouth of the creek, the gradient at Tributary 0310 flattens abruptly, which has caused sediment to plug culverts and fill in the channel during major floods. SWM staff were unable to identify any sites of accelerated channel erosion on Tributary 0310, suggesting that the sediment deposits result from background (natural) rates of erosion, perhaps accelerated by the low channel roughness.

Tributary 0316A (see Map 24)

In the section of channel south of Cedar Grove Road, this moderate-gradient channel appears stable and no erosion problems were observed, although steep, riprapped banks below the road attest to past bank erosion. Flows are low and have increased relatively little in this outwash-underlain basin with little development. Upstream of Cedar Grove Road, there is severe gully erosion where the channel passes through disturbed quarry soils (see *Chapter 6: Water Quality*). Some sediment eroded from this part of the channel passes downstream and is deposited where the channel gradient flattens (approximately RM 0.1).

Tributary 0317 (Webster Lake: see Map 24)

This subbasin has experienced almost no increase in flows due to its low level of development, permeable outwash soils, and flood storage provided by Francis Lake and a gravel pit. Only slight, discontinuous erosion with no more than one foot of incision was observed in the steepest section of this small creek.

Tributary 0328 (Peterson Creek: see Map 26)

Peterson Creek drains a large upland area and is unique in that it flows southeast, in the opposite direction from the Cedar River. The creek's flows are moderated by numerous lakes and wetlands, and the channel only becomes unstable downstream from RM 0.7 where it steepens and cuts below the Vashon till into older deposits. Erosion is particularly severe between RM 0.4 and 0.6, with continuous bare, steep banks and numerous bank failures. Distorted strata in the landslide scars reveal a long history of landsliding, and it is not clear to what extent the present conditions exceed pre-development background levels of landsliding. Based on evidence of active channel incision both upstream and downstream of this reach, it is likely that the historic landsliding rate has been accelerated by recent downcutting. Although stability improves as the valley widens downstream of RM 0.4, large landslides have occurred in three locations where the creek abuts the valley wall. Peterson Creek has a high sediment load and is one of the larger tributary sources of coarse sediment to the lower Cedar River.

Five short tributaries enter Peterson Creek from the northeast between RM 0.6 and 1.5. These tributaries drain low-density residential developments and the three that were inspected (0330, 0331, and 0333) show up to several feet of incision. Although the coarser sediment eroded by these channels drops out on the gentle slopes adjacent to Peterson Creek, the finer sediment contributes to turbidity and suspended load of Peterson Creek during storms.

Tributaries 0320 to 0327 (Taylor Creek Subbasin: see Map 27)

Taylor Creek (0320) has a lower gradient (1-3%) than the other lower Cedar River tributaries, as well as a relatively low degree of development and increased storm runoff. Consequently, erosion problems are commensurately less. Even in the most severely eroding part of the creek (RM 1.25 to 1.6), areas of active bank erosion comprise less than 10% of the bank length, and observations suggest that no more than one foot of downcutting has occurred in recent years. Although erosion problems in this channel are minor compared to other streams in the basin, they nonetheless generate enough sediment to be problematic in the lower reaches of the creek. In these reaches the gradient decreases dramatically and sediment drops out, filling the channel and increasing frequent flooding problems along Maxwell Road SE (*Chapter 4: Flooding*). Some minor channel incision has occurred on Tributary 0322, although most of the eroded sediment is probably trapped by obstructions and does not reach Taylor Creek.

MIDDLE CEDAR RIVER TRIBUTARIES

Tributaries to the Cedar River from Maple Valley to Landsburg drain catchments underlain primarily by recessional outwash deposits. Runoff rates are generally lower than in the lower basin because of the permeable soils and gentle slopes, and drainage density is larger (i.e., there are fewer streams per area of basin). Development is currently less dense and less extensive than downstream of Maple Valley, and flow increases are commensurately lower. The two natural tributaries that drain into this section of the Cedar River have few erosion problems; however the manmade Walsh Lake Diversion channel has severe incision and erosion problems.

Conditions on these upper mainstem tributaries are discussed in the remainder of this section. Refer to *Appendix A* for a listing of specific problem sites and Map 25 for a map showing locations of the most significant problems.

Tributary 0336 (Maple Valley: see Map 25)
The banks of this stream are generally stable and vegetated, but some channel enlargement has occurred and the channel generally lacks structure. Localized zones of minor incision were observed in the steepest reaches. Bank erosion and lateral shifting occur downstream of RM 0.2 where the stream's coarse sediment load drops out in a fan.

Tributary 0341 (Walsh Lake Diversion Channel: see Map 25)

Due to the poor water quality of Walsh Lake, this channel was constructed by the Seattle Water Department in the mid-1920s to divert outflow from the lake to enter the Cedar River below the intake at Landsburg. The diversion ditch maintained a gentle gradient in its upper part, then dropped steeply to the Cedar River some 170 feet below. Flows in the ditch cut down rapidly through recessional outwash and underlying older glacial sediments and formed a canyon that is still actively eroding 70 years later. The deepest parts of the canyon are 25 feet wide and have 30- to 40-foot-high vertical walls lined with bank failures. Upstream of RM 0.5, the canyon becomes progressively less deep and the walls are somewhat stabilized and vegetated. The canyon culminates at approximately RM 0.6 in a 6-foot-deep ditch. Numerous knickpoints in the channel are likely to progress up the canyon in the future, potentially destabilizing banks in presently stable areas. Sediment from the eroded canyon has formed a large fan below RM 0.2 and has delivered large amounts of coarse sediment to the Cedar River.

Tributary 0338-0339 (Rock Creek: see Map 25)

No erosion problems were observed on this relatively undeveloped, low-gradient stream.

TRIBUTARY CHANNEL PROCESSES

Tributary Channel Response to Hydrologic Change

Prior to development, stream channels in the Cedar River Basin were generally in equilibrium with the size of the floods they conveyed. Each channel adjusted its width, depth, and substrate size so that it maintained stability while at the same time transported its sediment load. Although relatively small, frequent floods (recurrence intervals of one to two years) have been found to transport most of a stream's sediment load over a period of time, several studies indicate that it is somewhat larger, less frequent floods (recurrence intervals of 5 or more years) that shape a channel's form (e.g., Carling, 1988). These larger floods are capable of removing the larger particles (cobbles, boulders, and LWD) that armor the bed and form structural elements of the channel.

Urbanization of a watershed increases not only the magnitude of flood peaks but also the frequency and duration of channel-forming discharges. When flows capable of altering channel form occur more often and last longer, erosion will occur until the stream forms a larger channel that is adjusted to the new flood regime. Channel enlargement often results in a loss of structural elements, leading to long reaches of riffles or cascades with few pools and steps (see *Chapter 7: Aquatic Habitat*). In extreme cases, the channel becomes destabilized and a much larger channel forms that is out of equilibrium, even with the new flow regime. The rapidity and severity of a stream's response will depend upon the magnitude of the flow increases, the total energy available for erosion, and erodibility of the channel.

Flood frequency under forested and current conditions for Cedar River tributary subbasins was modeled with the HSPF program (*Chapter 3: Surface Water Hydrology*). Selected changes in flood frequency are shown in Table 5-1 for all the major tributary subbasins, as well as for two smaller catchments where flow increases or stability differ between two forks of a stream system. The discharge of the 10-year flood (defined as the flow with a 10% probability of occurring in any given year) has increased slightly (10-40%) in the less-developed subbasins (e.g., Taylor Creek), but has doubled or tripled in the most densely-developed subbasins (e.g., Madsen Creek). In one-third of the modeled subbasins, the former 10-year flood now recurs more frequently than every two years. In two-thirds of the modeled subbasins, the former 5-year flood flow (about 20% smaller than the 10-year flood) now recurs every two years or more frequently.

Table 5-1 Changes in Flood Frequency for Major Subbasins

#	Channel Name	Forested Q10 (cfs)	Current Q2 (cfs)	Current Q10 (cfs)	Current Q10/ Forested Q10	Current Q2/ Forested Q10	Channel Stability
0341	Walsh Lk. Ditch	9*	79	103	11.9	9.00	unstable
0300	Ginger Creek	35	63	101	2.9	1.80	unstable
0305	Madsen	96	132	217	2.3	1.38	unstable
0304	Molasses	72	96	153	2.1	1.33	enlarging
0302	Maplewood	42	51	81	1.9	1.21	unstable
0307	Orting Hill	56	54	93	1.7	0.96	unstable
0308	Cedar Grove	65	59	92	1.4	0.91	enlarging
0316	Cedar Hills	9	8	13	1.4	0.89	stable
0320	Taylor Creek	132	108	167	1.3	0.82	enlarging
0310	E.F Cedar Grove	27	22	34	1.3	0.81	stable
0322	NF Taylor Creek	34	26	42	1.2	0.76	enlarging
0317	Webster Lake	7	5	8	1.1	0.71	stable
0338	Rock Creek	246	172	285	1.2	0.70	stable
0336	Maple Valley	49	34	56	1.1	0.69	enlarging
0328	Peterson Creek	180	104	218	1.2	0.58	unstable

Table 5-1 also shows a qualitative stability classification of tributary channels in the Cedar

River Basin, based on field observations in 1992. The stability classification and following analysis are based upon the condition of the steeper reaches of each channel—that is, the reaches between the Cedar River valley and the gently-sloping upland. **Stable** channels are those with little or no erosion of their bed or banks. Destabilized channels, in contrast, show evidence of recent, significant expansion of channel dimensions. In particular, **enlarging** channels have discontinuous but locally severe bank erosion, generally less than 2 feet of recent incision, and some evidence of increased sediment load downstream. Fully **unstable** channels have long, continuous reaches with bare, destabilized banks indicative of severe downcutting and widening; typically they also have massive and frequently problematic sediment deposits at their mouths.

Figure 5-7 compares current channel stability with the magnitude of flow increases. The results suggest that Cedar River Basin channels become fully destabilized and rapid erosion ensues when flows increase above a threshold condition. This threshold occurs when the 10-year flood under forested conditions recurs more frequently than every 2 years, corresponding to a "Channel Stability Index" of 1.0 on the y-axis of Figure 5-7; this same index of flow increases has been used previously to discriminate between unstable and relatively stable channels in the Hylebos, East Lake Sammamish, and Lower Puget Sound basins (King County, 1990). The 5-fold increase in frequency of the 10-year forested flood corresponds to a 60 to 70% increase in the magnitude of the 10-year flood (Table 5-1). Two unstable channels whose Channel Stability Indexes are well below 1.0 were not included in this data set: Peterson Creek (0328) had pre-existing, natural landslides and therefore may have been more easily destabilized than other channels, and a drainage diversion contributed to instability of the Summerfield ravine (0311).

Tributary Channel Response to Other Factors

The Channel Stability Index of flow increases does not discriminate well between channels that have remained apparently stable and streams that have enlarged but have not become fully unstable (the "stable" and "enlarging" classes). Channel response appears to be controlled by other factors within this range of smaller discharge increases. Slope and flow magnitude determine the total energy available for erosion, while geology, large woody debris, and bank vegetation all influence the erodibility of the channel and adjacent valley walls. These factors all combine to determine which stream reaches will experience accelerated erosion in response to flow increases.

Longitudinal channel gradient directly affects the energy available to a stream for eroding and transporting sediment, and the majority of the unstable channels in the Cedar River Basin have extremely steep gradients (steeper than 10%). Since flow increases were not modeled for these steep streams due to their small drainage areas, the magnitude of flow increase needed to destabilize these streams is unknown. However, it is expected to be significantly lower than the threshold value suggested above by the HSPF-modeled data.

Geologic conditions affect the erodibility of the stream bed and banks, as well as the availability of coarse sediment for armoring the bed and smaller gravels suitable for salmon spawning. Glacial till is the least erodible of the glacial deposits in the Cedar River Basin. Deeply incised channels in till were observed only in creeks with extreme flow increases (Madsen and Ginger creeks). Particularly severe incision and bank erosion were observed in upstream ravine reaches in Vashon advance-outwash deposits, which are noncohesive and contain little gravel for armoring the channel. The lower reaches of most of the tributaries flow through older glacial sediments, primarily sand/gravel and glaciolacustrine deposits, with lesser amounts of till (see Map 5 in *Appendix B*). The sand/gravel reaches typically have wide channels due to a lack of cohesive bank material. In rapidly-enlarging sand/gravel channels, undercutting causes shallow sloughs of bank material. Channels in the glaciolacustrine silts and clays are commonly narrower and deeper due to soil cohesion but have a tendency for large deep-seated landslides. Glaciolacustrine deposits form a barrier to downward movement of subsurface flow, causing landslides in overlying sand or gravel units (e.g., Peterson Creek).

Large woody debris (LWD) tends to be abundant in undisturbed streams, where it forms a major component of channel structure. Logs that fall into the channel tend to trap sediment upstream, locally lowering the gradient and forming a stable, stepped channel profile. The relative stability of Molasses Creek, despite large flow increases, may be due in part to its relatively high LWD loading. Most stream channels in the Cedar River Basin have only low to moderate amounts of LWD, which has contributed to destabilization of the channels. Even where LWD is present, its size is smaller than would occur in an old-growth forest. Where LWD is present in the channel, such as in Rock Creek, depositional zones typically extend upstream for as much as 100 feet, locally trapping sediment and slowing incision. Although bank erosion may occur where a stream erodes around a LWD jam, in most cases the sediment generated by bank erosion is compensated for by increased sediment deposition behind the LWD jam. In the most severely eroding reaches, such as in Madsen Creek, LWD tends to be less effective since incision proceeds so rapidly that logs are left stranded above the channel bottom. (See also *Chapter 7: Aquatic Habitat* for further information on LWD in relation to aquatic habitat.)

The downstream reaches of the larger ravines, such as Maplewood Creek, tend to show less evidence of severe erosion than the upstream reaches, for several apparent reasons. First, these ravines are quite wide and their streams flow primarily through alluvial or colluvial deposits on the valley floor. Channel erosion is less likely to cause landsliding in wide valleys than in narrow ravines, since the stream rarely impinges on the steep valley wall. Second, in its downstream reaches a stream receives sediment from upstream erosion sources, which reduces its ability to erode yet more sediment from its bed and banks. This, combined with decreasing channel gradient near the mouth of the stream, tips the balance from erosion to transport to deposition. Finally, banks in upstream reaches have not had as much time to stabilize as the downstream reaches, since incision tends to move upstream by the migration of knickpoints.

TRIBUTARY CHANNEL STABILITY UNDER FUTURE CONDITIONS

The channel-stability analysis for current conditions indicates that channels in the Cedar River Basin, as well as several other basins in King County, tend to become destabilized when flows increase above a certain threshold (Figure 5-7). This threshold condition is reached when the forested 10-year discharge is increased in frequency so that it now occurs every two years, on average. The threshold is equivalent to a value of 1.0 of the "Channel Stability Index", defined as the current or future 2-year discharge divided by the forested 10-year discharge. A stream channel is likely to become fully unstable and erode rapidly once its Channel Stability Index equals or exceeds a value of 1.0. Channels with Channel Stability Indexes below 1.0 but above 0.6 (the average value for forested subbasins) will in many cases experience channel enlargement and local areas of severe bank erosion, but are unlikely to become fully unstable (i.e., continuous reaches of severe downcutting and widening).

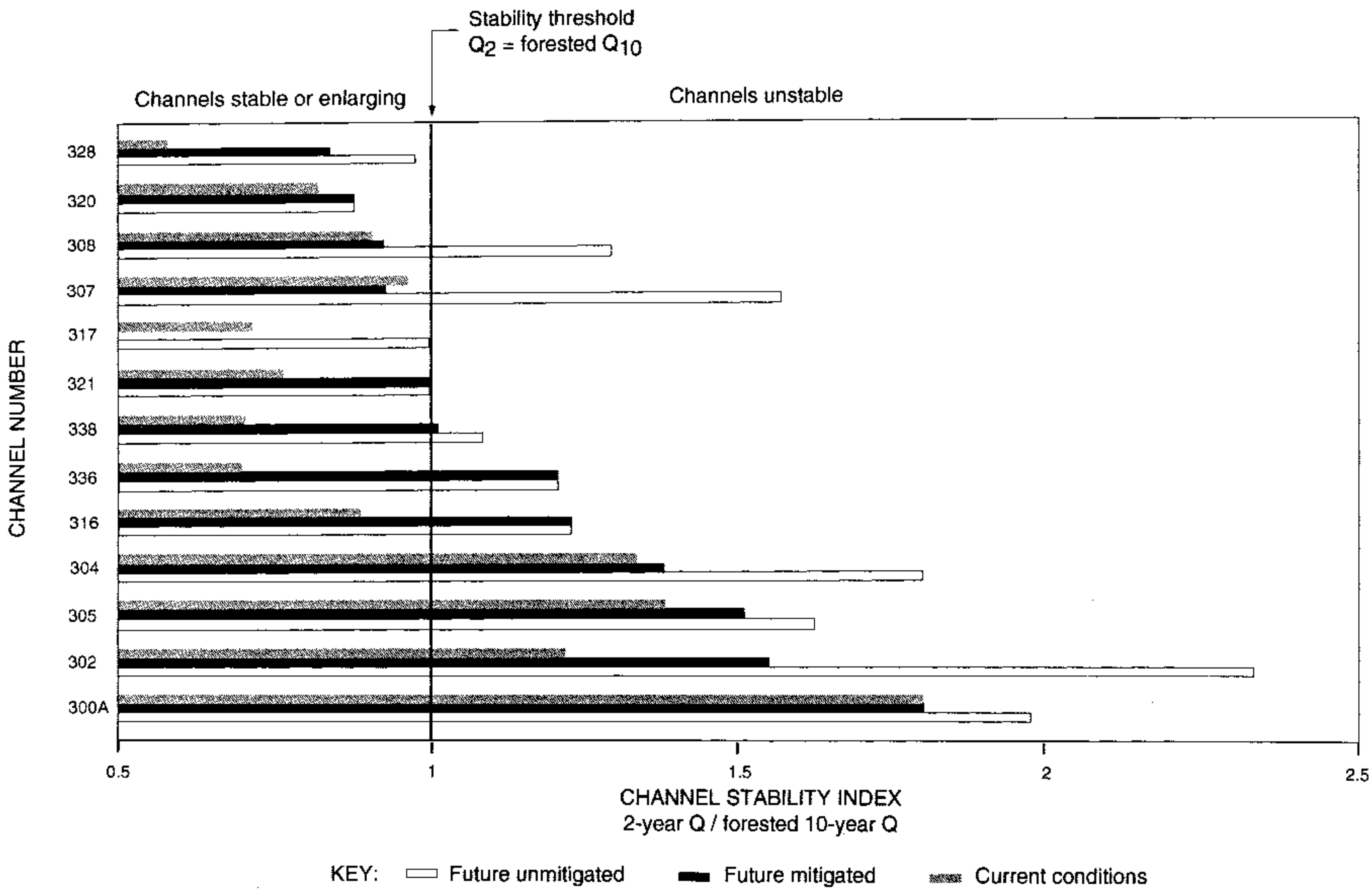
Figure 5-8 shows predicted future Channel Stability Index values for the HSPF-modeled Cedar River subbasins. Future-**mitigated** flows were calculated assuming that retention/detention will be utilized for new high-density and commercial development, including sub-divisions; the future-**unmitigated** flows show the predicted result if no retention/detention standards are required for new development (see *Chapter 3: Surface Water Hydrology*).

New severe erosion problems are likely to develop on steep sections of stream channels whose current Channel Stability Index values are less than 1.0 but whose projected future index values are 1.0 or larger. As shown in Figure 5-8, this is projected to occur for streams in five subbasins: Cedar Hills (0316), Dorre Don (0336), Rock Creek (0338), North Fork Taylor Creek (0321), and Webster Lake (0317). Because of the low-density uses anticipated in these subbasins, standard flow mitigation is not expected to be required. However, the assumed mitigation requirements appear adequate to maintain present channel stability conditions in two subbasins with denser future development: Orting Hill (0307) and Cedar Grove (0308).

Future flow increases were not modeled for the numerous small catchments that drain the steep sides of the Cedar River valley. Many of the ravines that drain these catchments already have severe erosion problems due to their steep gradients. Without mitigation, flow increases from future development would almost certainly destabilize more of these channels in the future. But by analogy with the Orting Hill and Cedar Grove tributaries, those that develop at high densities will probably experience little additional change with adequate detention.

Figure 5-8

Projected Future Changes in Channel Stability Index



5.4 EROSION AND SEDIMENT DEPOSITION IN THE CEDAR RIVER MAINSTEM

EFFECTS OF HUMAN ACTIVITY ON CEDAR RIVER MAINSTEM EROSION AND SEDIMENT TRANSPORT

The Cedar River flows 45 miles from its headwaters on the crest of the Cascade range to its mouth at Lake Washington in the Puget Sound Basin. The general pattern of erosion and sediment deposition in the river is set by the topography of the basin. Sediment eroded from the basin's mountainous headwaters is carried downstream by the river and deposited in the flat-lying Puget Lowland. Although this general pattern remains unchanged, human activities in the river basin have greatly affected the river's form and how it moves sediment from its upper reaches down to the mouth. The City of Seattle's water supply reservoirs in the upper Cedar River Basin have affected water and sediment flow on the river since approximately 1904. Seattle's water-diversion structure at Landsburg (RM 21.0) stores relatively little water and sediment. Upstream at RM 37.0, the much larger dams that impound Chester Morse Lake have significantly reduced the size and frequency of sediment-transporting flood flows. For example, an Army Corps of Engineers (COE) study estimated that under pre-dam conditions the 2-year flood had a discharge of 7,600 cfs, and that this 7,600 cfs discharge now has a 17-year recurrence interval under current dam operating guidelines (Eckman, 1990; see *Chapter 3: Surface Water Hydrology*). The same study estimated that the present 2-year flood has been reduced by 53% to about 3,550 cfs. The modern 100-year discharge may have been little more than the 10-year discharge under pre-dam conditions. The Cedar River has narrowed considerably since the closing of the dams, reflecting this reduction in flood size and frequency. The modern Cedar River is an 'underfit' channel that flows around and between fully revegetated river bars but with insufficient flow to modify them further. In contrast to the change in flows, alteration of the delivery of sediment to the lower basin was probably not greatly changed by dam construction. Cedar Lake was a pre-dam impoundment in the vicinity of the modern Chester Morse Lake that probably interrupted the movement of all coarse sediment since glacial time. Similarly, the Seattle Water Department intake at Landsburg has minimally affected sediment movement, because almost no material is stored in the impoundment area for more than a year at a time.

Channel realignment and reinforcement at the mouth of the Cedar River has dramatically altered the prehistoric pattern of sediment movement and deposition. The Cedar River was diverted in 1912 into the south end of Lake Washington, which now drains west to Puget Sound through an artificial channel (Chrzastowski, 1983). Prior to these diversions, the Cedar River flowed into the Black River, which carried outflow from Lake Washington southwest to the Green River (Map 9 in *Appendix B*). Only a small amount of flood water from the Cedar River flowed north into Lake Washington. The 1912 channelization extended the Cedar River one mile north to Lake Washington and also stabilized and straightened a mile-long reach of existing river channel. The Black River dried up due to lowering of Lake Washington in 1916, and its former course has largely been filled in. These alterations have promoted sediment deposition in the Renton Reach of the river, discussed below under *Bedload Transport of Sediment by the Cedar River*, section 5.5.

More recent changes have also affected erosion and sediment deposition on the Cedar River. Revetments constructed along riverbanks have reduced sediment input from eroding banks, reduced channel migration, and reduced the river's ability to store sediment on its floodplain. Land-use changes have increased the amount of sediment delivered to the river by some tributary streams within the BPA, although these stream inputs remain relatively minor compared to other sources of sediment to the river (see *Sediment Sources to the Cedar River*, below).

CHANGES IN CHANNEL PATTERN AND CHANNEL MIGRATION

The Cedar River has undergone major changes in its channel pattern and its ability to migrate across its floodplain since the turn of the century. These changes were caused by the combined effects of reduced flood flows due to regulation at the dam, construction of revetments, and channelization near the mouth of the river.

Mapping Changes in River Position

To investigate these changes in channel pattern, the river positions shown on an 1865 survey map and on 1936 aerial photographs were compared with the present river position. Tracings of the active river channel from these sources were scaled to a 1:12,000 base map compiled from recent USGS topographic maps, by matching section corners and landmarks such as roads and railroad tracks. Although this procedure accurately scales the size of the historic river channels, in some cases the placement of the channels on the maps is questionable due to distortion. The rectified maps were then digitized and entered into the CADD database. Aerial photographs were used to update the river channel shown on the base map to 1989 conditions in several locations where the channel had obviously changed course. The resulting maps of the 1865, 1936, and 1989 river channels are shown in Map 9. Channel length and area for each reach of the river were digitized from the completed maps, and average channel widths were computed by dividing channel area (excluding vegetated bars) by length. Channel area and width for 1936 and 1989 maps are for the mapped active channel, which includes unvegetated gravel bars. The definition of river edge used by the surveyors of the 1865 map is unknown, but because they mapped mid-channel bars in detail it seems likely that the wide river channel that they mapped includes gravel bar areas, and hence is comparable with our definition of active channel.

Spot comparisons of the base map and the 1989 photographs showed that the "1989" river width shown on the base map, obtained from USGS topographic maps, varies from the active channel width on the aerial photographs by 5 to 38%, with no systematic error. No attempt was made to adjust the 1989 channel width shown on the base map, but widths and areas measured from the 1989 channel on the base map were adjusted to correct for errors in the base map.

Results — Changes in Channel Pattern

Table 5-2 and Map 9 show that the Cedar River has narrowed dramatically. The historic changes in river width and pattern are too great to be explained by possible mapping error. Figure 5-9 shows average changes in channel area, degree of braiding, and extent of revetments for the entire length of river between Renton and Landsburg. The total area of active river channel, including side channels large enough to show on the base map, decreased from 620 acres in 1865 to 270 acres in 1989 (see *Chapter 7: Aquatic Habitat* for the effects of these reductions in channel area and complexity on habitat).

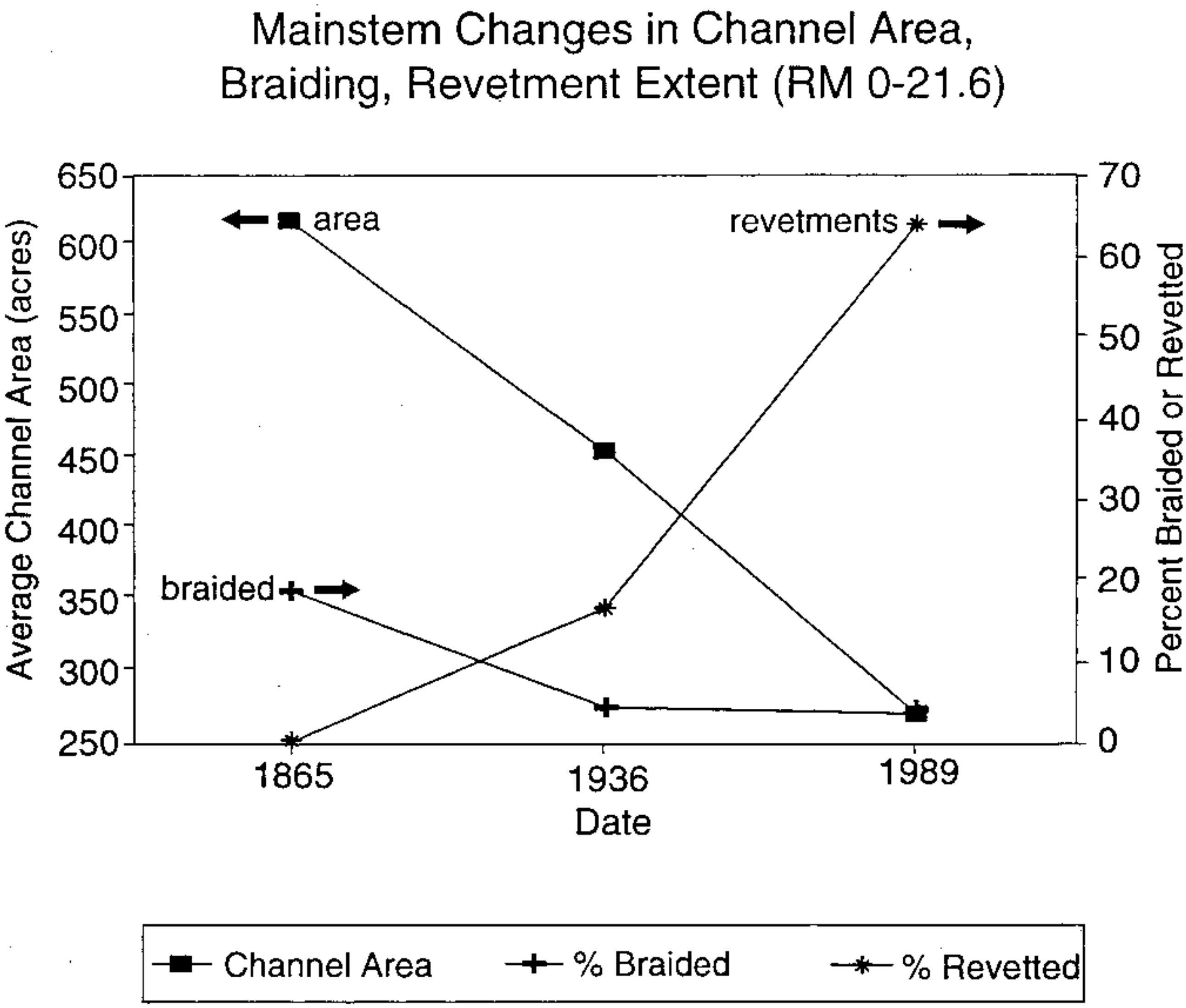
Table 5-2 Historic Changes in Cedar River Channel Pattern

Reach†	From RM	To RM	Average Channel Width (ft) ††			% of Channel Braided †††		
			1895	1936	1989	1865	1936	1989
A	0.0	1.6	200	130	130	0%	0%	0%
B	1.6	4.2	250	170	100	0%	0%	0%
C	4.2	5.8	260	220	110	67%	31%	0%
D	5.8	10.0	220	250	110	14%	0%	2%
E	10.0	13.8	460	160	120	73%	0%	13%
F	13.8	15.0	210	150	120	0%	0%	5%
G	15.0	16.8	230	170	80	32%	14%	0%
H	16.8	21.7	180	120	90	0%	4%	6%
Total A-H	0	22	250	170	110	18%	5%	5%

† See Map 9 for reach locations
†† Summed width of all channels, in braided reaches
††† Includes only channels separated by vegetated bars

Much of this lost area was in broad gravel bars, which held as much as 1 to 3 million cubic yards of sediment in temporary storage. Currently, the channel over the same reach covers only about 270 acres and the thickness of active sediment storage is much reduced; probably less than 20% of the historic sediment volumes of this reach are still in temporary storage. Between 1865 and 1936, average channel width decreased 32% from 250 to 170 feet. Much of the 1865-1936 width decrease corresponds to a change

Figure 5-9


Mainstem Changes in Channel Area,
Braiding, Revetment Extent (RM 0-21.6)
650
600
550
500
450
400
350
300
250
Average Channel Area (acres)
70
60
50
40
30
20
10
0
Percent Braided or Revetted
area
revetments
braided
1865
1936
1989
Date
Channel Area
% Braided
% Revetted

from a braided river pattern, with multiple channels, to a sinuous, generally single-thread pattern; however, single-thread reaches also became narrower. After 1936, the river channel narrowed an additional 35% to its present average width of 110 feet. From aerial photographs, it appears that most of the narrowing took place by 1970 and was accomplished by growth of vegetation on formerly active gravel bars as well as abandonment of braid channels in several reaches. It is interesting to note that although the 1912 channelization decreased the width of the Renton Reach (Reach A) to narrower than the rest of the river, subsequent narrowing of the rest of the river has now made Reach A the widest reach.

Causes of Channel Changes

With the exception of the Renton Reach (Reach A), which was channelized in 1912, very few revetments had been built on the Cedar River by 1936 (Table 5-2). The river's decrease in width and reduction in braiding from 1865 to 1936 therefore cannot be attributed to construction of revetments. Instead, it appears to be a consequence of the reduction in flood flows by the water-supply dams upstream, which were constructed between 1902 and 1914. By eroding or depositing sediment on their bed and banks, river channels constantly adjust their dimensions to most efficiently transport their water and sediment load downstream. In particular, channels typically are sized to carry a flood with about a 1.5- to 2-year (bankfull flood) recurrence interval. The Army Corps of Engineers' flood frequency curves for natural and post-dam conditions on the Cedar River indicate that the dams have reduced the 1.5-year flood discharge by 60% (Eckman, 1990; see *Chapter 3: Surface Water Hydrology*). Measurements on numerous river systems have shown that as discharge increases downstream, channel width increases proportional to about the square root of the discharge of the bankfull flood (e.g., Leopold and Maddock,1953; Osterkamp and Hedman, 1977). Using this relationship between bankfull discharge and width of single-thread channels, one would expect regulation by the dams to reduce the width of single-thread channel segments of the Cedar River by about 36%. The three river reaches that were not braided in 1865 (reaches B,F, and H) had by 1936 decreased in width by about 28 to 33% (Table 5-3). This suggests that the river had mostly completed its adjustment to regulation of flows by 1936, and that the large reduction in width that occurred after 1936 had other causes.

River channels tend to become narrower during periods between major floods, but this is normally balanced by widening when banks erode during floods. The wide, active gravel bars visible in the 1936 photographs probably formed during the 1933 flood (6,440 cfs). If conditions remained the same, one would expect the slightly larger flood in 1975 (6,860 cfs) and the much larger flood of 1990 (10,200 cfs) to result in a wide channel similar in nature to the 1936 channel. Although bank erosion and widening did occur locally during the 1975 and 1990 floods, by and large the river remained narrow.

Table 5-3 Cedar River Revetments (See Map 9 for reach locations)

Reach	River Miles		% Length of Channel with Revetment †		
	from	to	1865	1936	1989
A	0.0	1.6	0	100	100
B	1.6	4.2	0	11	63
C	4.2	5.8	0	6	72
D	5.8	10.0	0	10	69
E	10.0	13.8	0	13	79
F	13.8	14.8	0	0	45 ††
G	14.8	16.6	0	0	70
H	16.6	21.7	0	12	37 ††
Total A-H	**0**	**21.7**	**0**	**16**	**64**

† Revetment along at least one bank
†† River abuts bluffs of glacial deposits in many locations where revetments are not present

The most likely explanation for the post-1936 narrowing of the channel is the building of levees and revetments (armored banks), together with filling of the floodplain in a few locations (RM 1.9, 3.8, 8.4). With the exception of the Renton Reach, less than 10% of the length of the Cedar River was revetted in the 1930s. Presently, 64% of the length of the river has a revetment along at least one bank (Table 5-3 and Map 10 in *Appendix B*). Most of these revetments were constructed between 1960 and 1970 (Edmondson and Abella, 1988). Almost all river bends downstream from Landsburg are armored by a revetment or abut against erosion-resistant bluffs of glacial deposits, the latter case occurring most commonly in Reaches F and H. In the period between 1933 and 1975 revetments were built on the outside banks of most alluvial river bends. During this long period between 1933 and 1975, when no major floods occurred, vegetation colonized former gravel bars and grew into large trees capable of resisting erosion. The revetments and tree growth have combined to lock the river into position and prevented widespread channel enlargement during subsequent floods.

Reduced sediment input from the Cedar River watershed may also have contributed to channel narrowing, since rivers tend to respond to reductions in sediment load by becoming narrower and less braided (Schumm, 1977). Although this cannot be quantified, sediment loads to the river probably decreased substantially after the 1930s because of changes in land use and revetments (see *Sediment Sources to the Cedar River*, below). The 1936 photographs show locally wide zones of sediment deposition downstream from local sediment sources.

Channel Migration

The Cedar River is a migrating river—that is, it moves laterally across its floodplain by depositing bedload sediment in a bar on one bank and eroding the opposite bank (typically the outside of a bend). A more dramatic type of migration occurs when the river abruptly switches to a new channel, a process referred to as avulsion. Some reaches of the Cedar River are naturally very stable, while in other reaches bank erosion occurs almost every year where not constrained by revetments. Map 10 shows the present location of the river and its revetments, juxtaposed with the river's historic meander belt, the area of the floodplain with obvious traces of past river channels. Revetments have substantially reduced channel migration on the Cedar River since the 1960s. However, revetments in channel migration zones require repeated repairs and maintenance, and can be breached or seriously damaged in large floods such as the November 1990 event. (Refer to *Chapter 7: Aquatic Habitat* for effects of revetment-building on habitat, and to *Chapter 4: Flooding* for flooding problems associated with revetments).

Zones of rapid channel shifting can be crudely predicted from sediment transport patterns, since they tend to correspond with zones of bedload sediment deposition. However, sequential aerial photographs or maps provide the most reliable method of displaying the past sites of migration and thus the most likely future zones of activity. These historical data also provide the past rates and extent of migration, and thus they provide the basis for identifying areas of particular concern, either present or future.

In addition to comparing the 1865, 1936, and 1989 channels mapped in Map 9, channel changes that occurred after most revetments were built were identified using aerial photographs taken in 1970 and 1985. With the exception of the channelized Renton Reach, channel migration occurs to varying degrees throughout the river. Major zones of channel migration were identified in the lower mainstem from Elliot Bridge to the Taylor Creek confluence, and in the middle mainstem from Maple Valley to Dorre Don. In these zones, many homes are now located in areas formerly occupied by the river, which formerly had multiple channels instead of the present single-thread channel. The remainder of this section summarizes past channel migration and identifies potential areas of future channel migration for the different reaches of the river, from downstream to upstream.

Reach A — Renton Reach (RM 0.0–1.6) Although rapid lateral shifting of the Cedar River occurred in Renton prior to the river's diversion to Lake Washington (Chrzastowski, 1981), the straight, rock-lined channel has effectively prevented migration since its construction in 1912 and will likely continue to do so.

Reach B — I-405 to Maplewood (RM 1.6–4.2) No lateral migration could be detected at the resolution of the aerial photographs between 1936 and 1989, although widespread construction of revetments during that period attests to the river's ability to erode its banks (Map 10). Future channel migration is likely to be minimal because the outside of every river bend in this reach is constrained by revetments or the valley wall. The river shifted position substantially between 1865 and 1936, however, and during the last century it flowed through the sites of the Maplewood subdivision and the Riviera Apartments. A revetment was constructed in 1972 at the toe of a landslide-prone bluff at RM 3.9 to prevent further undermining of the slope by the river. Despite this revetment, a landslide on this bluff occurred in 1987 and delivered approximately 30,000 cubic yards of mostly sandy sediment to the river (Strieby and Booth, 1992).

Reach C — Elliot Bridge (RM 4.2–5.8) This reach was characterized by multiple channels, braiding, and major changes in position between 1865 and 1936; in 1865 a major channel flowed across what is now the Maplewood Golf Course. The width of the meander belt ranged from 400 to 1,000 feet in this reach in 1936. Two valley-wall landslides that are visible in the 1936 photographs appear to have been caused by impingement of the river against the toe of the slope. The larger of these landslide scars, at RM 5.0, is now protected from the river by a revetment. Further downstream, the river still flows at or near the base of the valley wall, and continued undercutting of the slope could trigger another landslide in the future.

Substantial revetment building occurred in this reach between 1936 and the present, and by 1989 the outside banks of all river bends in this reach were anchored in position by revetments or the valley wall. Two bridges in this reach also lock the river into position. Although the channel narrowed and changed from braided to single-thread form between 1936 and 1989, a new bend formed at RM 4.8 sometime between 1936 and 1963, when the Upper Elliot Park levee was constructed (Map 10). The bend grew approximately 300 feet during that 27 year period, at a minimum erosion rate of 11 feet per year. The Upper Elliot Park levee was destroyed in the 1975 flood and again in the Thanksgiving flood of 1990 and has not been repaired.

Reach D — Jones Road (RM 5.8–10.0) Reach D was historically braided and in 1936 the meander belt was 1/4 mile wide. Measurable channel migration occurred at four meander bends in this reach between 1936 and the construction of revetments in the 1960s, with minimum lateral migration rates of 6 to 10 feet per year. This reach has narrowed to less than half its 1936 width due to filling of the floodplain and levee construction. In many places levees line both banks, preventing flows from spreading over the floodplain and thereby creating extremely high velocities that severely damage revetments (see *Chapter 4: Flooding*). The present revetment system is extensive: as with Reach C, the outside of every bend is controlled either by the valley wall or a revetment.

Although this reach has experienced only minimal channel migration since the 1960s, rapid channel migration could occur in the future. Several revetments damaged by the 1990 floods are proposed for abandonment due to their adverse effects on flooding. Eventual failure of these revetments would allow the river to reoccupy old channels on the floodplain. Several such old channels exist on the undeveloped left bank between RM 8.2 and 9.0, at the site of a proposed spawning channel. In addition, the channel upstream of the Jones Road Bridge may change dramatically in the near future as a result of recent changes at RM 10.5 (see Reach E, below).

Reach E — Cedar Grove/Taylor Creek (RM 10.0–13.8) This reach was extensively braided in 1865, with braided zones ranging in width from 800 to 1,300 feet so that the river occupied almost the entire width of the valley floor. By 1936, the river had abandoned many of its channels but still had an obvious meander belt between 300 and 600 feet wide. Minimum erosion rates of 7 to 8 feet per year occurred at two bends between 1936 and 1970. Most bends in this reach are constrained by revetments or the valley wall, leading to a relatively stable channel in the past two decades. However, a major avulsion took place in 1990, when the river switched course to a side channel next to the east valley wall and abandoned its old channel except during floods (RM 10.1–10.5). The new channel alignment has directed flows against the left bank downstream. This could potentially trigger rapid bank erosion and major changes in course as far downstream as the upper Jones Road bridge, possibly endangering several houses on the left bank. Farther upstream, another potential avulsion site exists between RM 11.8 and 12.1, where the left bank (looking downstream) Lions Club levee was breached in the 1990 flood. If a large meander bend were to develop at this site, the river could eventually change course into an existing flood channel 250 feet west of the present channel. This flood channel already conveys a significant part of the flow during floods despite levee protection, leading to scour from high-velocity flows (King County; 1992 a, b, c).

Reach F — SR-169 to Maple Valley (RM 13.8–15.0) No lateral migration could be detected at the resolution of the aerial photographs between 1936 and 1989. The 1865 map and the presence of small channels on the floodplain both indicate that the river has historically occupied courses as much as 500 feet east of the present channel. This relatively straight, historically unbraided reach is constrained by the west valley wall as well as by revetments at both ends. Future changes in channel position are likely to be limited.

Reach G — Maple Valley to Dorre Don (RM 15.0–16.8) This reach was characterized by some multiple channels and major changes in position between 1865 and 1936; in 1865 the river flowed across what is now the lower Dorre Don neighborhood. The width of the meander belt exceeded 500 feet in this reach in 1936. During the 1936–1989 period, the channel narrowed and braid channels were mostly abandoned; two bends in the lower end of the reach migrated downstream at minimum average rates of 6 to 7.5 feet per year before being halted by revetments. Although revetments at least partially armor the outside banks of every bend in this reach, numerous old channels still exist on the nearly-undeveloped left bank floodplain. The potential exists for the river to switch course into one of these old channels.

Reach H — Orchard Grove to Landsburg (RM 16.8–21.7) This historically stable reach flows through a narrow floodplain that is constrained in many places by cliffs composed of glacial sediments. No lateral migration could be detected at the resolution of the aerial photographs between 1936 and 1989, although the cliffs are probably retreating slowly (rates of one to several feet per decade) at some slide areas at the outside banks of bends. Bank erosion of floodplain deposits has prompted installation of revetments in some locations, most notably from RM 18.4 to 18.6.

SEDIMENT SOURCES TO THE CEDAR RIVER

Sediment input to the study reach of the Cedar River (RM 0.0 to RM 21.0) can be subdivided into three categories based on its origin: 1) sediment carried into the upstream end of the study reach by the river, 2) sediment delivered to the study reach of the river by tributary streams, and 3) sediment eroded from the river banks or landslides within the study reach.

Sediment Carried into the Study Reach from Upstream

This report covers the 21 miles of the river downstream from Landsburg, which is only 35% of the Cedar River Basin. The remaining 65% of the basin is the area upstream from Landsburg (Map 1 in *Appendix B*). Chester Morse Lake (and formerly natural Cedar Lake) traps almost all sediment from the upper 78 square miles of the Cedar River watershed. In contrast, most sediment trapped behind the small diversion dam at Landsburg appears to be sluiced through when the gates are opened for annual forebay cleaning and during floods. Although no direct measurement exists, the sediment load of the Cedar River at Landsburg can be estimated from measurements made in the neighboring Snoqualmie River basin by Nelson (1971). Nelson's calculated average annual suspended sediment yields for Snoqualmie River subbasins with elevations similar to the Cedar River Basin range from 220 to 700 tons of sediment per square mile. Assuming a sediment yield of 500 tons per square mile, the 44 square miles that drain into the Cedar River between Masonry Dam and Landsburg should yield about 22,000 tons of suspended sediment (primarily fine sand and silt) per year. Bedload sediment (primarily coarse sand and gravel) yield is estimated at about 10% of suspended sediment load for steep rivers such as the Cedar River, or an additional 2,200 tons per year, for a total average sediment load of approximately 25,000 tons per year.

Approximately 500 cubic yards (about 750 tons) of fine sediment (primarily fine sand, which is transported in suspension) is removed annually by SWD from the Landsburg forebay, and an additional 500-1,000 cubic yards of sand and gravel were dredged from the river upstream of the dam once during the past 15-20 years (Michele Nielsen, City of Seattle, cited in Strieby and Booth, 1992). Thus, the sediment removed by SWD from the Cedar River at the Landsburg diversion is probably less than 5% of the river's sediment load at that point.

Sediment from Tributary Streams

A rough estimate of sediment yield from the basin downstream from Landsburg can be made by again assuming an average annual sediment yield of 500 tons per square mile: the 66-square-mile Cedar River Basin below Landsburg should produce about 33,000 tons of suspended sediment and 3,300 tons of bedload sediment per year. As described earlier in this chapter, many of the lower Cedar River Basin tributary streams have severe erosion problems caused by flow increases from development. Only five of the streams, which together drain 40% of the lower basin area, deliver a large part of their coarse sediment load to the river: Rock Creek (0338), Ginger Creek (0300A), Peterson Creek (0328), the Walsh Lake Diversion Channel (0341), and Molasses Creek (0304). The remaining tributary streams drop their coarse sediment load on the flat valley floor and deliver only sand and finer sediment to the Cedar River. For this reason, the majority of coarse sediment that enters the river downstream from Landsburg is probably derived from eroding cliffs and streambanks, which line much of the river. Revetments have probably reduced the sediment yield from eroding streambanks in recent decades.

Sediment from Bank Erosion and Landslides

Cliffs of glacial deposits line much of the Cedar River and contribute sediment to the river through landslides and gradual bank erosion. Although these cliffs generally erode much more slowly than the loose sediment of alluvial streambanks, their height and extent makes them an important source of sediment to the river. Although large landslides occur infrequently, they episodically deliver volumes of sediment that greatly exceed the river's typical sediment load. The most recent large riverside landslide occurred in 1987 at RM 3.9 and delivered about 30,000 cubic yards of sediment to the river (Strieby and Booth, 1992). Because of the complex glacial stratigraphy, the riverside cliffs most prone to large landslides are found in the Maplewood and Dorre Don areas. Increased runoff from upslope developments in some cases contributes to failure of these marginally stable slopes. In contrast, the steep bluffs downstream from Landsburg tend to be fairly stable and erode slowly through shallow sloughs and ravelling. In aggregate, these eroding bluffs are an important source of spawning-size gravel for the Cedar River system. Refer to *Appendix A* for a description of landslide and bank erosion conditions and problems on the Cedar River downstream from Landsburg.

On an alluvial river in equilibrium conditions, erosion of sediment from river banks is balanced by deposition of sediment in gravel bars, which in time become incorporated into the floodplain. Thus, bank erosion allows for the exchange of sediment between a river and its banks. The natural exchange of sediment between the Cedar River and its banks has been substantially reduced by armoring banks with riprap revetments (Table 5-3, Map 10 in *Appendix B*). In addition, revetments have been constructed at the toes of some glacial bluffs to prevent landsliding and bank erosion. Sediment input from river banks has thus been greatly reduced in the past 50 years, although many riverside landslides and eroding banks still exist. This does not necessarily mean that less sediment is transported by the river. Instead, the rate of exchange of sediment between the river and its banks appears to be much lower than in the past, since opportunities for floodplain deposition as well as sediment recruitment from banks have been reduced. Sediment moving through the river today tends to aggrade near the mouth of the river in Renton rather than being incorporated into and stored in the floodplain farther upstream.

Effects of Land-Use Changes on Sediment Supply

Land use in the Cedar River Basin affects the rate at which sediment is delivered to the river by tributary streams and by landslides. Widespread logging occurred in the basin during the 1880s through the 1920s, both upstream and downstream of Landsburg. Most of Seattle's watershed between Landsburg and Cedar Falls was logged by 1930, with the exception of the Taylor Creek basin (a different Taylor Creek than that within the BPA), which was logged in the 1960s (Seattle Water Dept., unpublished maps of stand age). It is likely that sediment loads increased substantially during that period due to logging-induced landsliding, channel disturbance, and increased flows during rain-on-snow events. Numerous landslides from the valley walls that enter the river are visible on 1936 aerial photographs of the study area. Another large source of sediment during the 1920s and 1930s was erosion of a ravine by the Walsh Lake Diversion Channel, which enters the Cedar River at RM 19.8 (see Section 5.3, above). Based on channel dimensions estimated during a 1992 field survey, up to 40,000 tons of sediment were eroded from this ravine. Aerial photographs taken in 1936 show a large sediment fan at the mouth of the channel, which apparently caused the river to cut off a bend, as well as large gravel deposits in the river downstream. Because gravel moves very slowly downstream (probably on the order of 1,000 feet per year), some of the coarse sediment that entered the middle and upper mainstem Cedar River early in this century is still making its way downstream today. However, much of the sediment is stored in the floodplain, in many cases trapped behind revetments and inaccessible to the river.

It is likely that delivery of coarse sediment to the Cedar River decreased after the 1930s, as logged land became reforested or was converted to other uses. Logging has continued in the basin but at a much lower rate. In recent decades, erosion of tributary channels in urbanizing subbasins has increased sediment production in the lower watershed. As pointed out earlier, however, many of these streams drop their coarse sediment load on the valley floor so that only fine sediment reaches the Cedar River. As described above, armoring of banks with revetments reduced sediment input from bank erosion during the latter half of this century. Thus, the aggregate effect of these land-use changes has probably been a decrease in coarse sediment delivery to the river since 1930. Despite this presumed decrease, the recruitment of spawning-size gravel to the river has remained adequate and consistent throughout the last 25 years (Paul Olsen, SWM, pers. commun., 1992), in part because there are many unarmored bluffs in the middle mainstem reach that deliver spawning-size gravel to the river.

5.5 BEDLOAD TRANSPORT OF SEDIMENT BY THE CEDAR RIVER

The problems associated with sediment transport and deposition by the Cedar River have been long-recognized. Most prominently, the deposition of sediment in the channelized reach through the City of Renton once motivated several decades of annual dredging; subsequent to that time, continued deposition has raised well-documented concerns over loss of flood capacity in the channel. The design of successful control or mitigation strategies for this loss will depend on the knowledge not only of the average rate at which sediment is being deposited, which has been estimated by others using measurements of the channel depth over time, but also of the likely variability of sediment transport from year to year and the likely sources of that sediment. To realize this broader understanding, the following sediment-transport study of the Cedar River was accomplished.

HUMAN INFLUENCES

The Cedar River is unusual among the large river systems of the region, in that it has been subjected to a particularly wide variety of human influences throughout its length. These influences, in turn, have had a profound effect on how the river moves sediment from its upper reaches down to the mouth. Noteworthy among them has been the construction of Chester Morse Dam, construction of levees and revetments along many miles of river bank, and redirection and channelization of the lower reaches of the river through the City of Renton. These changes and their effect on the river are described above in Section 5.4 but are summarized here also.

Although construction of Chester Morse Dam has dramatically reduced the magnitude and frequency of all discharges in the lower channel, it has not greatly altered the quantity of sediment delivered to the lower basin. Cedar Lake was a pre-dam impoundment in the vicinity of the modern Chester Morse Lake that probably interrupted the movement of all coarse sediment since glacial time. Similarly, the Seattle Water Department intake at Landsburg has minimally affected sediment movement, because almost no material is stored in the impoundment area for more than a year at a time.

Farther downstream, migration of the channel and exchange of channel sediment with floodplain sediment has been severely curtailed by the reinforcement of the channel banks (revetments) and the local construction of levees. As a result, the volume of bed sediment in temporary storage along the channel, located in point bars at the inside of bends and along broad reaches of braided mid-channel bars, has been reduced greatly during this century, and material that enters the channel probably now moves more rapidly towards the mouth of the river. Based on old maps and more recent airphotos, an estimated 350 acres of channel area between Landsburg and Lake Washington have been lost since 1865 (a little more than half the original area), mainly due to narrowing of the channel from dam-related flow reduction and the construction of revetments.

Channel realignment and reinforcement at the mouth of the Cedar River has dramatically altered the prehistoric pattern of sediment movement and deposition. Originally, the river flowed across a broad alluvial fan in the vicinity of Renton, where sediment was rapidly deposited and the location of the active channel probably shifted frequently. Just downstream, the flow of the Cedar River merged with the sediment-free outflow of Lake Washington, which was probably competent to flush whatever sediment the Cedar River brought to the confluence out to the Duwamish River (Map 9 in *Appendix B*). With the realignment of the Cedar River into Lake Washington in 1912, the zone of sediment deposition was localized through the City of Renton. All of the non-suspendable sediment load must now deposit along this reach because Lake Washington, with essentially no sediment-transporting capacity, lies at the river's mouth. With the path of the river fixed by armored banks, progressive infilling of the channel is therefore inevitable.

GENERAL PATTERNS OF SEDIMENT TRANSPORT ON THE CEDAR RIVER

Sediment carried by the Cedar River ranges in size from tiny clay particles to boulders. The smaller particles (clay, silt, and fine to medium sand) generally are suspended in the water column as they move downstream. The amount of suspended sediment carried by the river generally increases with water discharge but varies depending on the amount of fine sediment entering the river from the watershed. Turbidity, a measure of the extent to which suspended sediment particles reduce visibility through the water, depends on sediment characteristics but tends to increase with the concentration of suspended sediment. During floods, overbank flows deposit suspended sediment on the floodplain. Because even low flows can move fine sediment downstream, most of the river's suspended sediment load moves all the way downstream to Lake Washington, where it drops out to form a delta.

The coarser part of the Cedar River's sediment load (coarse sand, gravel, cobbles, and in a few locations boulders) moves downstream as bedload, so called because the sediment grains roll, slide, or bounce along the river bed. Bedload movement is slow, and it occurs only infrequently when flows are large enough to mobilize the gravel pavement of the streambed. In gravel-bed rivers such as the Cedar River, bedload sediment typically comprises 10% or less of total sediment load. However, its importance is disproportionately great because bedload forms the gravel bars and river banks and thus controls the shape of the channel. It is deposition of bedload, not suspended load, that causes the river channel to fill in or to shift laterally.

A river's ability to transport bedload sediment at a given location is a function of the shear stress exerted on the river bed by the water flowing over it. Shear stress increases with flow depth and slope of the water surface. Since flow depths and water discharges fluctuate only modestly between Landsburg and Renton, differences in shear stress along the length of the Cedar River are primarily controlled by slope. During a given flood, then, shear stress will be lower in shallow gently-sloping reaches of the river than in narrow steeply-sloping reaches. Were the channel significantly rougher in particular reaches, that too would affect the shear stress on the bed by reducing its net effectiveness at transporting sediment. By whatever means, wherever the basal shear stress decreases in a downstream direction the bedload transport capacity of the river also decreases and the river will deposit bedload sediment; the size of bedload sediment the river can carry will decrease as well.

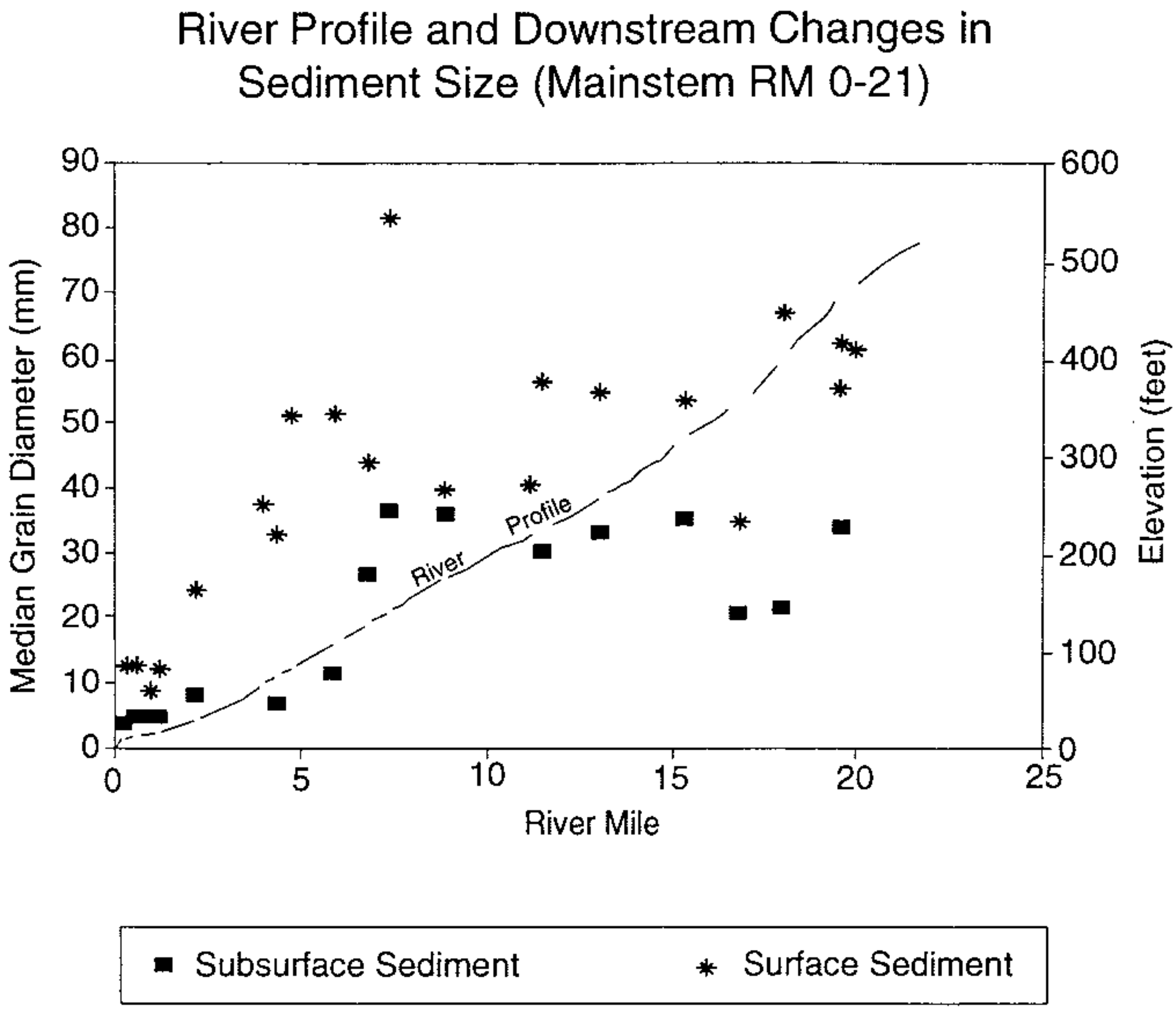
As shown on Figure 5-10, the slope of the Cedar River decreases in the downstream direction. The slope decrease is gradual upstream from Maplewood but more pronounced from the Maplewood area (RM 4.0) downstream through Renton to Lake Washington. Figure 5-10 also shows sizes of sediment sampled by SWM in 1992 from gravel bars throughout the study reach (see *Sediment Sampling Methodology*, below). The results show that sediment is relatively coarse (subsurface median diameters from 20 to 36 mm) throughout the upstream part of the river where the river slope decreases very gradually. Sediment size declines rapidly downstream from RM 6.0, reflecting the decrease in slope as well as an increase in width where the river enters the channelized reach below RM 1.6. Subsurface sediment in the Renton Reach has a median diameter smaller than 5 mm. This decrease in grain size indicates that the coarsest sediment fractions transported by the river farther upstream drops out downstream of RM 6.0, because the river cannot transport it farther downstream.

SCOPE OF STUDY

Because the sediment deposited in the lowest reaches of the river is derived from throughout the upstream basin, this study has assessed the movement of sediment throughout the Cedar River downstream of Landsburg. The results here are best quantified from RM 15.0 downstream, where water-level and sediment data are most complete. The emphasis has been on the coarser fraction of the river's sediment load, namely the fraction that moves by rolling, skipping, or sliding along the bed of the channel and termed "bedload." Although this type of sediment composes only a small proportion of the total sediment load in the Cedar River, it is the most important fraction for issues of deposition and channel form.

To accomplish the goals of this study, a combination of empirical and theoretical strategies was applied to the Cedar River. Measurements on thirty-seven surface and subsurface sediment samples were collected, covering most of the river bars in the lower 20 miles of channel, to determine the input sources and distribution of sediment into the lower basin. A simple bedload sediment transport model for the river was developed, with calculations made using estimated sediment inputs, modeled channel parameters,

Figure 5-10


River Profile and Downstream Changes in Sediment Size (Mainstem RM 0-21)
Median Grain Diameter (mm)
Elevation (feet)
River Mile
River Profile
0
10
20
30
40
50
60
70
80
90
0
100
200
300
400
500
600
0
5
10
15
20
25
Subsurface Sediment
Surface Sediment

and both gage-recorded and HSPF-simulated water discharges. The predictions of this model were then compared with expected quantities of sediment from the basin, with existing survey information in the lower river, and with a previous effort at sediment-transport modeling (Harza, 1992).

SUMMARY OF STUDY RESULTS

In the area of detailed modeling, from Lake Washington upstream through Maple Valley, the movement of bedload sediment follows a relatively predictable pattern. Sediment sizes and transport rates are generally highest upstream, varying erratically about a mean value. Both measured sediment sizes and calculated transport rates decline downstream, particularly from about RM 7.0 to RM 2.0. In the lowermost 2 miles, bed sediment decreases in size to mainly sand and fine gravel, and the river's transport capacity is at a minimum as well.

The relative differences between calculated rates at successive stations suggest an average annual accumulation of sediment in the canal of many thousands of cubic yards per year, consistent with recent measurements of channel infilling in this area (NHC, 1992). Past years of particularly high sediment transport have probably about doubled this long-term average value. In addition, the actual flux of bedload sediment passing out of this reach altogether and on into Lake Washington is at least several times larger than the amount actually deposited within the canal itself.

Although the pattern of sediment transport predicted by this study is well validated, the absolute magnitudes of the calculated transport rates are judged to be unrealistically high for the likely sediment supply of the basin. In other words, sediment transport is supply-limited: the river has the capacity to rapidly transport virtually all of the sediment delivered to it from bank erosion and from tributary stream inputs. Only in the lowest reach does the river approach a condition where sediment is readily available for transport under all conditions of flow and load; but even here, a variety of evidence suggests that calculated rates are about two to three times actual values.

The sources of the bedload sediment to the Cedar River are from the input of tributary streams above Landsburg and from bank erosion along the entire channel, particularly above Maple Valley. Lateral streams joining the Cedar River below Landsburg are not, in general, significant bedload sediment inputs to the river. In recent time, only one major "point" source, the 1987 landslide on the river's left bank near Maplewood at RM 3.9, could be recognized in airphotos. Its input of bedload-sized sediment (about 15,000 yds^3) was equivalent to about one year of total-basin bedload sediment, or about one-half the volume of the total accumulated sediment in the lower channel in the last 6 years. In contrast, the slide volume in total represents only about 20-25% of the combined 6-year accumulation of sediment in the channel and delta together. This site therefore represent a noteworthy but probably not controlling source of the recent depositional problems in the City of Renton. Only one other sediment source of roughly equivalent magnitude, a large right-bank landslide below the lower Jones Road bridge at RM 5.0, has been recognized in airphotos of the basin covering the last 56 years. This failure was clearly active in 1936; no other comparably sized feature is visible during this period in any part of the Cedar River Basin below Landsburg.

Control of channel infilling through Renton will require an approach that recognizes the conditions of sediment movement. On average, over 10,000 cubic yards of sediment will pass beneath the I-405 bridge each year as bedload; half or less of that material will be subsequently deposited in the channel just upstream of Lake Washington, with the balance coming to rest in the delta at the mouth of the river. This average annual amount, however, could be exceeded by a single flood of almost any significant magnitude if the supply of sediment from upstream were increased by landslides. In particularly large events, such as a 50-year flood, the amount of rapid deposition will be determined in large measure by the availability of landslide-delivered sediment, because the capacity of such a flow to move sediment would equal the measured annual accumulation rate in only a few days. If such material were available, the amount of deposited material in the canal could reach several thousand cubic yards in a single event. The total volume of sediment deposited in the canal in such an event, however, would be only a fraction of the volume of material transported through the canal and then deposited on the delta.

Control of the present-day (1992) upstream sediment sources is neither feasible nor generally advisable. With the exception of the 1987 landslide, no opportunities for localized control that might yield significant downstream benefits have been recognized. Avoidance of future landslides of a scale similar to that at Maplewood, however, is critical in avoiding even worse conditions downstream. Only one of the main sediment sources, namely channel-bank erosion and much smaller scale landslides, could be readily controlled at all, but only with even more bank protection than presently exists, and with resulting high economic and (probable) resource costs. Even with such action, several decades of typical bedload sediment flux is still stored along the active channel of the Cedar River in the form of point and mid-channel bars, and so the rate of deposition at the river mouth would decline only slowly in response to upstream source control. Thus, the problematic conditions recognized for the Cedar River result not from excessive sediment loading of this river system but rather from the intensive development of flood-sensitive land uses in a natural zone of sediment deposition, a zone that has actually been enhanced for sediment deposition as a result of channel modifications nearly a century old.

STUDY DESIGN

Introduction

The study area consisted of the mainstem Cedar River from the Landsburg diversion (RM 21.6) to its discharge into Lake Washington at the City of Renton (RM 0.0). This study combined field data on sediment sizes and channel pattern with a sediment-transport model to estimate downstream changes in sediment and sediment movement. Differences in transport capacity between successive reaches identify zones of potential scour or deposition. Correlating these results with some localized cross-section survey data, which show actual channel-bed changes over the last 6 years, provided an independent check on the predictions of the sediment-transport model.

Field Study--Procedures

Introduction The field sampling regimen was designed to meet the following criteria: the field data should 1) characterize downstream patterns in river sediment size; 2) document the major zones of deposition of different sizes of gravel; 3) provide subsurface grain- size data for theoretical sediment transport calculations at each site; and 4) be obtainable with a minimum expenditure of time and expense. A field grain- size analysis methodology was used that allowed a great deal of data to be obtained in a short time and with minimal expense. This methodology, described below, provides a reasonable compromise between analytical precision and the number of samples that can be processed under rather typical time constraints for a project such as this.

Field Site Selection Field sites were selected to accurately characterize sediment conditions, particularly in zones of anticipated rapid changes in sediment size. Ideally, only the best developed river bars with classic point bar morphology were to be sampled. This restriction was motivated both to establish a consistent sampling strategy and because such locations should best represent the active transport load of the river (Klingeman and Emmett, 1982; Parker and others, 1982). In almost every reach of the Cedar River, however, point bars are of only limited extent and display only poorly developed morphology. These conditions are reflected in both our 1992 field visits and from review of historic aerial photos. Sampling density was reduced where these conditions were most problematic, but some useful data were still obtained. The unusual condition of Cedar River bars, however, probably limits some of the utility of subsequent sediment-transport calculations.

All sites were visited in the late summer of 1992. Some river bars were easily accessible from land, but most were reached by wading or raft.

Choice of Samples When examined in detail, river bars commonly exhibit significant spatial variations in sediment size, owing to differing flow conditions over different parts of the bar form. The fact of this variability is well known in the geologic literature (e.g., Richards, 1982), and a standard approach to studying downstream variations in sediment size is simply to sample bars at a consistent and easily identifiable position relative to the flow, rather than to attempt to fully characterize the distribution of sediments on each bar. This approach allows samples of comparable sub- populations of the active river sediment load to be taken at each site because the sampling locations presumably have experienced comparable flow conditions.

In addition, the sampled material should resemble the sediment load carried in the main thread of the flow. In this study, we follow the conventional wisdom (e.g., Leopold and others, 1964) of sampling the bar at low flow near the river's edge at the point where, during flood, the high-velocity would cross over the bar- - approximately halfway between the upstream tip of the bar and the bar apex. Owing to irregularities in bar form, not all sites met this criterion exactly, but most of the chosen sites approximated it. The small size of most of the river's point bars, however, suggest that our sample population was not fully representative of the actual river load.

Sediment Sampling Methodology

Overview Grain- size analysis techniques employed in this study included measurement of gravel clasts on bar surfaces ("point counting"), standard laboratory dry sieving of small-volume grab samples, and field wet sieving of large subsurface samples. Surface point counting was done on every gravel bar visited; however, subsurface samples are needed from gravel bars for sediment-transport calculations and are by far the most time-consuming to process. Because of difficulties encountered with either very large sizes of subsurface sediment or the proximity of the water table to the bar surface, subsurface sampling was accomplished on only 16 of the 21 bars visited.

Point Counts On most gravel bars, surface point counts were made to characterize the upper pavement. For point counting, clasts were selected at random by "first touch" without looking at the ground. The chosen clast was measured along its intermediate axis and grouped into 1/2- phi size classes (e.g., 4, 5.6, 8, 11, 16, 22, 32, 45, 64, 90, 128, and 180 mm; Wolman, 1954). Clasts with their median axis less than 4 mm were combined into a single category. Such surface point counts are easily obtained and provide useful information on downstream changes in the caliber of river sediments, information that was used in part to interpolate between the less frequently obtained subsurface samples.

Sampling of the Subsurface Recent studies of gravel- bedded river systems have established that the appropriate grain- size parameter for use in sediment transport calculations is the median of measured diameters (D_{50}) of the subsurface sediment, not of the pavement layer (e.g., Andrews, 1983; Parker and others, 1982). But obtaining this subsurface grain- size data for coarse- grained gravel bars is made difficult by the large sample size required to accurately represent the sediment population being sampled (Church and others, 1987). The field sieving methodology used in this study represents a compromise between the large volume of sample required to accurately represent the coarse part of the grain- size distribution, the awkward logistics involved in standard laboratory sieving techniques, and the increased time required to process large samples.

Our field sieving technique takes advantage of the fact that only the largest clasts require a huge volume of sediment to be processed, and so conversely only a fraction of the total sample is needed to characterize the distribution of clasts smaller than 64 mm. Sample extraction proceeded as follows: first, a 1- 1.5 m^2 area was stripped of its armor layer (1- 2 grain diameters thick), planed off to a level horizon 2- 3 inches below the stripped surface, and then marked with a 1 m^2 grid to define the sampling area. This avoided contamination of the subsurface sample with clasts from the surface armor (Gomez, 1983). Next, a pick- axe was used to loosen the gravel to a depth of 6- 8 inches and the sediment was shoveled into an array of two to four 17-liter buckets. As sediment was transferred into the buckets, all clasts larger than 64 mm (median axis) were separated and placed on a tarp. The total volume of solids collected was thus the combined volume of the large clasts on the tarp, plus the volume of the three buckets, minus the bulk porosity of the sediment in the buckets.

The contents of one bucket was used to determine bulk porosity. Bulk porosity of the sample was determined by adding measured amounts of water to the bucket until the sample was saturated up to the 17-liter level. The volume of solids was therefore 17 liters minus the volume of water added. The field capacity of these bar sediments was measured at a few sites in an earlier study (Booth and others, 1991) and judged negligible (< 2% by volume).

The contents of a second bucket was wet sieved in the field to characterize the grain-size distribution of clasts less than 64 mm diameter. On bars with only fine to medium gravel, the subsurface sediment was sieved down to fine sand (0.0125 mm). On the coarsest gravel bars, a much larger total sample was taken but all material finer than 8 mm was allowed to wash through the sieves. In these cases, the bulk porosity measurement was used to estimate the total volume of sands and fine gravel in the total sample, by comparing the volume of total solids in the first bucket with the volume of sieved solids (i.e., > 8 mm) in the second bucket. The contents of all other buckets were discarded, having been collected in order to increase the total sample volume and thus the number of measured >64-mm clasts; the grain-size distribution within the bucket(s) is assumed from the results of sieving one bucket.

The volume of solids caught on each sieve, together with those greater than 64 mm which were size-segregated by hand, were determined by volumetric displacement of water. A combination of graduated buckets (marked off in 1- liter increments) and graduated cylinders (marked off in 10-ml increments) were used, adding first the (now damp) sediment of a given size class and then a measured amount of water until reaching a marked volume in the bucket (or cylinder). The graduated buckets could be read to an accuracy of +/- 50 ml, with greater precision limited by minor side- wall deformation and difficulties maintaining a level water surface in the field. The buckets were necessary, however, to accommodate clasts with diameters greater than 64 mm.

To compensate for the effect of water retention in the sediments after wet sieving, a correction factor for each size class was determined. Field conditions were recreated in the laboratory and a typical sample (both in total volume and size distribution) of river sediment was wet sieved and processed as in the field. These samples were then weighed wet, oven dried, and weighed again. Assuming a clast density of 2.65 g/cm^3, these numbers were converted into a volume percent of water in the wet samples, which were then applied to the field-measured volumes of each size class to adjust the measurements accordingly.

Explicit in the analysis is an assumption that no size- segregation occurred during the filling of the three buckets and that bulk porosity does not vary between sample buckets. Repeated measurements and the minor variation between sites in a similar study on the Snoqualmie River (Booth and others, 1991) suggest that the latter assumption is reasonable, with an estimated variability of about +/- 2%. Care was taken to minimize further this potential effect by filling all buckets simultaneously as the pit was excavated, rather than sequentially. In addition, given the volume of sediment involved (over 80 liters for the coarsest bars), size- segregation is potentially a problem only for the largest size fractions. We sought to minimize this problem by scaling the sample size to the size of the coarsest clasts, in an effort to achieve the criterion of either no clast greater than 5% of the total sample (Mosley and Tindale, 1985) or the more stringent criterion of a 1% threshold (Church and others, 1987). In nearly all cases, at least the first criterion was achieved (Table 5-4).

Analysis

Sediment Size Distribution Subsurface sieve data were used to generate cumulative size distributions, particularly the median diameter of the sediment in each sample (i.e., the diameter for which half of the sediment is coarser and half is finer). These results (Figure 5-11 and Table 5-4) characterize the downstream variations in sediment sizes. Three major zones along the 21 miles of the study area are evident:

1) The uppermost 13 miles, from RM 8.0 to RM 21.0, where sediment sizes are relatively uniform and coarse, and where deposition is limited;

2) A transition zone from RM 4.0 to RM 8.0, where subsurface sediment sizes decline rapidly; and

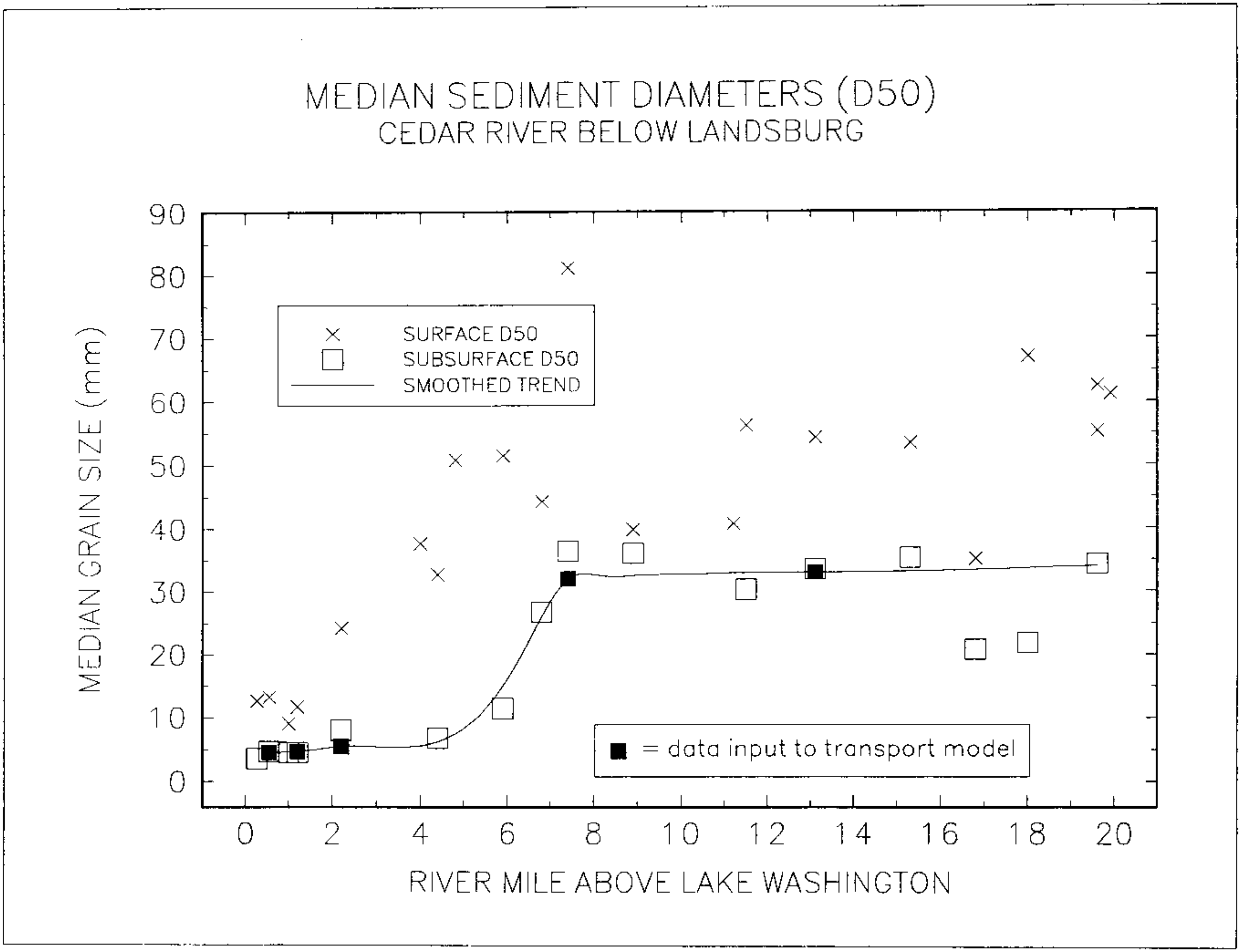
3) The major deposition zone below RM 4.0. Surface sediment continues to fine in the upper half of this reach but the subsurface sediment changes only slightly in size; and transport capacity of the channel (see below) is a scant fraction of its upstream value.

Because of spatial variability and inherent errors in field sampling, the distribution of sediment sizes as a function of downstream location was spatially smoothed; these smoothed values (Figure 5-11) were used as input parameters to the transport model.

Table 5-4 Cedar River Sediment Data—September 1992

Station #	River Mile	Surface (diameters (mm)			Subsurface			
		16%	50%	84%	16%	50%	84%	% sample of largest clast
1	0.27	5.9	12.6	21.0	0.7	3.6	9.8	1.4%
2	0.55	3.1	13.2	23.0	0.4	4.7	16.0	1.2%
3	1.0	(2	9.1	19.5	0.7	4.6	18.1	1.2%
4	1.2	4.4	11.7	23.4	0.7	4.6	17.7	1.3%
5	2.2	6.3	24.2	60.4	0.6	8.1	37.0	2.6%
6	4.0	16.9	37.7	85.2				
7	4.4	14.4	32.7	71.0	0.7	6.8	45.8	3.4%
8	4.8	25.8	50.8	86.6				
9	5.9	22.2	51.5	80.8	1.2	11.5	61.7	6.2%
10	6.8	18.3	44.3	109.9	3.4	26.8	90.2	7.3%
11	7.4	35.7	81.2	127.8	3.1	36.5	96.2	6.2%
12	8.9	17.0	39.8	89.4	5.7	36.0	69.1	3.7%
13	11.2	23.5	40.7	60.8				
14	11.5	22.7	56.2	110.1	2.5	30.3	56.2	6.2%
15	13.1	19.5	54.3	99.3	2.7	33.5	83.3	4.3%
16	15.5	17.0	53.4	98.8	2.7	35.3	93.5	5.0%
17	17.0	11.9	35.1	76.2	1.7	20.8	68.7	7.0%
18	18.2	29.1	67.0	143.8	4.1	21.8	68.3	4.8%
19	19.8	17.1	55.3	119.8	2.1	34.3	81.5	12.9%
20	20.1	1809	61.1	136.6				
21	20.8	17.6	62.4	131.3				

Figure 5-11



MEDIAN SEDIMENT DIAMETERS (D50)
CEDAR RIVER BELOW LANDSBURG
MEDIAN GRAIN SIZE (mm)
RIVER MILE ABOVE LAKE WASHINGTON
SURFACE D50
SUBSURFACE D50
SMOOTHED TREND
= data input to transport model
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
10
12
14
16
18
20

Sediment Transport Modeling—Introduction The movement of sediment along the stream system depends on both the supply of sediment to the channels and the competence of the flow to move that material. These two factors are not wholly independent: increased sediment loads cause deposition, which tends to steepen the gradient of the channel and so increase competence; and increased competence will tend to increase the sediment supply to downstream reaches, by scouring the channel bed and banks.

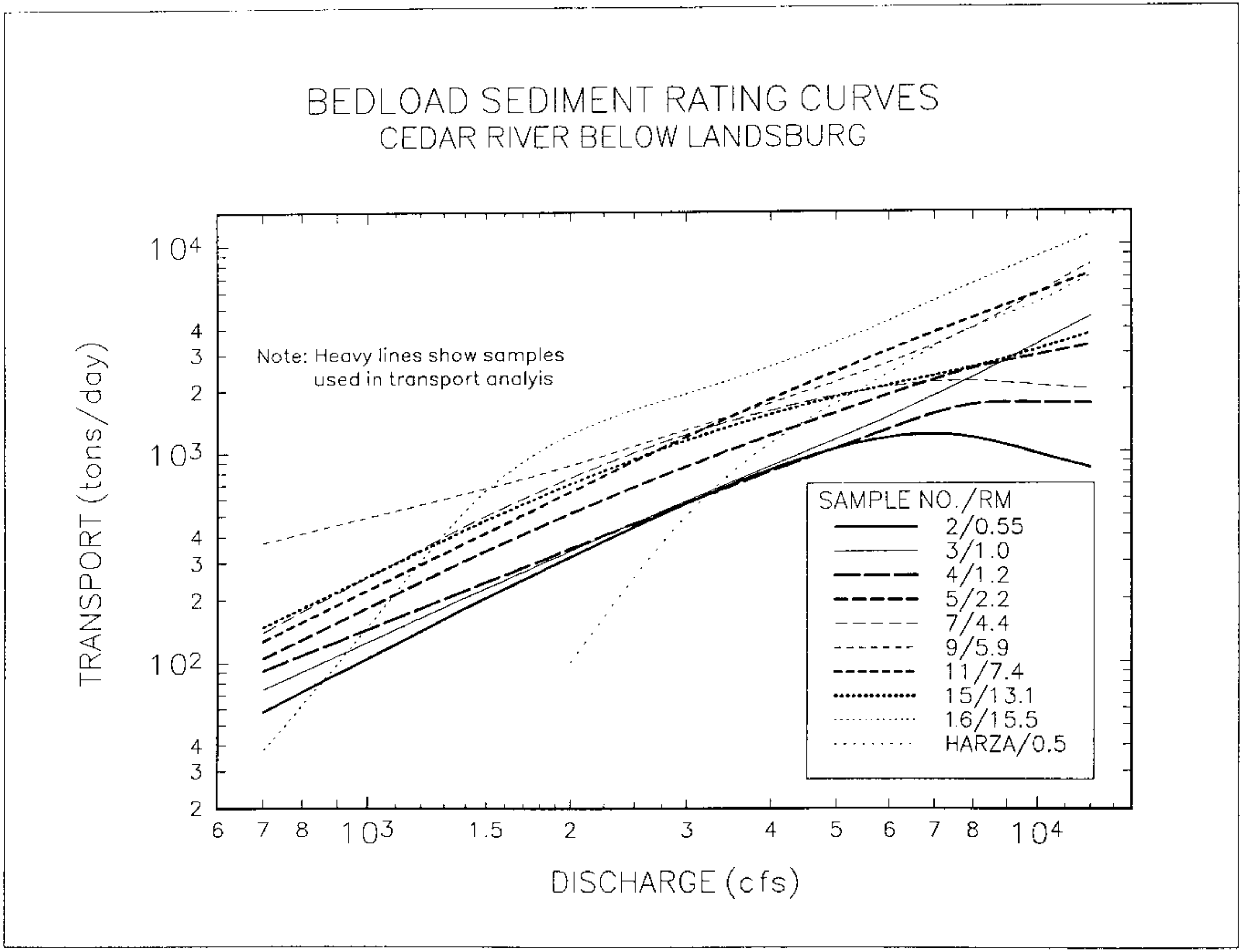
Because the flow parameters that determine sediment transport (depth, slope, and width) and sediment parameters (particularly median grain size) are continuously changing downstream, calculated bedload movement is not uniform and instead must be evaluated at multiple locations along the stream system. If the transport capacity at one location is less than the transport capacity upstream (plus any addition from intervening lateral tributaries), the difference is deposited within the reach. In contrast, if the transport capacity equals or exceeds the upstream sediment sources, scour may result if sediment is available; otherwise, the entire load entering the reach from upstream is simply passed on downstream and deposition will be quite limited.

Sediment Transport Modeling—Methods A large number of predictive equations to calculate bedload sediment transport have been developed over the last 100 years. All depend on identifying a threshold flow to initiate motion, and then each calculates the rate of sediment transport as a function of the flow in excess of that threshold. Different flow parameters are used by different formulas to calculate that transport rate, and different methods are used to predict the initial threshold of movement.

In general, the prediction of different formulas on the same stream are often wildly different, with results differing by factors of 10, 100, or more. Gomez and Church (1989) analyzed ten such formulas on the same data set (where the true transport rate had also been measured directly) and concluded that the formula of Bagnold (1980) was the most suitable for gravel-bedded rivers (such as most of the Cedar River system). In their study, predictions of this formula were typically within a factor of 2 of the actual measured values. This range of imprecision, low by engineering standards but typical of sediment-transport models, should be remembered throughout the discussion that follows. Furthermore, all of these relationships were developed for transport-limited systems, namely channels with an abundance of sediment available for transport. As discussed below, this condition is not met along the Cedar River, which leads to significant differences between model predictions and the observed behavior of the river.

The Bagnold formula correlates the movement of bedload with the "unit stream power," or rate of energy expenditure of the flowing water per unit area of the bed. To calculate this value, the flow depth, slope, and active channel width are needed. The threshold of sediment movement is determined from the size of the sediment awaiting transport, which for this formula is characterized by the median grain diameter of the subsurface

Figure 5-12



BEDLOAD SEDIMENT RATING CURVES
CEDAR RIVER BELOW LANDSBURG
Note: Heavy lines show samples used in transport analyis
TRANSPORT (tons/day)
DISCHARGE (cfs)
SAMPLE NO./RM
2/0.55
3/1.0
4/1.2
5/2.2
7/4.4
9/5.9
11/7.4
15/13.1
16/15.5
HARZA/0.5

bed sediment. In addition, the Bagnold equation returns instantaneous rates of transport, in units of kilograms per second for a specified water discharge. To convert this instantaneous rate to total amount transported, it must be multiplied by the duration of the discharge that produces this transport rate. The total transport is then the combination of all such products of duration and instantaneous rate, summed over the full range of discharges. For this analysis, flow durations under current conditions were used; under future conditions, the average durations increase by 17% and predicted sediment-transport rates would increase commensurately (see *Chapter 3: Hydrology*).

The Bagnold equation takes the following form:

$$i_b = (i_b)_* \left[\frac{\omega - \omega_o}{(\omega - \omega_o)_*}\right]^{3/2} \left[\frac{Y}{Y_*}\right]^{-2/3} \left[\frac{D}{D_*}\right]^{-1/2}$$

where i_b is the bedload transport rate (immersed mass per unit width in kilograms per meter per second), ω is the unit stream power of the bed (in kilogram-meters per square meter per second), Y is the mean flow depth (in meters), and D is the modal (or median, if the mode is unknown) grain size (in meters). The asterisked parameters are reference values from Bagnold's original calibration: $(i_b)_*$ = 0.1 kg/m-sec; $(\omega - \omega_o)_*$ = 0.5 kg/m-sec; Y_* = 0.1 m; and D_* = 0.0011 m.

The threshold of sediment movement, ω_o, is calculated by the following equation:

$$\omega_o = 290 D^{3/2} \log\left[\frac{12Y}{D}\right]$$

To use the equation, measured or modeled values of the flow parameters and sediment size are specified for a range of discharges. A bedload-transport rating curve results for each sampling site (Figure 5-12), which shows the instantaneous rate of transport for any desired discharge. When the appropriate instantaneous rates are multiplied by the duration of each flow discharge, the sum of all such products gives the predicted transport capacity of the channel at each point.

Flow parameters for this analysis were derived from the most current HEC-2 model outputs available for the Cedar River. From them, sediment rating curves were defined for each sediment-sampling site, which predict the instantaneous rate of sediment transport for any water discharge. When this rating curve is multiplied by either the duration of flows of a particular year, the duration of a particular flood flow, or the entire suite of flows over the period simulated by the HSPF model, corresponding estimates of the potential bedload transport rate result.

RESULTS

Sediment Transport with the Model of Bagnold (1980)

Transport Calculation Set-up Detailed calculation of the bedload transport was made at 5 stations along the river (stations 2, 4, 5, 11, and 15), located at RM 0.55, 1.2, 2.2, 7.4, and 13.1. These sites were chosen because the flow and sediment data appeared reliable and generally representative of the full suite of sample sites, giving adequate coverage of the zones of major interest along the river. Of the other locations of subsurface sediment samples (see Table 5-4), water-surface slopes predicted by the HEC-2 model appeared unrealistic in the vicinity of samples 1, 10, and 14, and were missing altogether above sample 17; measured sediment parameters suggested poor data for samples 10, 12, and 17; and no subsurface samples were taken at sites 6, 8, and 13. The 4 additional samples where data was judged to be of reasonable quality (samples 3, 7, 9, and 16) produce rating curves (Figure 5-12) that are largely consistent with the pattern established by the other 5 sites. Samples 7 and 9, however, would produce the somewhat anomalous prediction of a downstream increase in transporting ability in a zone of observed slight to moderate sediment deposition.

The choice of a threshold discharge for sediment motion, not particularly well represented by the Bagnold equation, was further investigated in the lower channel where some independent information was available. Using the equation of Andrews (1983), the critical shear stress (τ_c) under which bedload sediment begins to move is calculated as:

$$\tau_c = 0.083\left[\frac{D_{surface}}{D_{50,subsurface}}\right]^{-0.87} g\, D_{surface}(\rho_s - \rho_w)$$

where D is the grain size of the surface or median subsurface sediment, as noted; g is the gravitational acceleration; ρ_s is the density of sediment; and ρ_w is the density of water.

The shear stress of the water at any discharge can be calculated as the product of the water's depth, slope, and unit weight; where that shear stress equals the calculated critical shear stress, transport of that particular grain size will begin. In the canal reach, this is predicted by Andrew's equation with a discharge between 400 and 500 cfs, remarkably close to Harza's (1992) judgement, based on observation, of 425 cfs. This threshold was therefore used in all subsequent calculations of bedload transport.

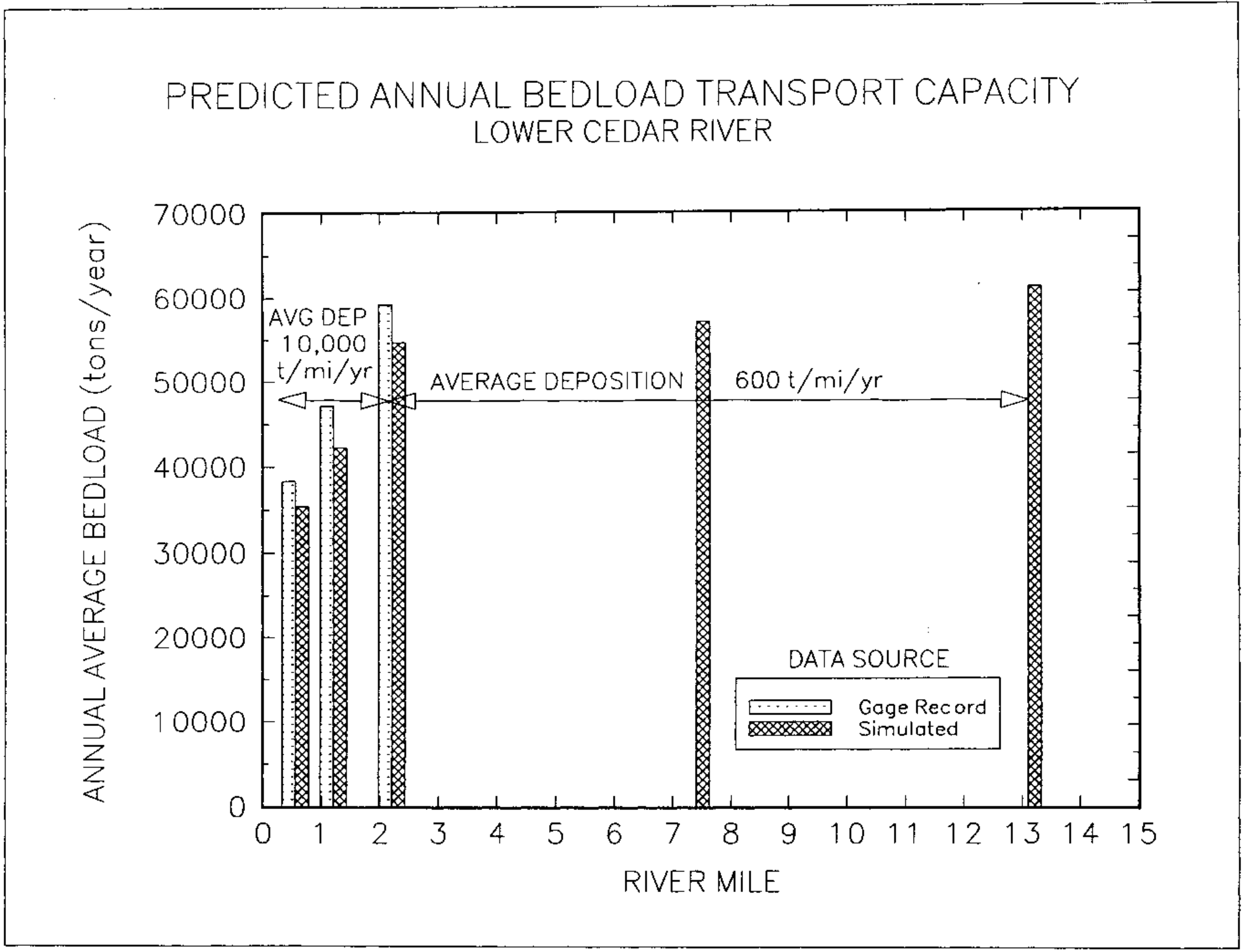
The choice of representative flow durations, necessary to calculate net transport and deposition rates, was limited by available data. In the lower reach of the river, daily average flows from the Renton gage for water years 1946–1991 supplied actual values. Elsewhere in the analyzed reaches of the river, flow-duration curves generated by the HSPF model for water years 1949–1989 under existing land-use and dam-operation conditions were the sole source of such information. To determine the reliability of the HSPF simulation for sediment-transport purposes, sediment transport in the canal was calculated using both daily gage flows and the HSPF flow-duration curve. Results using the two data sets were consistently within 12% of each other; and so the HSPF flows, available for the entire river, were used throughout.

Predicted Transport and Deposition Rates Calculated transport capacities for each of the 5 stations are graphed in Figure 5-13. The difference between calculated bedload transport at adjacent stations represents the potential deposition (where the rate is declining) or scour (where the rate is increasing). Along most of the lower 15 miles of the Cedar River (and probably well upstream as well), transport rates are nearly uniform and so predicted average deposition rates are very low. If the calculated deposition rate of 600 tons per mile of channel per year were evenly distributed along and across the channel, for example, it would represent an infilling of less than 1/4 inch per year. In addition, this deposition rate is calculated from transport rates with less than 10% difference between them, well within the error bounds of the method and so probably negligible. A few site-specific measurements show that some specific localities, however, have had up to several feet of bed-elevation change during the last several decades.

The calculated results also display graphically what is well recognized by many—deposition rates increase dramatically in the lower 2 miles of the river. About one-third of the transported bedload is predicted to settle out in this reach; the balance would come to rest shortly after reaching Lake Washington, where the flow of the Cedar River dissipates rapidly. The actual amount of deposition, however, will depend on the sediment load being carried by the river—if capacity is high but actual amount being carried is less, the measured deposition rate will be reduced as well.

This dramatic decrease in transport capacity raises an additional complication in calculating sediment deposition. Suspended sediment, that finer part of the river's load that normally travels up in the water column, is not accounted for in bedload transport equations but can nevertheless become a significant fraction of the deposited sediment in a low-gradient reach. Conversely, transport of bedload typically is assumed to cease by the time a river reaches a standing water body, such as Lake Washington; yet bedload-sized sediment may in fact travel some distance out into the lake and form part of the delta. In the Renton Reach of the Cedar River, the largest size of sediment likely to move in suspension at most bedload-transporting flows is about 0.5 millimeters, calculated by comparing the settling velocity of the sediment particle (which increases with increasing diameter) with the "shear velocity" of the flow (namely, the square root of the shear stress divided by the density of water, $[\tau/\rho_w]^{0.5}$). Along the canal, sediment of this size makes up 10% or less of the bed, suggesting that suspended sediment is <u>not</u> a

Figure 5-13


PREDICTED ANNUAL BEDLOAD TRANSPORT CAPACITY
LOWER CEDAR RIVER
ANNUAL AVERAGE BEDLOAD (tons/year)
70000
60000
50000
40000
30000
20000
10000
0
AVG DEP
10,000
t/mi/yr
AVERAGE DEPOSITION
600 t/mi/yr
DATA SOURCE
Gage Record
Simulated
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
RIVER MILE

significant component of the deposition here. Conversely, one-quarter to as much as one-half of the sediment in the delta built into Lake Washington is composed of sediment larger than 0.5 mm (Golder, 1992) and thus reached the delta as bedload, passing through the canal altogether.

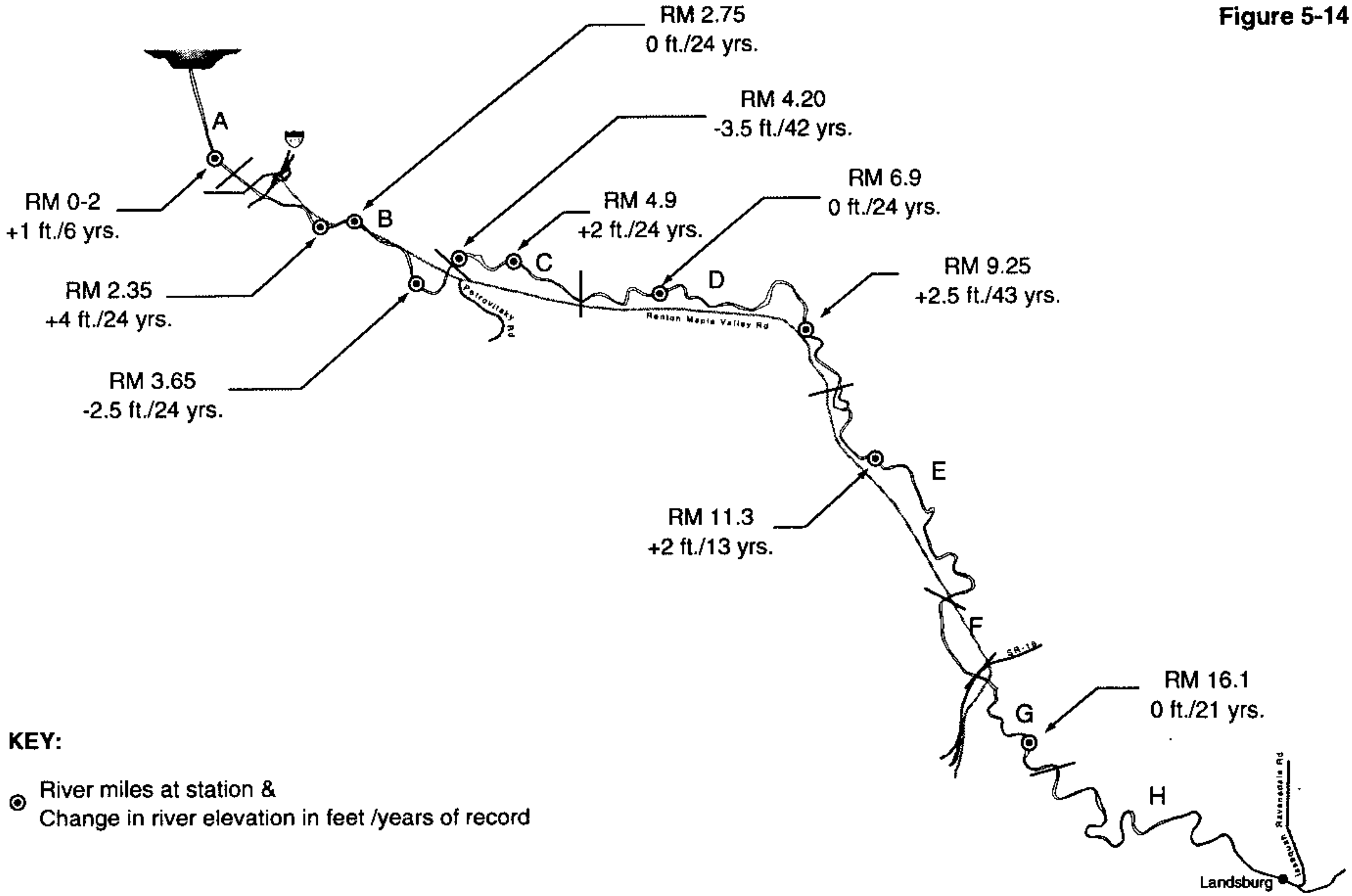
Average transport rates obscure the range of annual variation. Using the 45-year record of gaged flows at Renton, predicted annual bedload transport rates varied from as little as one-quarter the average value to as much as double that rate. The calculated median transport value was very close to the average value, and so any given year is as likely to lie above as below the long-term average. If an above-average year is encountered, however, the predictions of this model suggest that the unanticipated sediment rate would be no more than double the average rate. Such variability would almost certainly be obscured by the much greater potential variability in the supply of sediment.

Comparison of Calculated Transport Rates with other Information Two types of independent data are available to check the results of the transport calculations. The first is the regionally determined rates at which drainage basins of western Washington produce sediment (the "sediment yield"). No such data are available for the Cedar River Basin itself; but by analogy to other, similar basins (e.g., Nelson, 1971, for the Snohomish River basin) a rate of 200-1,000 tons/mi^2/yr is likely. This value represents the suspended load only; bedload, in contrast, is typically about a tenth or so of this value.

The area of the Cedar River Basin is 188 square miles; of that total, the upper 78 square miles lie above Chester Morse Lake. If only the lower 110 square miles are considered, no more than about 10,000 tons/year of bedload would be expected; if the presence of the lake were judged irrelevant, recognizing that sediment yield from a drainage basin is the result of flows eroding the banks of the lower channel as well as sediment physically carried from the upper basin, this amount of bedload might be nearly doubled. Because of the additional effects of Chester Morse Dam on reducing flows, the likely rate of transport is probably intermediary between the two conditions and very unlikely to exceed 15,000 tons/year.

This rate of bedload-sediment production is exceeded by the calculated bedload-sediment transport capacity by a factor of 4. This difference is within the plausible error range of the Bagnold equation; but a more likely explanation is that the Cedar River is a supply-limited system, where the transport capacity exceeds the availability of sediment to transport. This imbalance is reflected in the physical form of the river channel and river bars, where sites of active gravel bars are very limited in both size and distribution. The relative downstream change in transporting ability along the channel is probably well represented by our calculations, but the absolute magnitude of the predicted rate of movement is several times too high. Any change in the drainage basin that supplied additional sediment to the river, however, would result in fairly rapid transport of that sediment away from the site of its introduction and towards its ultimate deposition in the lower 2 miles of channel and (or) the delta just beyond.

Figure 5-14



Location of Scour and Deposition Along the Mainstem

Recent surveys permit an additional check on the calculated rates of transport. In the lowermost reach of the Cedar River, NHC (1992) resurveyed 25 cross sections in the lower 2 miles of channel after 6 years and estimated that about 8,000 tons (6,000 cubic yards) had deposited annually. Golder's (1992) survey of the delta result in an estimated volume of 831,000 cubic yards (Harza, 1992), or about 1.1 million tons of sediment (of which about one-third was of a size likely transported as bedload). If we add to this amount the 451,000 tons of (bedload) sediment removed from the lower river and 5,000 tons from the delta since 1940 (as estimated by Harza, 1992) and perhaps 80,000 tons of (bedload) sediment that has accumulated in the lower channel since the last dredging in 1982, the result is about 900,000 tons of bedload-size sediment in the lower channel and delta since 1940, for an annual bedload-sediment basin yield of 15-20,000 tons per year, only slightly higher than that estimated from regional sediment yields. This is 2 to 3 times less than the bedload transport rates we predict in the lowermost 2 miles of river; the measured rate of channel infilling is also about 2.5 times less than the difference in transport rates calculated at RM 2.2 and RM 0.55.

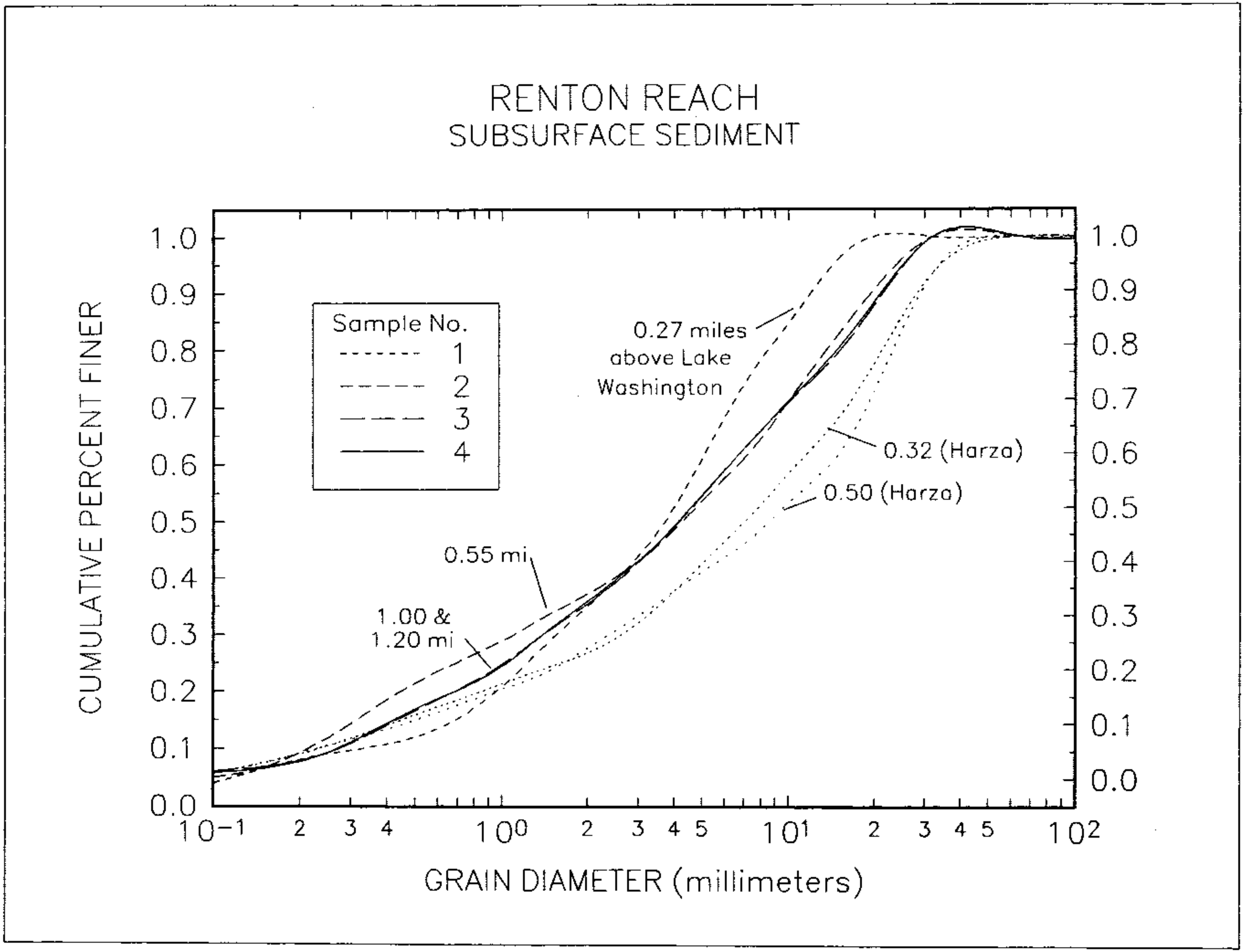
To determine rates of sediment deposition and scour upstream of RM 2.0, SWM staff resurveyed 11 channel cross-sections in October 1992. Data were also obtained from U.S. Army Corps of Engineers 1989 cross-sections, plans for bridges, and Washington Department of Transportation bridge resurveys. Rematching old survey locations was not always feasible, but plausible results were obtained at 11 locations shown in Figure 5-14.

Some cross-sections show scour while others show deposition, with no consistent trend from upstream to downstream. The magnitude of changes typically vary from 0 to 2 feet in a 24-year period, which are much lower rates than in the downstream two miles of the river. These results generally support the model's prediction of very little downstream change in sediment transport capacity above RM 2.2. The resurveyed cross-section at RM 2.35 showed four feet of deposition since 1968, suggesting that the depositional zone extends at least that far upstream.

Harza (1992) also calculated bedload transport in the lower channel using the Meyer-Peter bedload equation. Their results are significantly different from those presented here and are much closer to the measured rates of channel infilling. The reason for the differences between the two analyses are almost entirely a result of the sediment samples: using equivalent sediment data in the two different transport formulas yields almost identical results, but the median grain diameters used by the two studies in fact differ by a factor of two.

Sampling timing and location may be critical in explaining this difference, in that the Harza samples were taken in mid-channel in February 1992, whereas our samples were collected from low alternate bars along the channel margin during low water in September 1992. Figure 5-15 compares the grain-size distribution of samples in the Renton Reach; even with plotting an assumed loss of 5% of the finest size fraction during collection of the Harza samples, the populations diverge markedly. Using our sampling

Figure 5-15



RENTON REACH
SUBSURFACE SEDIMENT
CUMULATIVE PERCENT FINER
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Sample No.
1
2
3
4
0.27 miles above Lake Washington
0.32 (Harza)
0.50 (Harza)
0.55 mi
1.00 & 1.20 mi
10⁻¹ 2 3 4 10⁰ 2 3 4 5 10¹ 2 3 4 5 10²
GRAIN DIAMETER (millimeters)

convention along this reach of the river was not strictly possible, because point bars do not in fact exist along this straight reach. Thus, our collected samples probably do not represent the range of sediment actually in motion, resulting in too fine a measured sediment load and so too high a calculated rate of transport. In contrast, the Harza calculation of bedload transport rates is probably too low, as their rate of transport cannot account for the full measured aggradation of bedload sediment in the canal and the delta together since 1940.

IMPLICATIONS FOR SEDIMENT MANAGEMENT AND FLOODING

There are several conclusions that arise from the comparison of independent information with the transport calculations. Although the Bagnold equation likely overpredicts transport in the Cedar River by a factor of 2 or 3, its application nevertheless yields certain useful results. The flux of bedload sediment through the lower channel is several times larger than the amount of material that is actually deposited. On average, significantly more than 10,000 cubic yards of bedload sediment will pass the I-405 bridge each year; half or less of that material will be subsequently deposited in the channel just upstream of Lake Washington, with the balance coming to rest at the mouth of the river. A sediment trap above the lower 2 miles of channel would need to accommodate 20,000-30,000 tons of sediment annually, on average, to be effective. Any large new inputs of sediment to the river, of the scale seen at the Maplewood slide in 1987, could be readily transported within a year or two and so added rather rapidly to this underlying rate. In particularly large floods the amount of rapid deposition will be determined in large part by the availability of landslide-delivered sediment.

Avoidance of future landslides of a scale similar to that at Maplewood is critical in avoiding rapid and unanticipated deterioration of sediment conditions downstream. The main sediment sources, however, are small tributaries above Landsburg and small-scale landslides and bank erosion along the mainstem below Landsburg. These mainstem sources cannot be readily controlled without even more bank protection than presently exists, with prohibitively high costs and additional loss of aquatic resources.

Thus the problematic condition recognized for the Cedar River is not "excessive" sediment loading of this river system; indeed, throughout most of its length the river is presently limited in sediment supply as is. Instead, the oft-recognized problems of the lower channel represent the intensive development of flood-sensitive land uses in a natural zone of sediment deposition, now enhanced by the 1912 rerouting of the Cedar River and the immovability of its present course. Trapping of sediment before it enters the zone of greatest impact, namely the lowermost 1.5 miles, may not be feasible, owing to the large volumes of material that pass through the lower river system. If maintenance of channel capacity to reduce flooding ultimately is judged to be an overriding management goal of the basin plan, periodic removal of that sediment by dredging in the channel itself is probably inevitable, although the frequency of sediment removal may be significantly affected by management of the channel and riparian corridor farther upstream.

5.6 KEY FINDINGS: EROSION AND SEDIMENT DEPOSITION

TRIBUTARY STREAM CHANNELS

- ★ Many tributary channels show evidence of downcutting and accelerated sediment production above natural levels where they drop steeply down the valley sides. Upon reaching the valley floor, channel gradients drop abruptly and the streams deposit sediment prior to reaching the Cedar River. The sediment clogs drainage ditches and stream channels, damages structures, and adds to existing alluvial fans. Erosion and deposition problems are minimal, however, on the gently-sloping plateaus above the Cedar River valley.

- ★ The most severe erosion problems occur on tributaries that enter the Cedar River downstream from Maple Valley, and in particular in the high-density, developed lower end of the valley. Upstream from Maple Valley, erosion problems are rarer and less severe, due to less development, moderation of streamflow by permeable outwash soils, and gentler slopes.

- ★ The most severe channel incision has occurred on Madsen Creek and on many small, very steep streams that flow down the sides of the Cedar River valley. Due to their steep slopes and marginal stability, even slight increases in runoff from upslope development can cause rapid channel incision and slope failures on these small streams.

- ★ Many stream channels have responded to flow increases by eroding their bed and banks to expand their channel dimensions. When the former forested 10-year discharge becomes more frequent than the two-year flow, channels tend to become extremely unstable, with rapid severe downcutting and widening, often accompanied by landsliding.

- ★ Based on modeled future flow increases, severe future channel erosion problems are likely in five subbasins that currently have stable channels. These subbasins are Cedar Hills (0316), Dorre Don (0336), Rock Creek (0338), North Fork Taylor Creek (0321), and Webster Lake (0317). Future flow increases could also cause new erosion problems in small, steep catchments on the valley sides.

CEDAR RIVER MAINSTEM

★ Chester Morse Dam has greatly reduced the flood flows that transport the river's sediment load. Reduced flows appear to be the cause of an approximate 30% decrease in river channel width between 1865 and 1936.

★ River banks have been extensively armored with revetments, which have greatly reduced bank erosion as well as channel migration. Construction of levees and revetments appear to be the major cause of an additional 35% decrease in river width since 1936.

★ The Cedar River now occupies only approximately 45% of its area at the turn of the century. Many sections of the river that formerly had multiple channels now have only a single channel. The decrease in area and complexity of river channels has resulted in corresponding losses of sediment storage sites as well as riverine habitat.

★ Where not constrained by revetments or erosion-resistant cliffs, average long-term bank erosion rates on the Cedar River have ranged from 6 to 11 feet per year.

★ Sources of sediment to the Cedar River study area are the basin area from Landsburg to Cedar Falls, tributary streams in the BPA, and erosion of banks and riverside cliffs along the mainstem. Although major landslides from riverside cliffs occur infrequently, they can deliver large amounts of sediment to the river in a short time and worsen sediment deposition problems downstream.

★ The river's ability to carry sediment drops rapidly in Renton, where its gradient flattens. Sediment is continually deposited in the downstream two miles of the river and in the delta in Lake Washington. Periodic dredging of sediment from the channel and delta was discontinued in about 1982. The sediment build-up since 1982 has severely reduced the size of flood that the channel can convey (see *Chapter 4: Flooding*).

★ The movement of coarse sediment into the Renton Reach averages over 10,000 tons per year and is largely limited by the existing upstream supply of material. Only one-half or less of the sediment flux entering the Renton Reach is actually deposited in the channel; the balance adds to the delta growing into Lake Washington. New sediment sources (particularly from large landslides) could appreciably worsen existing rates of channel infilling.

★ The Cedar River does not carry an "excessive" sediment load; instead, deposition and loss of flood capacity in the Renton Reach is an inescapable consequence of basin geometry, further enhanced by an artificially constrained channel.

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Chapter 6: Water Quality

6.1 INTRODUCTION

Historically, the water quality in the basin has been prized as the drinking water supply for millions of people served by the City of Seattle Water Department facilities in the upper basin. In recent years, however, the lower portions of the basin have been under considerable development pressure. With the attendant population increases, water quality in the basin planning area (BPA) has become increasingly degraded. Although the effects may appear subtle now, they are expected to become more obvious with population increases. High concentrations of typical urban pollutants can be found in the smaller tributaries where they can affect aquatic biota or groundwater supplies. Often these contaminant concentrations are diluted by the high volumes of water in the mainstem of the Cedar River. However, this dilution does not lessen the effects in the tributaries or in the receiving water bodies. The Cedar River contributes over 50% of Lake Washington's water; therefore, the quality of the Cedar River will have a direct effect on the quality of Lake Washington. Nonpoint sources, compared to point sources, are the main contributors to the degradation of water quality in the BPA.

In accordance with the Nonpoint Rule, Chapter 400-12 of the Washington Administration Code (WAC), the Watershed Ranking Committee ranked the Lower Cedar River Watershed (the area between Lake Washington and Maple Valley) as the number one watershed for nonpoint pollution planning in King County (King County Watershed Ranking Final Report, 1989). Criteria used to determine the ranking included water quality, beneficial uses, nonpoint pollution sources, increasing development pressures, naturally occurring environmental factors, opportunity for prevention of nonpoint pollution before correction is necessary, and evidence of local commitment to water quality and inter-jurisdictional programs. The Lower Cedar River Basin was ranked number one due to the relative importance of its natural resources and the need to protect the area from further water quality degradation.

6.2 WATER QUALITY CONCEPTS

In general, a pollutant can be defined as any substance that degrades the quality of water and impairs the beneficial use of a waterbody. Sources of pollution can be natural or a result of human influences. Examples of natural pollutants are sediments and nutrients. The influence of human activities can increase the amount and rate at which these pollutants are released into the water system. Sediments naturally occur in virtually all surface waters, but an excess of suspended or deposited fine sediments can be detrimental to aquatic life. Sediment can adversely affect aquatic vegetation and thereby damage habitat for aquatic fauna and can "cement" the spawning gravels (see *Chapter 7: Aquatic Habitat*). In addition, pollutants tend to adhere to fine sediments, which then become the mode of transport or accumulation of the pollutant. Accumulated pollutants in sediments can threaten the benthic community and food chain. Removal of sediments can also provide a method of pollutant removal. Nutrients are necessary for plant growth, but an excess of nutrients can cause excessive aquatic plant, phytoplankton, or algae growth, often referred to as "blooms." Phosphorus is typically the limiting factor in fresh water aquatic systems, but, depending on the system, nitrogen can also trigger excessive plant growth. These "blooms" often utilize large quantities of dissolved oxygen in the water and reduce the available oxygen necessary to support aquatic life. In addition, certain kinds of algal blooms (e.g., blue-green algae) can disrupt aquatic food webs. Nitrates are a human health concern in drinking water and can become a problem when infiltrated into groundwater. Excess nutrient sources include failing septic systems, animal wastes, and fertilizers. Human and animal wastes can also cause health hazards by contributing disease bacteria. Pollutants from human influences include chemicals, pesticides, and metals (e.g., lead, cadmium, copper, zinc) are toxic to both human and animal life. A major source of these pollutants is road runoff; oils/grease and fluids drip from vehicles, while tire and brake wear contribute heavy metals.

Point source pollution originates from a definite source such as an outflow from an industrial waste pipe, is readily identifiable, and can be traced to a particular individual residence, business, or activity. Point source pollution can therefore be treated or controlled directly at the source. Point sources discharged into surface waters are regulated by the Clean Water Act and require a National Pollutant Discharge Elimination System (NPDES) Permit for municipal and industrial wastes. The Washington State Department of Ecology (DOE) may require a State Waste Discharge Permit to discharge stormwater into the groundwater through infiltration processes. These permitting systems establish discharge limitations for specific chemical parameters, specify practices for limiting discharges of contaminants, and require monitoring of discharges.

In contrast, nonpoint source pollution does not originate from a specific point such as a pipe. Instead, it originates from diverse sources that enter surface waters and, in combination, can degrade water quality. Some forms of nonpoint pollution originate from routine daily activities, such as driving a car, that most people do not identify as sources of water quality problems. Other potential sources of nonpoint pollution that currently cause water quality problems in some areas of the Cedar River Basin include agriculture (small noncommercial farms), urbanization (i.e., construction and stormwater runoff), failing onsite septic systems, improper pesticide/fertilizer applications, hazardous wastes, underground storage tanks, landfills, resource extraction, and forestry operations.

BENEFICIAL USES

The characteristic beneficial uses for the Cedar River and its tributaries include: water supply (domestic, industrial, agricultural), stock watering, fish and shellfish rearing, wildlife habitat, recreation (including primary contact recreation, sport fishing, boating, and aesthetic enjoyment), commerce, and navigation (Chapter 173-201A WAC, Water Quality Standards for Surface Waters of the State of Washington). These uses fall into five main categories: 1) water supply, 2) recreation, 3) aesthetics, 4) fisheries and wildlife, and 5) wetlands. Fisheries and wetlands are discussed in *Chapter 8: Aquatic Habitat.*

Water Supply

Soos Creek Sewer and Water District, Cedar River Sewer and Water District, Water District 90, and the City of Renton supply water to the residents of the Cedar River Basin (Map 11, *Appendix B*). The water service areas are concentrated in the more urban/residential areas of the basin, primarily within and adjacent to the Renton city limits. Private residential wells provide the remaining water supply for basin residents.

The City of Renton's water supply is from an aquifer located within the Renton city limits and extending into unincorporated King County, within the Cedar River and May Creek basins. Water is extracted from this aquifer at a wellfield near downtown Renton. Renton is also developing a wellfield in the area of the Maplewood Golf Course. The Environmental Protection Agency (EPA) has designated the Renton aquifer as a "sole source aquifer." This designation recognizes that the aquifer is the City's only source of water and mandates additional protection measures against contamination of the City's water supply. Renton has designated certain areas as Aquifer Protection Zones and has adopted an aquifer protection ordinance to further protect the water supply from contamination. These zones currently do not extend into unincorporated King County. The City aquifer protection ordinance provides additional protection to the aquifer by restricting land-use activities in areas that have the potential to contaminate the aquifer.

Other municipal water supplies within the basin include the City of Seattle Watershed above Landsburg Dam (outside of the BPA), which supplies both the Soos Creek and the Cedar River Water and Sewer Districts, and the City of Kent's wellfield within the Rock Creek Subbasin, which provides 70% of Kent's drinking water.

Surface-water contamination can also be a groundwater contamination source. Surface water and groundwater interact in areas of recharge and discharge. If a pollution source is located in a recharge area, depending on the underlying geology, there is the potential for the contamination of shallow aquifers. The areas of high recharge are the most vulnerable to contamination, and any source of nonpoint pollution could potentially contaminate the groundwater. Recharge areas were mapped (Map 6, *Appendix B*) for the Cedar River Basin, based on the soil, surficial geology, topography, and depth to water. .

This map of potential recharge areas is the first cut in determining whether there is a threat to groundwater quality. Final determination is dependant on the underlying geology.

Recreation and Aesthetics

The Cedar River provides a wide variety of recreational (see *Chapter 1: Introduction, Recreational Land Use*) and aesthetic resources to residents and visitors by virtue of its interconnected system of streams, lakes, and wetlands. In addition, several parks, hiking trails, and equestrian trails have been developed or proposed to feature the scenic views afforded by water bodies. Water resources provide active recreation opportunities such as swimming and wading (primary contact), and fishing and boating (secondary contact). They also provide passive recreation opportunities through their high aesthetic value, such as the visual quality of the Cedar River, which provides unity and variety within the landscape.

The recreational and aesthetic beneficial uses depend on preservation of water quality, which in turn depends on the overall health of the basin's land and water resources.

STANDARDS

Water Quality

One of the main objectives of the Basin and Nonpoint Action Plan is to protect the resources or beneficial uses of the Cedar River Basin. Water quality standards (Chapter 173-201A WAC Water Quality Standards for Surface Waters of the State of Washington) establish use and quality criteria to protect the water resources of the state. Surface waters are defined by classes depending on a waterbody's existing water quality and beneficial uses. Water quality standards are established to protect and maintain the beneficial uses for each class, such as water supply and recreation. These standards are consistent with public health goals and the protection and propagation of fish, shellfish, and wildlife. The standards apply to the following parameters: fecal coliform bacteria, dissolved oxygen, total dissolved gas, temperature, pH, turbidity, and aesthetic value impairment. Table 6-1 displays these standards for both Class AA and A.

All surface waters are required to meet both acute (short-term) and chronic (long-term) toxic criteria for the protection of aquatic life. Metal toxicity is dependant on the water hardness; in general, the softer the water, the more toxic the metal. Acute and chronic criteria are determined by the water hardness. The result of acute toxicity may be death and is based on death due to exposures to high concentrations over a short period of time. However, chronic toxicity may result from extended exposures to lower concentrations and has less observable results, such as behavioral changes (loss in competitiveness) or reproductive failure. The observation period is often the lifetime of the organism or the timespan of more than one generation.

Table 6-1 Summary of Water Quality Criteria

Variable	Washington State Class AA	Washington State Class A	Basin Plan Threshold Value
Fecal Coliform	50 colonies/100 ml	100 colonies / 100 ml	
Temperature	< 16 ° C	< 18 ° C	
pH	6.5 to 8.5	6.5 to 8.5	
DO	> 9.5 mg/l	> 8.9 mg/l	
Turbidity	< 5 NTU over background	< 5 NTU over background	
Total Phosphorus			.02 mg/l
Total Suspended Solids			50 mg/l
Nitrate + Nitrite - Nitrogen			1.25 mg/l
Toxics	Calculated based on water hardness		

The state currently categorizes the Cedar River and its tributaries as Class A (excellent) from Lake Washington to the Maplewood Bridge (SR-169 overpass, RM 4.1), and Class AA from the Maplewood Bridge to the Landsburg Dam (RM 21.7). Waters under AA classification are characterized as "markedly and uniformly exceeding the requirements for all or substantially all beneficial uses." Therefore, this chapter discusses current and future water quality in the basin for both Class AA and Class A criteria.

Three parameters, commonly used to evaluate the existence of a water quality problem, do not currently have criteria for the protection of aquatic life. These include the nutrients, phosphorus (total phosphorus, TP) and nitrogen (nitrate+nitrite-nitrogen), and total suspended solids. The DOE is currently considering establishing nutrient criteria for the water quality standards (E. Schlorff, pers. commun.,1993). For the purpose of this report, basin plan threshold values of 1,250 µg/l as nitrate+nitrite-nitrogen and 50 mg/l Total Suspended Solids were set to allow comparisons of sampling sites and to identify problems. These threshold values, although highly subjective, were arrived at by reviewing other study results, water quality monitoring data, and the professional judgment of King County SWM Division staff (Table 6-1). The total suspended solids threshold is based on a study of the effects of suspended solids macroinverebrate and benthic invertebrate populations (Gammon, 1970).

To reduce algal growth and maintain water clarity, total phosphates (TP) as phosphorus (P) should not exceed 50 µg/l in any stream at the point where it enters any lake or reservoir (US EPA, 1986). The current phosphorus concentration in the south end of Lake Washington, the receiving waters for the Cedar River, averages 20 µg/l. Any increase in phosphorus loadings will pose a water quality problem for Lake Washington (J. Frodge, pers. commun.,1993). Therefore, a basin threshold of 20 µg/l will be used to maintain the quality of Lake Washington.

Sediment

The DOE is developing numeric criteria for fresh water sediments pursuant to Chapter 173-204 WAC. These standards are intended to serve as the basis for management or direction of pollutant discharges, thereby reducing and ultimately eliminating adverse effects on biological resources and significant health threats to humans from surface sediment contamination (Chapter 173-204 WAC). Standards have been established for marine sediments, and DOE is establishing standards for fresh water sediments. Until these standards are adopted, DOE is providing guidance in "Summary of Criteria and Guidelines for Contaminated Freshwater Sediments" (DOE, 1991). These guidelines are based on a compilation of criteria from various sources and will be used by DOE in the development of Washington State freshwater sediment standards. Parameters addressed in this guidance include metals, pesticides, chlorinated organics, and other compounds.

Groundwater

Groundwater quality standards for the State of Washington are defined in Chapter 173-200 WAC.

PERMITS

The 1972 federal Clean Water Act amendments require that all point source dischargers of pollutants obtain an NPDES permit, which, depending on the discharger, regulate the quality of water that can be discharged. Historically, this permit was issued to industrial and wastewater treatment facilities.

The 1987 Clean Water Act amendments expanded the permitting system to include industrial and municipal stormwater discharges. Industries that fall within specific industrial classifications are required to obtain, and are in the process of obtaining, a NPDES stormwater permit. No permits have been issued in the Cedar River Basin, and the number of specific permits that will be required in the basin is unknown. Municipalities with a population of over 100,000 are required to obtain a NPDES municipal stormwater permit. King County has applied for a municipal stormwater NPDES permit for the unincorporated portions of the basin. Smaller municipalities, such as Renton, will be required to obtain a NPDES permit, but the procedures and timetables have not yet been determined. The DOE has recently proposed a watershed-based process that would permit all industrial and municipal stormwater discharges within a watershed.

The State Waste Discharge Permit Program (Chapter 173-216 WAC) regulates the discharge of waste materials from industrial, commercial, and municipal operations into ground and surface waters. This permitting system covers the discharge of pollutants not addressed by the NPDES requirements.

The DOE has issued two permits within the Cedar River Basin. The City of Seattle has a NPDES permit for discharges of chlorinated water (RM 3.8) from the municipal water plant and pumping facility in Renton. In the past, chlorinated water has been discharged, due to malfunctioning dechlorinating equipment, and caused localized fish kills (P. Olson, pers. commun.,1993). The Stoneway Batch Plant has a State Waste Discharge Permit that sets controls for onsite infiltration of process water. Cedar Grove Composting has applied for a State Waste Discharge permit for the infiltration of compost contaminated water in its process ponds but has been required to obtain a NPDES permit for discharges into an adjacent stream (Tributary 0316A).

6.3 DATA COLLECTION AND ANALYSIS METHODS

Due to the difficulty of identifying and isolating nonpoint pollution, a combination of source identification and assessment of the resulting water quality conditions has been used to determine existing and potential water quality problems. By using these two approaches, a comparison between identified sources and the extent of water quality degradation throughout the basin can be made.

SOURCE IDENTIFICATION

Potential nonpoint sources in the BPA were identified by assessing the land uses and human activities in the basin. Activities thought to contribute to nonpoint pollution were determined by indirect means depending on the potential source. Methods used include reviews of existing preventive programs and their effectiveness, file searches of reported problems, operational assessments of businesses/activities, and field observations. Likely nonpoint sources include forest conversion and development (i.e., logging, land clearing, and grading), urbanization (i.e., increase of impervious surfaces and runoff of land-use linked contaminants), onsite sewage disposal, agricultural activities, waste management, pesticide applications, underground storage tanks, small quantity hazardous waste generators, and resource extraction. Identification of each of the above mentioned sources is described in Section 6.4. Differing methods used in the analysis are discussed in relation to each of the sources described below.

WATER QUALITY ASSESSMENT

In addition to identifying the potential range of nonpoint pollution problems in the BPA, water quality problems were also identified by examining the chemical composition of the water and sediments. Comparisons of water quality sampling results were made with State Water Quality Standards for Class AA and A waterbodies, EPA water quality criteria, and State Board of Health drinking water regulations.

Water quality assessments were made by examining existing water quality data from monitoring points throughout the basin. Existing conditions were assessed using historical data, ambient (non-storm) data, storm water quality sampling data, and field surveys. Data used in this assessment were collected from Metro's Freshwater Assessment Program, DOE's monitoring, King County Solid Waste Division's monitoring, SWM's stormwater monitoring program, sediment sampling, and additional sampling of identified problems in the basin.

Ambient conditions, which are typically determined by baseflows, give an indication of the continuous quality of the water. These conditions are monitored by Metro and, to a lesser extent, DOE. Metro has sampled at several locations in the basin, but the extent of sampling and analyses at each site varies greatly. Many of the sampling locations have been abandoned and/or data is outdated and not representative of existing conditions. Data from DOE is limited to conventional parameters such as dissolved oxygen, temperature, and pH.

Storm events wash accumulated pollutants into the streams. The type and amounts of pollutants washed off during storm events is dependent on the type and extent of land uses, the amount of time pollutants have accumulated since previous storms, and the size of the storm. By sampling storm events, "hot spots" or problem areas can be identified. In addition, current and future pollutant loadings can be predicted based on land uses.

Sediment samples provide a good indication of problems that could be easily missed in water quality samples. Many contaminants tend to adhere to sediments and settle out, leaving a historic record of loadings or periodic releases of contamination into the system.

An assessment of the current water quality, based on the chemical composition, is described in Section 6.5. Section 6.6 predicts future conditions based on changes in land uses. Water quality problems, by subbasin, are discussed in Section 6.7.

DETERMINATION OF PROBLEM SIGNIFICANCE

Once a water quality problem has been identified, the level of significance must be determined. Many factors contribute to the significance of a water quality problem. A framework for defining levels of significance was developed to describe those factors that influence the significance of the problem (See the Water Quality Appendix following this chapter). Each function or value (beneficial use) the problem is impacting is assessed as having a high, medium, or low significance level for both the extent and severity of the problem. The factors used in determining the significance are examined through questions addressing the reasoning or thought process used to assess the problem. An overall significance level is then given to each problem or potential problem identified.

6.4 NONPOINT POLLUTION SOURCE IDENTIFICATION

This section defines and evaluates the wide variety of activities that contribute to water quality degradation in the BPA from nonpoint sources. Nonpoint sources include: industrial forest practices, land conversion and development; urbanization and stormwater runoff; failing onsite sewage disposal (septic) systems; livestock keeping practices; improper pesticide/fertilizer applications; small quantity hazardous waste generators; underground storage tanks; waste management (landfill, transfer station, recycling practices); resource extraction; and other sources.

FOREST PRACTICES

The Puget Sound Cooperative River Basin Team (PSCRBT) conducted a survey of existing forest practices and forest conversion trends in the BPA (PSCRBT, 1992).

Industrial Forest Practices

Forest practices are defined as activities "conducted on or directly pertaining to forest land and relating to growing, harvesting, or producing timber," (RCW 76.09.010(19)). In this report the term "industrial forest practices" refers to perpetual-timber production activities. These activities are differentiated from forest practices that convert timberland to urban uses. Industrial forest harvest and management are not a major source of nonpoint pollution within the BPA (PSCRBT, 1992).

Forest land ownership includes large company holdings in the eastern part and scattered smaller ownerships varying in size from 5 to 80 acres in the BPA (Map 12). Long-term timber management is being practiced in 16% of the watershed, all above Maple Valley.

Private industrial forest land ownership comprises approximately 6,500 acres outside of the Seattle Watershed near Georgetown and in the eastern portions of the watershed. Nearby, in the Rock Creek Subbasin, there is a 300-acre tract managed by the City of Kent to provide most of Kent's drinking water.

The middle Cedar River basin is characterized by contiguous stands of Douglas fir and Western red cedar. These species are also found scattered or clumped among hardwood stands. Most of these lands are located on well-drained soils that exhibit low erosion potential. The sideslopes in these areas are flat, averaging 5 to 10%. Forest stands over ten years of age usually have full crown cover and present little concern for increasing runoff or erosion. Except where disturbance is severe and overland flow occurs, stabilization of bare soils occurs within one or two years (Geppert and others, 1984). Previous harvests should not pose an erosion problem because few harvests have occurred in the past two years.

The Department of Natural Resources (DNR) historical record of Forest Practice Applications (FPA) for industrial lands indicates a decline of acreage harvested since 1987 when 1,079 acres were recorded (Table 6-2). This acreage reduction trend is expected to continue during the next decade because a high percentage of commercial forest lands are in the 0-10 age class and will be unavailable for harvest (PSCRBT, 1992).

Table 6-2 Forest Practice Applications

	Harvest Permits			Conversions	
Year	Number	Acres	Road Miles	Number	Acres
1987	26	1079	3.5	6	32
1988	10	378	2.2	2	56
1989	10	334	1.8	3	77
1990	10	94	7.1	2	10
1991	10	134	1.6	2	129*

* one permit covers 120 acres for gravel mining operation

The City of Seattle manages approximately 90,000 acres in the upper watershed (from Landsburg to the Cascade Crest) primarily for the production of high-quality water supply and hydro-electric power. Permanent reserve areas will be established for long-term timber management. Secondary uses such as education, research, recreation, and timber harvest are currently being evaluated in relation to the primary management goals. Management practices in the upper basin will have a direct effect on the downstream resources, but because the primary management objective is to maintain high-quality water, adverse water quality impacts are not expected. However, the effects of contaminant inputs from the lower and middle basins tend to concentrate during low-flow periods.

Forest Conversion and Development

The BPA is characterized by intensive, widespread, urban and suburban residential development in and around Renton, with small farms, commercial uses, and large and small lot development scattered throughout the valley and adjacent plateaus. Land development and associated construction activities are two of the major contributors to nonpoint pollution in the area. Tree removal associated with forest conversion to residential and commercial uses has significantly increased water runoff and erosion.

Clearing and grading of forestland for conversion to more intensive uses can produce more sediment per acre than tree removal associated with clearcut or partial removal harvest. Increased site disturbance, including road construction, stump removal, grading, and attendant soil compaction, creates potential for serious erosion long before a site is stabilized. Furthermore, the phasing of construction on development sites often leads to prolonged soil disturbance. Natural erosion rates from forested or well-sodded prairies vary from 0.01 to 1.0 tons per acre per year while construction sites lacking effective erosion and sedimentation control measures erode soil at the rate of 50-500 tons per acre per year (DOE, 1988a). During storm events, the eroded soils deposit in streams, lakes, and wetlands where they can smother fish eggs and other organisms in these water bodies.

Many of the remaining timber stands that could be converted in the future are located along stream corridors and in other sensitive areas where eroded soils can readily enter surface waters. To assess future conversion activity in the basin, aerial photographs taken between 1985 and 1989, were compared. Generally, the subbasins closest to Renton are the most urbanized and have the least remaining forest cover. Areas that have recently experienced substantial forest conversion to residential development tend to be located along the urban fringe south and southeast of Cedar River, within the Madsen and Peterson Creek Subbasins. Between 1985 and 1989, 76 acres were cleared for four subdivisions in these subbasins. Residential developments in these areas have increased to the point where forest cover has been reduced to approximately 33 and 22% in the Fairwood and Madsen Creek subbasins, respectively. During the same period, 12 small sites (0.5 to 10 acres) and one 16-acre subdivision were cleared in the Peterson Creek Subbasin.

Presently, large parts of the Peterson Creek Subbasin remain relatively undeveloped, with approximately 73% of the subbasin still in forest cover. However, the eastern section of the subbasin, surrounding Lake Desire and Shady Lake, is currently zoned for urban densities. Several subdivision proposals are pending in this area, portending widespread land clearing.

Water quality and quantity problems have been previously identified in Lake Desire and associated wetlands (See *Chapter 7: Aquatic Habitat*). While the problems in Lake Desire are not well understood, increased runoff from the recently developed 16-acre subdivision, Shadow Ridge, has been identified as a possible source.

URBANIZATION

Urban watersheds have many types of impervious surfaces, including, buildings, sidewalks, highways, roads, driveways and parking lots. Sediments and other pollutants tend to accumulate on these surfaces between storm events, and then are washed off into storm drains or directly into streams during storms. Thus, surface-water runoff becomes the principal method by which pollutants are transported to lakes, streams, and wetlands. Urban development exposes the area to a wide variety of chemical substances from commercial and industrial activities. Pollutant types become more complex and variable with increasing urbanization.

Surface-water runoff represents both a quantity and quality problem in urban areas where land use has been converted from primarily forested and open space into large impervious surfaces in residential, commercial, and industrial areas. Peak streamflows associated with urbanization result in streambed scouring, erosion, and degradation of spawning and rearing habitat for fish. Typical pollutants found in surface-water runoff in urbanized watersheds include sediments, nutrients, pathogens, heavy metals, petroleum products, and organics.

Extremely high levels of heavy metals (including copper, zinc, and lead) were detected in stormwater and sediment samples at a stormdrain outfall (Logan Street) in the commercial area of Renton. Sediment concentrations of metals are considered to be in the "heavily polluted" range (see Section 6.5). As a result, the City of Renton is investigating commercial activities within this area that could be the source of these pollutants to the Cedar River via improper connections to the storm drainage system. Field inspections are being conducted at chosen sites to trace the sources of this contamination. Commercial discharges through improper connections (point sources) to the storm systems could be masking actual nonpoint contributions. Once these point sources are identified and corrected, nonpoint sources can be reevaluated.

Roads cross streams at numerous locations in the Cedar River Basin, and untreated road runoff is discharged directly to streams from the many roadways built before current surface-water design standards. Petroleum products, heavy metals from automotive tires and brakes, and atmospheric emissions (soot) are the common pollutants contained in this runoff. A recent study estimated that vehicle related uses, such as brake pad wear and atmospheric emissions, contribute over 50% of the mean annual nonpoint source loadings for copper into aquatic systems (SCVNSPCP, 1992). The wear of steel belted radial tires is a contributing source of zinc. Generally, runoff from most roads in the basin contains toxic metal concentrations. The acute copper toxicity standard was exceeded in 47% (40 out of 86 samples) of all stormwater samples taken throughout the basin. Acute metal toxicity in the tributaries can have a detrimental impact on the fauna in localized tributary reaches. In the past five years, over 16 miles of road have been constructed (Table 6-2), many of which drain into streams or other conveyances. Without mitigation, increased road construction and vehicle operation without BMPs will increase these pollutant levels. While toxic concentrations occur at times in the small tributaries, dilution in the mainstem often reduces the concentrations to below toxic levels. However, this does not lessen the impacts in the smaller tributaries. The influence of road runoff on water quality in the BPA is discussed in more detail in Section 6.5.

Stormwater from urban residential areas within the basin currently contains high levels of sediment, nutrients, fecal coliform bacteria, and metal toxicity (see Section 6.5). Future development without mitigation will make the problems worse.

ONSITE SEWAGE DISPOSAL SYSTEMS

Storm water quality data showed elevated levels of fecal coliform bacteria and nutrients throughout the basin. Fecal coliform bacteria, found in the intestines of warm-blooded animals, is an indicator of the presence of other pathogens. The two principal sources for this type of contamination are animal waste runoff from animal keeping activities and failing septic systems; both are potential health concerns. It is often difficult to separate the two sources from coliform counts in water samples, but an attempt to distinguish between the two sources by subbasin is discussed in Section 6.5.

The Cedar River Basin is currently served by three sewer districts. The City of Renton provides sewer service to areas within the city limits. The plateau areas of Fairwood are served by the Soos Creek Water and Sewer District, and a small area along Maple Valley Highway is serviced by the Cedar River Water and Sewer District. The Soos Creek Water and Sewer District has annexed the Lake Desire area and, in the future, may extend service to this area. The City of Renton has proposed to increase the capacity of the sewers in East Renton and to extend sewer service further east into the Maplewood Heights area. Map 13 in *Appendix B* shows the extent of existing public sewers. The remainder of the basin uses onsite sewage disposal systems.

A typical onsite sewage disposal system consists of a septic tank and drainfield. The system provides initial treatment of liquid-borne wastes and settling of solids before purification occurs in native soils. The average life expectancy of an onsite sewage disposal system is from 20 to 40 years, if adequately maintained. Increased septic system failures are common for systems over 20 years old.

Onsite sewage disposal systems become a nonpoint source of pollution to groundwater and surface waters when they begin to fail. By traditional definition, a system failure occurs when the volume of effluent exceeds the absorbent capacity of the soils and results in a backup in the plumbing or the release of partially-treated effluent onto the ground surface. This definition of failure represents only the most obvious sewage system malfunction, and does not address potential contamination of groundwater through inadequate treatment of effluent by surrounding soils. System failures are usually due to siting in marginal or unsuitable soils, inadequate design, inadequate construction, lack of maintenance, or abuse of the system.

Systems often show signs of prefailing when a malfunctioning system releases partially-treated effluent onto the ground surface but has not resulted in a backup of the system. Prefailing onsite systems typically display one or more of the following characteristics: 1) heavy lush growth over the drainfield area, which indicates sewage may be rising near the surface of the ground; 2) wet or swampy areas adjacent to or in the drainfield area; or 3) profuse growth of wetland plants over the drainfield area. These symptoms are a result of the backup and surfacing of effluent and, as mentioned previously, will not indicate inadequate treatment and potential groundwater contamination. Not all failing systems will display these symptoms and lack of these symptoms does necessarily indicate that a failure is not occurring. There are no visual characteristics that indicate problems associated with inadequate treatment of the effluent.

The ability to treat and absorb sewage effluent depends on the receiving depth, structure, and texture of the soil. Soils such as clays, or clay loams (i.e., Kitsap series) are efficient in filtering and attenuating contaminants but are limited in their ability to absorb effluent. Coarse soils (i.e., Everett series) have a substantial capacity to accept effluent, but high permeability renders these soils ineffective in removing contaminants. Septic systems installed on these highly infiltrative rocky or sandy soils or on steep slopes may fail due to the inadequate ability of the soil to absorb the effluent. The majority of soils in the Cedar River Basin are silt loam and sandy loam. These soils are moderately well drained with a dense impermeable glacial till layer at a depth of 20 to 40 inches on the plateaus and terraces.

In 1991, the Seattle-King County Department of Public Health (SKCDPH) reviewed the status of onsite sewage disposal system failures (SKCDPH, 1991a). The review included a file search of onsite sewage disposal records and a field survey within specific areas. Based on an examination of the files of 3,390 systems, failure rates ranged from 1 to 22% depending on the area reviewed. The average estimated failure rate for the basin is 8.8%. This is several times higher than the 3 to 5% failure rate for the entire Puget Lowland (PSWQA, 1989). The average failure rate for Puget Sound is based on reported conventional failures and is probably a low estimate for the region. However, the Cedar River failure rates are also based on reported failures within the basin, and can therefore be compared to the Puget Sound average.

Table 6-3, which compares repair rates and ages by neighborhood for the systems reviewed, shows that there are several neighborhoods with failure rates that far exceed the regional average. For instance, the lakes (Desire, Spring, and Shady) within the

Peterson Creek Subbasin have reported failure rates of 15.8, 11.5, and 22.6%, respectively.

Table 6-3 Septic System Failures in the Cedar River Basin Planning Area

Subbasin	Area	Number of systems	Repair Rate (%)	Average Age (years) Repaired	Nonrepaired
Rock Creek	Lake Retreat	40	5	11	15
Peterson Creek	Lake Desire	101	15.8	23	20
	Maple Valley Rd. & SE 162nd	261	9.2	27	21
	Spring Lake	78	11.5	20	14
	SE 192nd & 208th SE	100	1	18	13
	Shady Lake	53	22.6	20	21
Taylor Creek	Dorre Don	208	6.7	12	10
	Hwy 18 & 236th SE	238	5.5	22	16
Lower Cedar River Subbasins	Maplewood Heights	121	13.2	23	20
	Maplewood Heights	475	13.1	27	26
	Maplewood Heights	674	4.8	20	19
	Maplewood Heights	409	3.9	20	19
	Maplewood Heights	229	8.7	26	22
Lower Cedar River Mainstem	Wasmita Park	123	15.4	27	26
	Jones Road	116	13.8	29	20
	Maple Valley Road	164	16.5	19	19
TOTAL		**3,390**			

Field inspections were conducted in areas with clusters of malfunctioning onsite systems. Of 469 systems examined, 33 (or 7%) were found to be failing or prefailing. These results likely represent the current condition of onsite sewage systems throughout the basin because many failures are not reported or otherwise documented. The survey also revealed that 15 of the 33 failing or prefailing systems had either marginal or inadequate reserve area in which to make repairs. The inability to repair such systems results in repeated overflows and environmental contamination. As a standard practice, the health department does not take action for prefailure conditions, although owners are required to repair failing systems. According the Health Department, if a failed system has inadequate reserve area, construction of an alternate system (such as a mound system) will be required to adequately treat the wastes.

Prior to 1970, onsite sewage disposal systems were generally designed for disposal, not treatment of wastewater. These older systems account for approximately 40% of the systems reviewed and surveyed, and may be a source of groundwater contamination if located in areas with high aquifer recharge potential. The survey also revealed that only 13% of the systems within the study area had maintenance records. This lack of maintenance may lead to even higher failure rates in the future.

ANIMAL KEEPING PRACTICES

Animal keeping practices in the BPA are currently, and are expected to remain, a significant source of nonpoint pollution if best management practices (BMPs) are not used in the future. Land-use trends are toward smaller land ownership with numerous small noncommercial farms. These small noncommercial farms often have higher densities of animals than the land can support without good management practices. Streams and wetlands provide a convenient and inexpensive source of water and pasturage for livestock. However, unrestricted animal access to these waterbodies contributes pollution both from animal wastes and eroded banks trampled by livestock. In addition to direct access to waterbodies, stormwater can wash excess nutrients and bacteria into the water system. Several studies have isolated animal-associated enteric viruses and bacteria that can be transmitted to humans in stormwater or surface waters in urban, rural, and agricultural watersheds, indicating that the disease-causing potential of these sources cannot be overlooked (O'Shea, 1992). Streambank destruction eliminates the riparian vegetation that filters pollutants. In its statewide assessment of nonpoint pollution, the DOE stated that "the primary water quality threat created by noncommercial farms was due to poor animal-keeping practices" (DOE, 1988a).

A recent study conducted by The Puget Sound Cooperative River Basin Team (PSRBT) and King County SWM located and evaluated the condition of each farm site in the basin in relation to water quality (PSCRBT, 1992). Sites were located by examination of aerial photographs and by windshield surveys of the basin. The study identified 487 animal-keeping sites (Map 14, *Appendix B*). The highest concentration of these farms is north of the community of Maple Valley in the Taylor Creek Subbasin. Most of the sites were small noncommercial farms characterized by a few animals on no more than five acres of land. Livestock actually seen during the survey includes 670 horses, 165 beef cattle, and 148 "other" (e.g., sheep, goats, mules, llamas). However, actual livestock numbers in the basin are assumed to be higher since livestock were not visible on 16% of the sites and more animals may have been present than were actually seen. Daily waste volume from these animals is estimated at 53,000 pounds, or the equivalent amount of wastes produced by a human population of 11,000.

Lot sizes in this area are five acres or less and the amount of land available for the livestock on these sites is usually less. Many sites (43%) had fewer than three horses per acre. Table 6-4 shows the distribution of farm size and the livestock density (animal units per acre of utilized pasture). This table also shows that most of the pastures are small (five acres or less), and that animal densities exceed the capacity of the pasture to support them (discussed later). The density of livestock on a farm site, however, does not in itself pose a nonpoint pollution problem if animal keeping best management practices (BMPs) are followed. However, the absence of BMPs in combination with high animal densities, dramatically increases the potential for chronic nonpoint pollution. The livestock survey showed that farm BMPs were implemented on very few sites.

Table 6-4 Distribution of Livestock by Farm Size in the Cedar River BPA

TOTAL FARM SIZE	Farms #	Farms %	Average Livestock Density AU/ pasture acre
Less than 1.5 acre	31	6	3
From 1.5 to 5 acre	203	42	1.2
From 5 to 10 acre	151	31	0.6
From 10 to 15 acre	57	12	0.4
More than 15 acre	45	9	0.4

AU = Animal Unit; a measure of equivalency based on weight.
1 AU is equivalent to 1000 lb. beef animal. A 1250 lb. horse would equal 1.25 AU.

Overgrazing and soil compaction are the two most common causes of reduced pasture production and animal keeping nonpoint pollution in the basin. Compared to an overgrazed and compacted pasture, a healthy pasture with uniform production of grass will utilize more of the nutrients in the animal wastes while protecting the underlying soil from erosion and filtering out sediments, bacteria, and organic debris. Sites with good pasture conditions can utilize more of the nutrients produced and can support higher densities without increasing the pollution potential. Overgrazing reduces the health and productivity of the grass and therefore reduces the amount of nutrients utilized during vegetation growth. During storm events, nutrients and bacteria from manure wash off compacted soils into receiving streams and wetlands. Poor pasture conditions are compounded by the compaction and damage to grass plants when pastures are grazed during saturated soil conditions.

A comparison of the amount of available nutrients on a site and the amount of nutrients actually used by vegetation is a tool used to evaluate the pollution potential of a livestock operation. If animal waste is not being taken up by plants, pollutants from excess manure may reach surface or groundwater. Alderwood soils and bluegrass are typical throughout the BPA. A well-managed pasture on Alderwood soils can produce up to three tons of bluegrass per acre per year (PSCRBT, 1992). This grass production will fully utilize the nitrogen in the waste produced annually by one full-grown steer or horse (one animal unit). Pasture conditions on one third of the farm sites surveyed were rated as poor or very poor and were therefore unable to meet the production potential necessary to fully utilize animal wastes. Based on the pasture conditions and the amount of nutrients the grass can utilize, it is estimated that it would require three acres of pasture to utilize the waste of one animal unit (PSCRBT, 1992). Approximately half of the farms surveyed produce more livestock manure than could be utilized by the pasture (PSCRBT, 1992). With the poor plant cover, soil conditions, and wet weather typical of the basin, excess nutrients and bacteria are likely to be washed to creeks at these sites. Sites with good pasture conditions can utilize more of the nutrients produced by the animal waste and can support higher densities without increasing the pollution potential.

All farms that were field surveyed in the basin were rated based on their potential to contribute to nonpoint pollution. Ratings were based on the presence or absence of practices that prevent water contamination and the presence or absence of conditions that contribute to water contamination. The following conditions and practices were assessed: pasture size and condition; slope; soil type; number and type of livestock; proximity and access to a stream, creek, or ditch; stream, bank, and canopy condition; presence of swales in pasture; wetland proximity and access; pasture management; waste storage facilities; confinement facilities; and roof runoff systems. The potential for a site to contribute to nonpoint pollution was rated from 1 to 5. Farms most likely to have little or no negative impact on water quality were rated as 1, while a rating of 5 was assigned to those farms most likely to have a negative impact on water quality. A rating of 3 indicated moderate potential for impacting water quality. Although somewhat subjective, this method is considered to be a useful tool for assessing the overall health of the system and for evaluating the relative pollution impacts from animal keeping practices. Table 6-5 shows the results of the pollution potential assessment, which indicate that over 75% of the farms evaluated have at least some potential for contaminating surface waters.

Table 6-5 Potential Pollutant Impact from Agricultural Practices in the Cedar River Basin Planning Area

Rating	Impact	Percent
1	Little or no potential for negative impact	7
2	Low to moderate potential for negative impact	16
3	Moderate potential for negative impact	36
4	Moderate to high potential for negative	30
5	High potential to negatively impact	11

A comparison of pasture conditions for nine King County watersheds is shown in Table 6-6 (King Conservation District, 1992). County-wide, pasture conditions are evenly distributed among good, fair , and poor. This table shows that, compared to the other King County basins, the Cedar River Basin has fewer farms under five acres, and yet has the highest percentage of poor pasture conditions and fewer BMPs (i.e., roof runoff systems). The King Conservation District (KCD) has concluded that 57 of the 101 farms that have access to a stream, creek, or ditch running through the property, would benefit from stream fencing. An estimated 68,400 feet of fencing (13 miles) would be needed to protect the Cedar River and its subbasins from livestock damage (KCD, 1992).

Table 6-6 Pasture Condition of Farms in Nine King County Watersheds

Watershed	Farms <5 acres (%)	Roof Runoff System (%)		Pasture Condition (%)		
		with	without	Good	Fair	Poor
May Creek	72	22	59	16	37	38
Newaukum Creek	42	22	36	26	49	25
Lower Green River	72	23	58	30	38	32
Bear - Evans - Sammamish	80	unknown	unknown	28	40	32
Issaquah Creek	72	32	50	31	41	27
Middle Green River	76	19	53	24	35	21
East Lake Sammamish	80	30	38	25	39	36
Jenkins Creek	89	23	60	25	35	36
Cedar River	48	3	75	22	37	41

Note: percentages may not add to 100%; remainder was classified as "could not see."

Domestic Animal Keeping and Wildlife

As urbanization increases, land-use practices shift from being more rural and agricultural in nature to residential, and animal keeping practices shift from livestock (e.g., horses) to domestic pets (dogs and cats). Domestic animal wastes become a nonpoint pollution source for nutrients and bacteria (fecal coliform). Wastes are washed from yards and impervious surfaces into the streams during storm events. In the high-density residential areas of Fairwood and Maplewood, domestic animal wastes are a nonpoint source of bacteria and nutrients to receiving streams.

Wildlife wastes can also be a source of fecal contamination. Within the BPA, sources of contamination from wildlife wastes can be expected in open spaces, wildlife corridors, and parks. Examples of this include the high fecal coliform levels found in the ditch adjacent to the Cedar River Trail at the mouth of the Cedar River. This is probably due to the large numbers of birds in this area.

PESTICIDES

The use of pesticides in agriculture, roadside maintenance, forestry, and household products presents a potential water quality threat in the Cedar River Basin (SKCDPH, 1991b). The actual use of pesticides in the basin is not well documented. Nevertheless, the potential for groundwater contamination from chemical residuals and surface-water contamination from over-spraying is a concern relative to the long-term protection of the resources. Pesticides can have impacts outlasting the actual presence of the material. For instance, by killing off some organisms vital to a particular habitat, a pesticide can create long-lasting disruptions in biotic systems without itself leaving measurable contamination.

Pesticides are a chemical group that includes a wide range of substances that can be lethal to a wide spectrum of organisms (biocides), or they may be targeted to control specific organisms judged to be pests such as algae (algicide), weeds (herbicides), insects (insecticides), rodents (rodenticides), and snails/slugs (molluscicides). Pesticides that can migrate from application sites to waterways, where they can be toxic to nontarget species as well as target species, have the highest potential to be nonpoint pollution problems. In particular, herbicides tend to be water soluble, and therefore more easily transported to the nearby waterbodies.

Primary large-scale users of pesticides in the BPA are the Washington State Department of Agriculture (WSDOA), the State Department of Transportation (WSDOT), the King County Department of Public Works (DPW), the Burlington Northern Railroad, and various cities, school districts, commercial applicators, and private households. Pesticides sprayed along railroads, highways, and county roads are a greater concern since these transportation corridors are often located directly adjacent to main waterways, they are generally applied in porous soils, and they are sprayed routinely in the basin. Consequently, runoff from these sites can have a more immediate impact as a nonpoint source than runoff from other areas.

Pesticides are currently regulated by the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA, Public Law 80-104). This law requires product labels containing instructions for use as well as warning statements about the potential environmental health effects; WSDOA is the lead agency for regulating this law. All commercial users of pesticides are required to obtain permits from WSDOA and to keep records on the amounts, locations, and types of pesticides they use.

The Seattle-King County Board of Health (SKCBH) has recently recognized that WSDOA is primarily concerned with the agricultural applications of pesticides and that WSDOA's programs do not adequately address urban pesticide problems. To address this regulatory gap, a new King County pesticide ordinance was adopted in 1993. This ordinance, which applies to all commercial pesticide applicators and will be amended to include pesticide retailers, establishes a Pesticide Advisory Council and requires registration of businesses and master applicators. All registered master applicators must pass an examination concerning topics such as pesticide applications in environmentally sensitive areas, integrated pest management, and pesticide storage.

WSDOT has two herbicide spraying programs in effect along SR-169 and SR-18; one involves spraying of shoulder strips and the other is to control noxious weeds. This application program is not expected to change in the near future. WSDOT continues to monitor new products as part of their pesticide program and will integrate these into their spraying program when appropriate.

King County DPW also operates a roadside herbicide program. In addition, alternative methods are used to control weeds, including biological weed control through the use of insects, the introduction of low-growing grasses that will outcompete weeds along roadsides and ditches, and an "Owners Will Maintain Program." The goal of these alternative programs is the elimination of roadside and ditch spraying.

The Seattle-King County Department of Public Health (SKCDPH) has an ongoing soils and water monitoring program to determine residual pesticide levels within sprayed areas and to monitor the degradation of these compounds over time. The conclusions of the 1989 report states "the spray operation appeared to be well-managed." No herbicide residuals were detected at soil test depth of 4 inches.

Data pertaining to household usage in the BPA are unavailable. Nevertheless, given the number of households and the nature of the soils in the area, it is likely that residential pesticide use poses a threat to surface and groundwater.

Golf courses routinely use a variety of pesticides for the maintenance of the greens and fairways. The herbicide 2,4-Dichlorophenoxy (2,4-D) was detected in sediments downstream from a golf course in the Fairwood area. Extremely high levels of this compound would have to be present in the water column to produce detectible levels in the sediment. This is of particular concern since 2,4-D is a highly soluble compound and would not be expected to occur in the soils (see Section 6.5). Trace herbicide levels were also detected in the sediments at the Maplewood golf course.

SMALL QUANTITY HAZARDOUS WASTE GENERATORS

Small quantity hazardous waste generators (SQHWG) were investigated by the SKCDPH as a potential source of nonpoint pollution in the basin (SKCDPH, 1991b). A small quantity generator (SAG) is defined by the State of Washington as any business that generates hazardous waste in quantities less than 220 pounds per month or extremely hazardous waste in quantities less than 2.2 pounds per month. The increase in use of chemicals in the home and in small businesses has resulted in growing quantities of leftover wastes. Cleaners, paints, pesticides, solvents, coolants, oven cleaners, polishes, epoxy resins, and other products containing hazardous chemicals are typically generated from households. In addition, businesses such as dry cleaners, print shops, medical labs, automotive repair shops, electroplaters, and photographic shops also produce other hazardous wastes. Improper storage, use, or disposal of these compounds can pollute surface water or penetrate to groundwater resources.

Currently, hazardous wastes from small quantity generators and household hazardous wastes are not regulated. The actual number of businesses that produce small quantities of hazardous waste within the basin is not known since onsite hazardous waste audits have not been conducted. Based on an analysis of all businesses in the basin, however, it was estimated that 211 commercial uses have the potential to generate hazardous wastes. Of these, 42% were located in the City of Renton, 14% were concentrated in the Renton highlands, and 44% were scattered throughout the rest of the basin (Map 15, *Appendix B*). The proximity of these businesses to creeks is of particular concern. Forty-three percent are located within one half mile and 40% are located within one half to one mile of the Cedar River, while many of these are also located in areas with a high aquifer recharge potential.

An analysis of sediments at the Logan Street stormwater outfall in Renton showed extremely high concentrations of some heavy metals indicating possible improper storage or disposal of hazardous wastes. An illicit storm drain survey of commercial uses in Renton will include inspection of possible sources and education on proper management practices to reduce the potential pollution from this source. In addition, Metro and DOE are conducting a survey of SQHWGs in the automotive repair businesses within the basin.

Improper disposal of household hazardous wastes is also a potential nonpoint pollution source. Household hazardous wastes include household cleaning products, pesticides and fertilizers (as discussed previously), paints, and automotive maintenance fluids, such as oil and antifreeze. King County Solid Waste Division and Renton Solid Waste Utility currently have household hazardous waste collection and recycling programs to address the residential sources.

UNDERGROUND STORAGE TANKS

Underground storage tanks (USTs) were investigated by the SKCDPH (SKCDPH, 1991) as a potential source of nonpoint pollution in the BPA. USTs are used for the storage of petroleum and other regulated substances. The EPA has estimated that as many as 25% of all USTs may be leaking nationwide (US EPA, 1988). Tank leakage may be caused by deterioration of the tank, improper installation, pipe failures, and/or spills and overfills. The substances leaked can pose a threat to both surface and groundwater in the basin.

Twenty-five underground storage tank have been reported in the BPA since January, 1989 (DOE, Leaking Underground Storage Tank List, March 10 1993, unpublished data). Most of these are located within the commercial area of Renton and on the Fairwood plateau along 140th Avenue SE.

The DOE has identified and registered 160 commercial tanks in the BPA. This does not include the thousands of home heating oil storage tanks in the basin that are not covered by DOE UST regulations. Based on size classification, 37% of the tanks fall within the range of 10,000 to 20,000 gallons. Leaded, unleaded, and diesel fuels account for 74% of the compounds stored in the known USTs in the BPA.

Map 15 (*Appendix B)* shows the distribution of registered USTs in the basin compiled from a 1991 EPA list. The identified USTs are concentrated in the commercial centers of the basin. Since the City of Renton and most small business centers are located adjacent to the river and its tributaries, spills and leaks from USTs are of major concern. Since soils in these areas are very permeable and volatile organic compounds and petroleum products migrate rapidly through permeable soils, USTs are a threat to the groundwater in the basin.

The DOE is currently implementing a program to identify and register USTs. This program mandates the implementation of leak detection methods on all existing USTs. Required detection methods are being phased in depending on the age of the tank, and all tanks are requited to implement leak detection by December 1993. Detection methods include, but are not limited to, tank tightness testing, automatic monitoring control of product level, vapor monitoring, groundwater monitoring, barrier interception monitoring, and interstitial monitoring. The DOE is registering USTs and enforcing upgrades and monitoring systems on all tanks covered by the Act. The DOE does not conduct regular UST monitoring.

A review of the 1991 EPA list showed that several tanks were not in compliance with DOE's regulations. However, an updated review of the March 30 1993 DOE list indicated that all registered tanks either had some type of leak detection (i.e., daily inventory) or pipe release detection (i.e., automatic leak detector). There are three tanks that do not have leak detection, but they are not required to comply until December 1993.

The DOE currently assesses a fee to fund the UST program (Chapter 173-360 WAC). The DOE can transfer the responsibility for enforcement of the state UST program to any city, town, or county upon request; the annual fees would then be appropriated equitably between DOE and the local jurisdiction. In addition, stricter requirements for USTs in areas designated as "Environmentally Sensitive Areas" can be developed and higher tank fees levied.

Home Heating Oil Tanks

The number of home heating oil tanks in King County is unknown. These tanks are likely to be found in older residential areas since new homes tend to utilize energy sources other than oil. Most home heating tanks are single walled without cathodic protection and are subject to deterioration and leakage. In addition, as other sources of energy replace oil, many home oil tanks have been abandoned and not removed. Since these tanks have not been properly abandoned, their contents pose a growing threat to the groundwater as their walls deteriorate. The King County Fire Marshal's office regulates the removal of abandoned home heating oil tanks and requires that tanks that have remained unused for one year be abandoned. Since there is no system to identify residential home heating oil tanks, it seems likely that many abandoned tanks do not comply with the code.

SOLID WASTE MANAGEMENT

The management of municipal wastes--from the source, to collection via transfer stations, to final disposal at the landfill--can be a source of nonpoint pollution. With the increased volume of wastes, limited landfill capacity, and heightened environmental concerns, extensive efforts are being made to recycle what was once considered wastes into useful commodities. In addition to three landfills and a transfer station, the basin also contains facilities for composting and metal recycling.

Transfer stations and landfills are considered a point source of pollution but are discussed here to give an overall view of solid waste issues. Composting facilities and metal recycling facilities may also be considered point sources but are not currently being sufficiently regulated to control water quality impacts. Nonpoint pollution sources include illegal dumping and unpermitted landfills.

Transfer Station and Landfills

Mixed municipal solid waste, both residential and commercial, can pose a threat to water quality if not managed cautiously. Collected wastes can contribute to nonpoint pollution at all stages from generation to ultimate disposal. Liquids can leak out of dumpsters and collection trucks and be washed into the storm drains. Transfer stations, where trash is consolidated, compacted, and transferred to large trucks for transporting to the landfill, can also contribute contaminated runoff. In areas such as these, where wastes are stored or transferred, there is a high potential for contaminated runoff to leave the site if proper containment is not provided.

Landfills are potential sources of nonpoint pollution due in part to earth-moving activities in their day-to-day operations. Inadequate erosion and sedimentation control can result in excessive quantities of sediments being entrained in storm water. Improper management of landfill leachate can also lead to nonpoint pollution. Landfill leachate is the wastewater that is generated from the decomposition of the wastes that have been disposed of in the landfill. Leachate that is not collected, treated, and disposed of properly can result in surface-water and groundwater contamination. Commercial and municipal landfills are required to have operating permits from the Seattle-King County Department of Public Health (SKCDPH) and to meet Minimum Functional Standards.

Any water from external sources, such as precipitation or groundwater intrusion, coming into contact with the wastes is also considered to be leachate. Leachate from municipal landfills typically exhibits elevated specific conductivity (dissolved ions) and elevated concentrations of iron, manganese, zinc, biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia, fecal coliform, and several volatile and semi-volatile organics such as methylene chloride, acetone, benzene, toluene, and phenols. The nutrient phosphorus is usually detected in very low concentrations in landfill leachate.

Renton Transfer Station The Renton Transfer Station is situated in the Renton highlands, approximately 0.5 miles north of the Cedar River, in the same general vicinity as the Mt. Olivet Landfill and a gravel pit (Map 15, *Appendix B*). The Renton Transfer Station is operated by King County Solid Waste Division (KCSWD) and serves to combine the waste loads of many vehicles into a smaller number of large load transportation trailers. Loaded trailers are then trucked to Cedar Hills Regional Landfill for disposal.

The Renton Transfer Station does not yet comply completely with State Minimum Functional Standards for managing solid waste facilities. Areas of noncompliance include insufficient buffers around the site and lack of surface and groundwater pollution controls (SKCDPH, 1991c). KCSWD submitted plans to upgrade the facility to the City of Renton in June 1988. The Renton Transfer Station sewer upgrade plans have been approved by the City of Renton. Conditions of approval include the implementation of a water quality and soil sampling/monitoring program at all stormwater outfalls. The KCSWD has also prepared an emergency spill response plan and a landscape plan to be implemented concurrently with the sewer upgrade project. Construction is scheduled to be completed by September 1993.

The major environmental concern at this facility is its storm drain system that empties directly into an unlined borrow pit west of the transfer station. All contaminated water from truck washing, site clean-up, storm runoff, and spills are conveyed to this pit for disposal via groundwater infiltration into highly permeable soils. The infiltrated runoff could contaminate the underlying groundwater in Renton's designated Aquifer Protection Area, which supplies the city with drinking water. Proposed facility upgrades include connection of all water from areas of potential contamination to the sanitary sewer line and treatment of stormwater runoff from the access roads in biofiltration swales prior to infiltration.

Cedar Hills Landfill The Cedar Hills Landfill, a 920-acre regional municipal solid waste facility located north of Maple Valley (Map 15, *Appendix B*), is operated and managed by KCSWD. At this landfill, an extensive leachate collection and pretreatment system has been constructed, consisting of a network of perforated collection pipes located in and around active and inactive landfilling areas. The leachate is conveyed to two aerated lagoons where it is treated prior to discharge into the Metro sewage collection system.

Cedar Hills is divided into two separate surface-water drainage basins. The northern half drains to the Issaquah Creek Basin and the southern half to the Cedar River Basin. The primary objectives for the surface-water control system at Cedar Hills are 1) to collect stormwater runoff from nonwaste and nonactive (closed) waste areas, 2) to prevent leachate from entering the stormwater collection system, 3) to convey runoff to stormwater detention basins for peak flow attenuation and sediment removal, 4) to release flows from detention basins at lower than predevelopment rates, and 5) to minimize onsite erosion and sedimentation in downstream areas.

As areas of the landfill are completed, an impermeable clay and high-density polyethylene (HDPE) cover is constructed, which prevents surface water from infiltrating the buried refuse and generating excess quantities of leachate. This also prevents surface water from contamination due to contact with the wastes.

Surface water that is not impacted by landfill operations is directed to onsite stormwater detention lagoons for sediment and silt removal and control of peak release rates (J. Komorita, pers. commun., 1992). The existing drainage area for the central discharge location consists of a soils stockpile area, an undisturbed area, the closed South Solid Waste Area, and the southwest and south buffers. Surface water from these sites is discharged to Queen City Lake (Wetland 13) on the Queen City Farms property, which in turn drains to aquifers located below the general area. An overflow outlet on the south side of Queen City Lake conveys discharges to an artificial lake formed by mining operations north of Cedar Grove Road. The gravel pit lake is the surface expression of one of the aquifers in the area and lacks a surface-water outlet.

Surface water from a small area of the south landfill buffer is discharged directly into Tributary 0316A. This stream also receives runoff from an upstream residential development and downstream composting facility and gravel pit. Drainage from the landfill access road and a portion of the southwest buffer is combined with other road runoff and flows toward Cedar Grove Road. This runoff may flow west toward the Cedar River, but the majority flows east toward the Issaquah Basin. Water quality samples of Cedar Grove Road runoff contain high pollutant concentrations. These pollutants could be a result of the increased landfill traffic.

Surface drainage from the active site is currently directed to the Metro sewer. However, when final cover has been completed, surface water will not discharge to Metro. Drainage from an equipment storage and vehicle wash area is discharged to Metro.

Baseflow water quality samples were evaluated at the three locations where water was discharged offsite into natural drainages (KCSWD, 1991). KCSWD has made extensive efforts to control, treat, and evaluate point and nonpoint pollution at this landfill. A full evaluation of nonpoint impacts is difficult due to the lack of hardness data during past sampling events. Without hardness data, acute and chronic aquatic criteria for metals can not be evaluated. Hardness has recently been added to the Solid Waste Division's surface-water sampling program and surface-water quality will be compared to acute and chronic aquatic criteria. Cedar Hills Landfill is currently applying for an NPDES industrial stormwater discharge permit. In meeting the requirements of the permitting process, current storm water quality will be evaluated.

Hobart Landfill Hobart Landfill, a 35-acre municipal solid waste facility, is constructed at an old gravel pit site and located on the Issaquah-Ravensdale Road just south of the Walsh Lake Diversion Ditch (Map 15, *Appendix B*). Final closure of the Hobart Landfill is expected in 1994, when the facility is expected to reach its capacity.

A system of perimeter ditches directs all surface water either to onsite infiltration ponds or to Metro for treatment (Okereke, V., pers. commun.1992). The northern half of the landfill has already been closed and covered with an impervious cap to eliminate contact between surface water and the buried wastes. This relatively clean runoff is discharged into infiltration ponds. Contaminated runoff from the active, southern portion of the landfill is conveyed via perimeter ditches into partially lined ponds. Currently, this contaminated runoff is pumped into aerated leachate lagoons and ultimately to Metro's wastewater treatment plant. When the landfill is finally closed and capped, all runoff will be directed to infiltration ponds.

The site is underlain by a shallow and a deep aquifer, which are separated by an impermeable till layer. The low hydraulic conductivity of the till minimizes downward migration of groundwater from the shallow aquifer to the deep aquifer, which supplies several offsite domestic wells.

In 1986, some leachate indicator constituents (such as dissolved solids, metals and volatile organic compounds) were detected at low levels in the shallow aquifer (KCSWD, 1992). Remediation has included 1) lining the Walsh Lake Diversion Ditch streambed to reduce recharge to the shallow aquifer upgradient of the site and 2) constructing a low-permeability subsurface slurry containment wall around the site to isolate the shallow aquifer beneath the site and to minimize offsite migration of dissolved contaminants. Groundwater levels within the landfill site are kept below the lowest solid waste elevation by pumping groundwater/leachate to an aeration basin before discharge to the Metro sewer line. Since remediation, the problem constituents have become progressively less concentrated in downgradient wells.

Mount Olivet Landfill Mt. Olivet Landfill is a 8.9-acre site located in the Renton highlands just north of the Cedar River (Map 15, *Appendix B*) near the Mt. Olivet Cemetery, a gravel pit, and the Renton Transfer Station. The landfill accepts demolition debris and includes a recycling operation for concrete. Other wastes include brick, masonry, wood, roofing, and miscellaneous debris from the demolition of buildings, roads, and other structures. Demolition debris is mostly inert and therefore unlikely to produce significant gases or leachate during decomposition.

As a demolition debris landfill, Mt. Olivet is not required to meet municipal solid waste landfill regulations. Nevertheless, the operator of Mt. Olivet has installed approved liners, a leachate collection system, retaining walls, a permanent connection to the sanitary sewer, and a groundwater monitoring system. Future improvements will include facilities to pretreat wastes before discharge to the Metro sewer.

Mt. Olivet Landfill is located within a half mile of the City of Renton water supply wells and is within the City of Renton's Aquifer Protection Area. Previous to its use as a landfill the site was a gravel quarry where gravel was extracted to the till layer. There is a localized perched aquifer above the till located on the west side of the landfill. The City of Renton's aquifer is located 170 feet below this impermeable till layer. This layer forms a geologic barrier between an aquifer perched on top of the land fill and the Renton aquifer (SKCDPH, 1991c). However, contaminants from the Mt. Olivet Landfill could migrate near surface groundwater and enter Renton's aquifer from the northeast. It was recently discovered that wells monitored in the vicinity of the landfill were contaminated with coliform bacteria exceeding the drinking water standard (Dotson, pers. commun., 1993)

The landfill is not currently operational. Although a final closure is planned, the closure date has not been determined. Final closure, which includes the installation of an impermeable cap, will help to further reduce the possibility of contamination of surface or groundwater. There is currently no method of surface-water collection and treatment. The owner, operator, and the City of Renton are currently negotiating the methods to be used to close the landfill in an environmentally sound manner.

Illegal Dumping and Unpermitted Private Landfills Illegal dumping and unpermitted private landfills can be a source of nonpoint pollution, depending on the composition of the waste, because controls to protect the environment are not being used. Aesthetic values of the basin can also be impaired. Illegal dumping of trash is a problem throughout the county, especially rural areas. Instances of illegal dumping can be observed throughout the Cedar River Basin in and along the Cedar River, in residential areas, and in remote areas. Illegal dumping is often observed in recreational areas that do not provide for the disposal of trash. In addition, large dumping of trash tends to increase when disposal rates increase at the transfer stations and landfills. Private landowners occasionally dispose of trash on site in non-permitted areas. As with all landfills, this material will leach into the ground and surface waters. Since control measures are not in place to prevent the release of contamination, these sources could be major nonpoint source.

Recycling Facilities

Composting The Cedar Grove Composting Facility is located north of the Stoneway Gravel Pit and east of Cedar Hill Landfill (Map 15, *Appendix B*). This facility composts yard wastes such as grass clippings, shrubs, branches, and leaves and produces fertilizer. Composting has become a popular way to reduce the volumes of these wastes put into landfills and to recycle the nutrients they contain.

The yard wastes are composted in an open area unprotected from rain. Runoff that comes in contact with the decomposed wastes leaches nutrients and tannic acids that are collected in two ponds that enable storage and recycling of the water. Contaminated runoff is aerated in the first pond and some of the water is infiltrated in the second pond. When the holding capacity of these ponds is exceeded, contaminated contents are released into Tributary 0316A.

In-stream water quality samples were taken by SWM staff upstream (background) and downstream from the detention pond effluent. The downstream sample showed extremely high levels of phosphorus and turbidity. Total phosphorus (TP) and turbidity were measured at 0.03 mg/l TP and 0.84 NTU turbidity upstream and at 6.74 mg/l TP and 250.0 NTU turbidity downstream of the detention pond effluent. Based on the preservation of Lake Washington water quality, total phosphorus should not exceed 0.02 mg/l (see Section 6.2). Turbidity can not exceed 5 NTU over background levels under Washington State Surface Water Quality Standards. Phosphorus is the growth limiting nutrient in freshwater streams and an excess can promote algal blooms and accelerate eutrophication. This stream feeds Wetland 32, where there have been unconfirmed reports of increased algal blooms. The phosphorus input from Cedar Grove Composting contributes to the increased productivity (algal blooms) in Wetland 32.

The DOE has investigated this situation and notified the composting facility of illegal discharge into waters of the state. The composting facility is seeking a National Pollutant Discharge Elimination System permit from DOE.

Metal Recycling Metal recycling is a common practice to reduce wastes and reuse metallic materials. Metal recyclers collect scrap metal, strip the useful parts, and separate them by metal types. The scrap metal often contains oils, grease, and other pollutants, which can contaminate water that comes into contact with the metal. These contaminants are typically washed off by surface runoff and/or infiltrated into groundwater. In addition to metal recycling businesses, there are numerous private scrap piles or accumulations of unused vehicles and appliances throughout the basin. Each of these could be a nonpoint pollution source if contaminants if they are not contained properly.

Metal recycling or scrap metal yards are not currently being regulated. However, a regulatory program would be compatible with the existing Seattle-King County Department of Public Health (SKCDPH) solid waste regulations. SKCDPH is considering the expansion of their regulatory system to include a permit and inspection system for metal recycling facilities (W. Swafford, pers. commun.,1993).

The Cedar Grove Metal Recycling facility is located on SR-169 across from the intersection with Cedar Grove Road. A small unnamed tributary flows along the southwest side of the site into the Cedar River. There are no water quality data from the site, but oil spills have been observed. The site is not covered from rain and runoff enters directly into this adjacent tributary. Collected materials are stored on exposed soils, increasing the possibility of contaminated soils, groundwater, or both.

RESOURCE EXTRACTION

Gravel Mining

Gravel mining is the leading mineral extraction industry in Washington State and occurs primarily west of the Cascades (DOE, 1988a). Sediment is the most common pollutant associated with gravel mining. During the extraction process, large areas of rock and soil are mined and sorted according to size. Fine silts and sands that result from this separation process are often washed into streams or into the drainage system during storm events producing significant amounts of sediment in surface-water runoff. Downstream, these silts and sands are deposited into the large pores found in streambeds, in essence "cementing" salmon spawning gravels and other aquatic habitat. The BPA contains several gravel mining sites.

Stoneway Gravel Stoneway Gravel is located off of Cedar Grove Road, adjacent to the Cedar Hills Regional Landfill and Cedar Grove Composting Facility (Map 15, *Appendix B*). Mining operations have significantly altered both the surface and subsurface hydrology of the area. For example, gravel extraction has reduced the quantity of water supplied to Tributary 0316A, which in turn feeds Wetland 32. In an effort to restore adequate flows to the stream and wetland, a hydrologic connection was created between the process water pond (Wetland 30), which exhibits high concentrations of suspended silts, and the stream. This stream traverses the gravel pit area, which is devoid of riparian vegetation and stabilizing large organic debris. As a result, the channel is extremely unstable, and high sediment loads are carried to Wetland 32.

Runoff from the western portion of the site is directed to two ponds in the southwest corner of the site, which are intended to infiltrate runoff into groundwater. However, the ponds appear to be undersized and unmaintained, and pond overflows have severely eroded the bank above Cedar Grove Road. This erosion appears to be a significant source of sediment in the lower reaches of the system.

Other Gravel Operations There are several other gravel mines in the Cedar River Basin, either active or inactive. One is located in the Renton highlands, adjacent to the Renton Transfer Station and Mt. Olivet Landfill. Drainage from this site enters the Renton storm drain (3rd Street). The site is not currently in operation, and closure BMPs, including soil stabilization and a drainage system, have not been implemented. There are several reports of high volumes of sediment from this site. There is an inactive site off of Lake Francis Road, which is currently being "filled." Tributary 0317 passes through the site to a pond that infiltrates and resurfaces at several seeps above Maxwell Road. The fill site has truck washing operations that wash directly into the onsite pond. Other mining operations include an active site east of Jones Road, an active site in Maple Valley, and several inactive sites along the mainstem. In addition, King County Roads Division owns a parcel of land near Retreat Lake that is zoned for resource extraction.

Coal Mining

There are several abandoned coal mines throughout the BPA that are potential nonpoint pollution sources. When water comes into contact with the sulfur-bearing coal deposits, sulfuric acid is produced. This acid will then dissolve the naturally occurring metals in the surrounding geologic formations and soils.

The DOE has investigated a water quality complaint from a seep in the mainstem and concluded that the cause was from natural coal deposits in the basin and was considered a "natural phenomenon" (R. Devitt, pers. commun.,1992).

Municipal Water Supply

The cities of Seattle, Renton, and Kent divert drinking water from surface and groundwater resources in the Cedar River Basin (see Section 6.2).

HAZARDOUS WASTE SITES

There are several state and federal hazardous waste sites listed in the BPA (DOE Toxic Cleanup Program List, February 12, 1993, unpublished data). The major sites include one federally listed Superfund site (Queen City Farms) and two state hazardous waste sites (PACCAR and Landsburg mine) in the BPA. Site investigations and remedial actions taken at these sites are under the jurisdiction of the EPA and DOE, respectively. In addition, the list includes Four Teck Industries, Lake Youngs Supply Line, Four Corners Auto Wrecking, Boeing Company, Puget Power Talbot Hills Station, Hobart Landfill, Cedar Hills Landfill, and Renton Transfer Station. All of these sites are considered point sources. The three major sites are listed below.

Queen City Farms Superfund Site

Queen City Farms is listed on the National Priority List (NPL) of Superfund hazardous waste sites. The site is located just south of the Cedar Hills Landfill in the Cedar Hills subbasin (Map 15, *Appendix B*). Between 1955 and 1960, industrial wastes, including paint and petroleum products, organic solvents and oils, were disposed of in three unlined ponds (US EPA, 1992). The EPA tested the soil, water, and sediment from the former waste ponds and found heavy metals and organic compounds. Groundwater sampling has shown low levels of heavy metals in the underlying shallow and deep aquifers.

Runoff from the superfund site (and runoff from Cedar Hills Landfill) enters Queen City Lake (Wetland 13) where it is connected with a perched aquifer. Overflow enters a gravel pit lake, which is in hydrologic connection with underlying aquifers. Groundwater in this area is thought to flow away from the Cedar River.

The EPA has evaluated alternatives for the cleanup and remediation of the site. The proposed plan includes removal of remaining contamination, treatment of contaminated groundwater, and continued groundwater monitoring. Implementation time is estimated to be three years. (See *Chapter 7: Aquatic Habitat* for a full discussion of Wetland 13)

PACCAR

From 1908 to 1988, PACCAR operated a foundry and rail/military vehicle manufacturing plant on North 4th Street in Renton (Map 15, *Appendix B*) (DOE, 1992a). During this period, soils were contaminated with heavy metals, petroleum products, volatile organic chemicals, and other hazardous substances. In 1990, interim bioremediation of the petroleum contaminated soils was performed and full-scale cleanup addressing soils, groundwater, and surface water began in 1991. Partial remediation has been completed and cleanup and monitoring continues on the remainder of the site.

Landsburg Mine

The Landsburg mine is an abandoned coal mine located near Ravensdale (Map 15, *Appendix B*). Between 1969 and 1971, hazardous substances, including industrial wastes, were disposed at the site (DOE, 1992b). The northern tip of the disposal area lies within 500 feet of the Cedar River. The cleanup process is still in the beginning phase and DOE is developing a work plan for the detailed investigation. The work plan will describe the tasks necessary to evaluate the nature and extent of the contamination and will be used to develop cleanup alternatives.

OTHER SOURCES

Powerlines

The Bonneville Power Administration, Puget Sound Power and Light, and Seattle City Light operate substations and approximately 24 miles of high voltage powerlines that traverse the watershed. Powerline corridors cover approximately 3% (1,400 acres) of the watershed. Unpaved access roads to tower sites have become popular areas for off-road vehicle use. Bike use on steep grades causes water channelization on road surfaces and failures of cross ditch water structures can contribute to sediment problems. Many of these roads are gated to restrict four-wheel vehicle traffic, but uncontrolled access continues in many areas. Powerline areas, especially in the City of Kent watershed, have experienced increases in trash dumping (PSCRBT, 1992).

Stoneway Batch Plant

Stoneway Gravel operates a batch plant, where cement and gravel are mixed to produce concrete, adjacent to the Cedar River, at approximately RM 2.2. Process water from the operation is infiltrated under a State Waste Discharge Permit. The plant site also has a stormwater runoff pond that discharges to the Cedar River. Washing of cement trucks into the stormwater ponds has also been observed by SWM staff, and pH levels of 11.5 have been detected in effluent samples entering the Cedar River from the stormwater ponds. This effluent is dangerously close to standards that classify substances with a pH of 12 or greater as hazardous wastes. The caustic nature of the discharge indicates that substantial concentrations of lime used in processing cement are entering the stormwater runoff pond.

Pipelines

There are several pipelines that either cross the Cedar River or run along tributaries. Three petroleum lines cross the Cedar River. Olympic pipeline, at RM 3.6, had an undetected leak, in about 1987 and laked a large quantity of toluene into the aquifer, leaving a visible sheen on the river (P. Olson, pers. commun.,1993). Several wells were pumped for over a year to remove the petroleum products. There are also petroleum pipeline crossings at RM 9.3 and RM 14.3.

Two tightlined leachate pipes cross the Cedar River; the line from Cedar Hills Landfill crosses at the Cedar Grove Road Bridge (RM 11.3), and the line from Hobart Landfill crosses at the railroad bridge (RM 13.7).

A sewer line from the residential areas of Fairwood runs down the steep ravine in Madsen

Table 6-7 Cedar River Sampling Locations

Sampling Site A*	St*	Sd*	Site Description	Characterization
	1	1	Boeing Co./Cedar River Trail drainage ditch (St). Drainage ditch and Boeing outfall (SD)	large impervious areas/dangerous waste storage areas
		2	Mainstem above Boeing Company	industrial, mouth of river
		3	Renton Municipal airport outfall	airport housekeeping practices, commercial
	2	4	Logan Bridge outfall	Renton commercial areas, auto repair shops
	3		Bronson Way Bridge	highway runoff and residential drainage
	4	5	I-405 Outfall	I-405 runoff and residential (4th St. area)
	5	6	Stoneway R/D outfall	industrial R/D effectiveness
	6	7	Wooden Bridge, mainstem	Mainstem, residential
	7	8	Maplewood Creek	Maplewood Creek Subbasin. Residential. Golf course influence.
		9	Maplewood Cr. above sed. pond	Residential
	8	12	154th Pl/ Jones Rd. trib.	Residential
	9	10	Madsen Cr., above sediment pond	Fairwood, residential.
		11	Madsen Cr. below golf course	Fairwood, residential.
A438			Jones Rd. Bridge	Mainstem conditions (baseflow)
		14	Cedar Grove Rd. runoff diversion	road runoff
	10	13	Cedar Grove Rd. trib.	Industrial
	11		Old King County Shop ditch	Industrial
	12	15	Maxwell Rd. at bridge	Agricultural/Residential
	13	16	Peterson Pond trib.	Peterson Creek Subbasin. Rural residential, low density.
	14	18	Mainstem below Landsburg Dam	Background W, entering BPA from Seattle watershed.
	15		Taylor Cr. at 216th Way & 236th Ave SE	Agricultural/Residential
	16		Road drainage entering Site 15	Road runoff
	17	17	Upper Taylor at SR-18 & 244th St	Agricultural/Residential/SR18 runoff
	18		Upper Dorre Don Way SE & 236th Ave SE	Residential
	19		Walsh Lake Diversion Ditch	Walsh Lake catchment
	20		Retreat Lake outflow	Retreat Lake, residential

* A: Ambient sampling site; Metro.
St: Stormwater sampling site; SWM.
Sd: Sediment sampling site; SWM.

Creek. This ravine is very unstable and past washouts have threatened the integrity of the sewer line. The ravine is currently being stabilized, but the dynamic nature of the ravine is not conducive to maintaining the integrity of the sewer line. The sewer line has broken and leaked in the past and is expected to continue. There is limited access to the line for maintenance and repair.

6.5 WATER QUALITY ASSESSMENT

WATER QUALITY ANALYSIS

The BPA water quality analysis is based on the chemical composition of the ambient water (non-storm) water sampled during storm events and on sediment samples. A site description and characterization of each sampling site is given in Table 6-7 and shown in Map 16 in *Appendix B*.

AMBIENT MONITORING

Ambient water quality samples were taken in the Cedar River, its tributaries, and selected lakes in the basin. Ambient samples are usually, but not always, taken during baseflow and typically reflect the non-storm event conditions.

Streams

Metro's primary sampling location on the Cedar River is site A438, located at approximately RM 9.3. In the past, Metro has sampled at several locations in the BPA, but the data from most of these locations is more than ten years old and not considered representative of current conditions. Therefore, these data were used only for comparison purposes to determine trends.

Site A438 meets all water quality standards for the conventional parameters such as temperature, dissolved oxygen, turbidity, and pH. Occasional exceedances of fecal coliform bacteria levels occur, but no seasonal trends are evident. When an exceedance does occur, it is usually within the range of 200 to 300 organisms/ml (the standard is 50 organisms/ml for Class AA waters).

Metal toxicity standards for lead, cadmium, copper and zinc were calculated based on an average hardness of 20 mg/l. Cadmium and lead concentrations were consistently below their respective chronic toxicity standard. The analytical detection levels for copper and lead were higher than the calculated toxicity standards. Copper was detected in four (out of 13) samples, all of which exceeded the chronic toxicity standard; there were no acute copper toxicity exceedances. The acute toxicity standards for lead were also less than the analytical detection levels. Lead was detected in six (out of 47) samples; four of these exceeded the acute toxicity and two exceeded the chronic toxicity standards. The high analytical detection limits of these samples makes it impossible to determine if the toxicity standards are exceeded and therefore difficult to characterize the ambient metal concentrations in the basin. Ambient monitoring is conducted an a random basis and sampling could be influenced by storm events a day or two before the sampling event. Exceedances could be due to storm influences. In addition, it is believed that exceedances can occur from a combination of the natural metal content of soils in the area and the softness of the water (see metals discussion below).

Lakes

Lakes are often described according to trophic level (eutrophic, mesotrophic, or oligotrophic), which takes into account their physical, chemical, and biological conditions. Eutrophication is the process of excessive addition of inorganic nutrients, organic matter, and/or silt to lakes (or reservoirs), which results in increased biological production and a decrease in lake volume (Cooke and others, 1986). Eutrophication can be accelerated by human activities. Phosphorus is often the limiting nutrient in a lake system and any inputs of phosphorus can cause excess algae growth. Therefore, human activities that contribute to the phosphorus loadings of a lake—such as excess lawn fertilization, small noncommercial farm runoff, and failing septic systems—will contribute to eutrophication. Eutrophic conditions often reduce the aesthetic appeal of lakes and may also limit use of the lake for recreation and fish habitat. Characteristics of eutrophic lakes include high nutrient levels, which increase algal (measured as chlorophyll a) production, which in turn reduces the transparency and dissolved oxygen.

Four lakes in the Cedar River Basin—Lake Desire, Spring Lake (also known as Otter Lake), Shady Lake (Mud Lake), and Lake No. 12—were monitored as part of Metro's Freshwater Assessment Program. Lakes Desire, Spring, and Shady drain into Peterson Creek located in the Peterson Creek Subbasin. Lake No. 12 is located in the Rock Creek Subbasin. There is no data available to assess the condition of the remaining lakes in the BPA: Lakes Francis, Webster, Peterson, Retreat, and Walsh. Locations of these lakes are shown on Map 1 in *Appendix B*.

Table 6-8 (Metro, 1990) shows a classification of lakes within the BPA based on monitoring results in 1990. The points assigned are based on the trophic level exhibited by the indicator; a rating of one indicates oligotrophic (less productive), two indicates mesotrophic (moderately productive), and three indicates eutrophic (very productive) for phosphorus, chlorophyll a, and transparency. Based on these indicators, Lake Desire is considered to have poor water quality, Lake No. 12 very good, and Spring and Shady Lakes good water quality.

Table 6-8 Lake Classification (1990 data only)

Lake	Winter Total Phosphorus	Summer Chlorophyll a	Summer Transparency	Total Points	Rating
Desire	3	2	3	8	Poor
No. 12	1	1	2	4	Very Good
Shady	2	1	2	5	Good
Spring	2	1	2	5	Good

Source: Metro, 1991.

Phase I restoration and feasibility studies are currently being conducted on Lake Desire and Lake No. 12, by King County SWM under Centennial Clean Water Grant funds, in order to determine appropriate restoration alternatives to improve and prevent further degradation of the lakes' water quality.

STORM FLOWS

Water quality conditions of the Cedar River during storm events were monitored by Metro and by King County SWM. Analyses of storm events are useful to identify problem areas since runoff will wash accumulated pollutants into the streams. Storm events can represent the worst conditions, other than spills.

Metro

Metro sampled five high flow events between October 1989 and February 1990. Table 6-9 shows the results of the conventional parameters for each storm event. The levels of total suspended solids (TSS), turbidity (Turb), fecal coliform (FC), Ammonia (NH3), Nitrate (NO3), and total phosphorus (TP) were compared to the ambient level at the same site. Wet weather values that were at least two times those of the preceding ambient samples are noted in bold. There is variability among events, but the larger intensity storms tended to produce higher concentrations of pollutants. The storm of January 9, 1990 resulted in high concentrations of pollutants that are reflected by the intensity of the storm, a 35-year event.

Most metal concentrations were below the detection limits and there was only one instance where the chromium levels exceeded the toxic criteria. However, the analytical detection limits for copper and lead were above the chronic toxicity standard (based on an average hardness of 20 mg/l). Therefore, it is impossible to assess the existing conditions.

Table 6-9 High Flow Analyses at Metro Site A438

DATE	RAIN inch	TSS mg/l	Turb NTU	FC Colonies/ 100 ml	NH3 mg/l	NO3 mg/l	TP mg/l
10/26/89	0.5	5.4	0.6	50	0.049	0.245	0.027
12/04/89	1.41	30.6	9.2	290	0.043	0.685	0.070
01/04/90	0.25	4.0	2.4	27	0.015	0.363	0.020
01/09/90	2.83	342.0	75.0	1900	0.017	0.497	0.367
01/30/90	0.26	11.6	4.7	24	0.027	0.441	0.020

Reference: Metro, 1991

Site A438 is located in the mainstem where pollutant concentrations tend to be diluted by the high flows. Therefore, this site reflects the overall condition of the mainstem during a storm. This does not allow for the detection of problem areas on tributaries where pollutant concentrations are not yet affected by the increased water volumes. In addition, site A438 is located upstream from the most urbanized portion of the basin.

King County Surface Water Management

Twenty-one locations were sampled during five storm events during 1990 and 1991 (Map 16, *Appendix B*). The monitoring program was designed to identify nonpoint source problem areas throughout the BPA. In general, sampling sites were chosen at the mouths of tributaries to characterize the water quality from a specific drainage basin or at a specific site suspected to be a problem. Storms were sampled in 1990 on October 16 and December 4 and in 1991 on February 5, November 20, and December 5. Rainfall for the above samples was 0.14, 0.64, 2.1, 0.18, and 1.04 inches respectively, as measured at the Renton highlands gage. Seasonal differences in water quality are reflected by sampling at various times through the wet season. Storms were sampled after at least three days of dry weather, allowing the accumulation of pollutants. All quality assurance and quality control practices were followed. Samples were taken during the rising limb of the hydrograph to catch the more concentrated runoff, or first flush. Samples were analyzed for pH, temperature, total suspended solids (TSS), turbidity (Turb.), alkalinity (alk.), hardness (hard), total phosphorus (TP), nitrate and nitrite nitrogen (NO3 + NO2 - N), Aluminum (Al), Copper (Cu), Lead (Pb), Zinc (Zn), oil and grease (O/G), and fecal coliform.

Table 6-10 shows the average and range of pollutant concentrations taken during storm events. Complete data for all sampled storm events can be seen in the Water Quality Appendix following this chapter. Areas contributing high concentrations of total suspended solids include Logan Street outfall, an intermittent tributary on the right bank of Maplewood Creek (Maplewood Creek tributary), and Madsen Creek.

Table 6–10 Average Concentrations in Stormwater Samples

Site		TSS, mg/l	Turb, NTU	TP, µg/l	NO3 + NO2 – N, µg/l	Fecal Coliform, Colonies /100 ml
1	avg	31	17	91	59	975
	range	4 – 93	6 – 37	59 – 171	33 – 85	380 – 1800
2	avg	767	303	870	48	2090
	range	4 – 1530	6 – 600	8 – 31	39 – 57	1680 – 2500
3	avg	25	9	82	340	733
	range	10 – 41	4 – 17	19 – 25	265 – 420	60 – 1840
4	avg	111	86	205	428	2162
	range	41 – 310	28 – 330	98 – 400	275 – 526	10 – 4600
5	avg	109	70	321	288	312
	range	45 – 285	49 – 128	91 – 980	114 – 550	10 – 1200
6	avg	96	30	288	347	250
	range	10 – 233	4 – 51	28 – 780	264 – 444	140 – 400
7	avg	227	66	275	1226	980
	range	16 – 643	20 – 240	53 – 880	782 – 1420	420 – 1820
7A	avg	1098	163	1320	158	2750
	range	1022 – 1173	56 – 270	960 – 1680	132 – 185	2300 – 3200
8	avg	158	20	150	953	3180
	range	3 – 633	3 – 170	27 – 710	481 – 1860	420 – 9600
9	avg	904	85	639	505	2492
	range	13 – 2230	14 – 290	52 – 1960	200 – 695	520 – 6800
10	avg	134	88	228	546	1285
	range	1 – 344	3 – 320	13 – 520	337 – 989	28 – 2800
11	avg	51	22	110	459	227
	range	5 – 136	4 – 54	27 – 190	48 – 970	20 – 580
12	avg	59	14	111	1002	1554
	range	4 – 174	6 – 33	19 – 270	265 – 1580	52 – 3960
13	avg	102	19	106	946	167
	range	21 – 230	5 – 41	43 – 220	800 – 1020	60 – 300
14	avg	10	4	18	290	13
	range	2 – 19	3 – 6	13 – 23	222 – 414	10 – 20
15	avg	76	17	162	1203	1633
	range	55 – 108	13 – 26	116 – 201	999 – 1520	800 – 2980
16	avg	102	13	219	1466	83
	range	2 – 186	6 – 23	43 – 446	919 – 2390	10 – 180
17	avg	54	14	135	1265	1576
	range	48 – 61	11 – 19	115 – 133	984 – 1550	920 – 2610
18	avg	51	11	181	1352	890
	range	3 – 99	3 – 19	176 – 187	954 – 1750	240 – 1540
19	avg	19	8	39	513	130
	range	6 – 38	2 – 19	30 – 56	358 – 648	10 – 180
20	avg	<0.5	0.7	8.3	428	230
	range	<0.5	0.3 – 1.3	6 – 12	271 – 510	10 – 520

Turbidity and total phosphorus tend to be high at Logan Street and Maplewood Creek tributary. Nitrates are high in Maplewood Creek and all sampling sites on Taylor Creek. Fecal coliform levels exceed the standard of 50 colonies/100 ml at all sites and are highest in the higher density residential and commercial areas. Dissolved oxygen and pH were not a problem during storm events, except at the Stoneway Batch Plant outfall, where pH was 11.5.

Metals

Table 6-11 summarizes the stormwater metal toxicity exceedances. The actual concentrations and calculated toxicity criteria can be found in the Water Quality Appendix following this chapter. Both acute and chronic metal toxicity standards were exceeded consistently throughout the basin during storm events. This is not surprising because both copper and lead exceeded chronic toxicity levels during ambient monitoring. Catchments receiving runoff from commercial, medium to high-density residential, or direct road runoff exhibited the highest concentrations and exceeded the standards most frequently.

Table 6-11 Summary of Stormwater Metal Toxicity Exceedances

	Location	# of samples	Cu acute	Cu chronic	Pb acute	Pb chronic	Zn acute	Zn chronic
1	Boeing Co.	4	2	2	1	4	2	2
2	Logan St	2	1	1	2	2	2	2
3	Bronson St mainstem	3	1	1	0	1	2	2
4	I-405	5	3	4	3	4	4	4
5	Stoneway	4	2	2	0	2	4	4
6	Mainstem	4	1	2	0	2	0	0
7	Maplewood	5	3	3	0	3	1	1
7A	Maplewood	2	2	2	2	2	2	2
8	Jones Rd	5	4	4	0	4	1	2
9	Madsen	5	4	4	1	4	3	3
10	Cedar Grove Rd	5	3	4	0	4	0	0
11	Old KC Shop	4	0	0	0	1	0	0
12	Maxwell Rd	5	1	1	0	2	0	0
13	Peterson	3	2	2	0	1	1	1
14	Landsburg	3	1	1	0	1	0	0
15	Taylor	3	2	3	0	3	0	0
16	drainage to Site 15	3	2	2	0	3	1	1
17	Taylor	3	1	1	0	3	1	1
18	Dorre Don	2	1	1	0	2	1	1
19	Walsh Lake diversion	3	1	1	0	3	1	1
20	Retreat Lake	3	0	0	0	0	0	0
21	clearcut	3	1	1	1	2	0	1
	TOTAL	**79**	**37**	**41**	**10**	**53**	**26**	**28**

Metal toxicity is a function of the water hardness. Metals are most toxic in soft water and waters of the Cedar River are considered very soft. Therefore, metals can exceed the toxicity criteria at extremely low concentrations. Copper toxicity concentrations are often exceeded in the basin. This is due to the abundant sources (automotive use), Copper's high solubility, and the softness of the water. This is of particular concern in the Cedar River Basin since copper is extremely toxic to salmonids. Lead and zinc toxicity is exceeded to a lesser degree than copper.

The metal toxicity criteria may often be exceeded due to the natural conditions of the water. It is unknown what the metal compositions are in the soils, what form the metal is in, or the relative solubility of these metals. It is possible that natural metal concentrations, in combination with the softness of the water, may still exceed toxicity criteria. Samples considered to be background, taken at Landsburg Dam and in the Walsh Lake Diversion Ditch, exceeded criteria on two occasions. Both of these samples had low levels of total suspended solids, or sediments. Therefore, it can be assumed that most of the metals were naturally dissolved metals. In addition, many of the ambient (non-storm) samples taken by Metro in the mainstem upstream from urbanization exceeded toxic metal criteria.

The fact that the background water quality may not occasionally meet the criteria does not lessen the severity of the threats from the urban areas. Background concentrations are very low and may barely exceed the criteria. However, urban concentrations can be many times higher than the criteria and pose a threat to the aquatic fauna.

Regardless of the high concentrations of metals in stormwater, there has not been a major fish kill in the Cedar River. These concentrations may have a chronic effect on the fauna and interrupt behavioral and reproductive patterns.

There is a current discussion occurring between the regulated community and regulators about the validity of using water quality criteria for wet weather samples. Storm samples represent intermittent conditions for some length of time, dependent on watershed characteristics and storm intensity. Criteria are typically used to represent the continuous, non-event conditions. Many believe that wet weather criteria should be established that would be more representative of the high intensity, short duration of storm events.

The water quality samples were analyzed for total metal concentrations. Previous to December 1992, the Washington State Water Quality Standards criteria for determining toxicity was based on total metal concentrations. Since total metals were analyzed in the Cedar River samples, the old criteria were used to compare toxicity. The revised criteria are based on dissolved metal concentrations. It is unknown what the dissolved metal concentrations were in the samples taken. However, based on National Urban Runoff Program (NURP) data from four urban sites, it was concluded that the percent of total metals present in the dissolved form vary according to the metal, but are relatively consistent from site to site. Average percent dissolved metals for the sites are approximately 20% for lead, 30% for copper, and 50% for zinc (Paulson and others, 1992). When these percentages were applied to the total metal concentrations from samples in the Cedar River representing urban runoff—such as the Logan Street outfall, the I-405 outfall and the high-density residential areas of Maplewood and Madsen creeks—and were compared to the dissolved metal criteria, there were from 40 to 50% less exceedances than with the total metal concentrations. It would be expected that the dissolved fraction of metals in non-urban area water quality samples would also have much fewer metal toxicity exceedances.

Aluminum was also monitored in the stormwater samples, but there is no criteria for aluminum toxicity. Total aluminum concentrations ranged from 0.1 to 33 mg/l and correlated with the total suspended solids concentration. The sediment sample at Landsburg Dam, considered to be background conditions, showed a high aluminum content, indicating that the local soils have naturally high concentrations of aluminum.

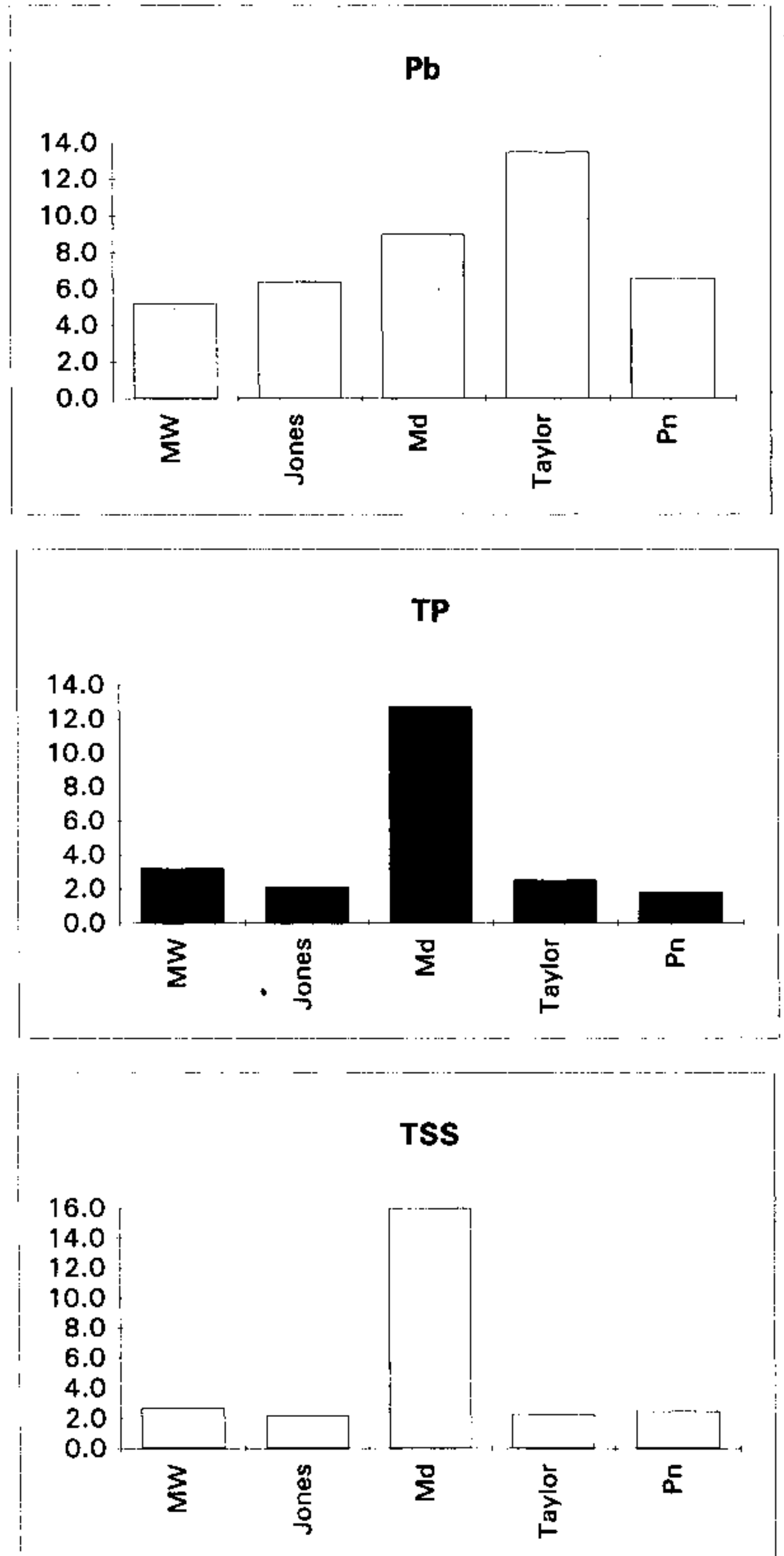
Loadings

Examination of the pollutant concentrations alone does not reflect the relative contribution of pollutants from the tributaries. Concentrations can vary with flow and are affected by dilution, such as in the mainstem. A flow with a high pollutant concentration may contribute the same amount of total pollutant as a higher flow with a low concentration of pollutant. Pollutant loadings, the total mass weight of a pollutant, provides a better comparison for relative contribution from each subbasin or tributary because it accounts for the total amount of pollutant input over some specified time. Pollutant loadings, the flow or quantity of water multiplied by the pollutant concentration, can be compared for relative input. For this report, an attempt was made to determine the relative loadings of pollutants from several tributaries to the Cedar River. Pollutant concentrations from the February 19 1991 storm were used with simulated flow data (mean daily flow, HSPF) for the same storm to demonstrate the relative contribution of total suspended solids, total phosphorus, and lead from Maplewood, Jones, Madsen, Taylor, and Peterson catchments. These catchments contributed 41% of the lead, 22% of the total phosphorus, and 26% of the total suspended solids loadings to the Cedar River between Landsburg Dam (RM 21.1) and RM 2.9. This is a comparison of inputs to the system at the time of sampling and gives an indication of the contributions from each catchment. This is intended to be used as a tool, with other information, to demonstrate the relative contributions from each of the above mentioned catchments (Figure 6-1). The concentration of lead in Taylor Creek was less than that of Maplewood, Jones, and Madsen creeks, but the contribution to the total lead loading of the system is higher. Madsen Creek contributes the most phosphorus and solids to the system.

It was not feasible to perform a chemical assessment of each tributary to the Cedar River. Therefore, a correlation of calculated current loadings, using land-use based pollutant coefficients and current land uses (see Section 6.6) and the chemical analyses of

Figure 6-1

Pollutant Contribution by Catchment



MW = Maplewood
Md = Madsen
Pn = Peterson

measured tributaries was made to determine if water quality problems were likely to exist in those tributaries where measured concentrations did not exist. Current pollutant loadings (see the Water Quality Appendix following this chapter) for total suspended solids, total phosphorus, and lead were ranked for the individual pollutant as a percentage of all subcatchment contributions (Table 6-12). This also shows the relative amounts of each pollutant predicted to be contributed from each catchment area. The cumulative contributions were ranked from 1, contributing the most, to 14, contributing the least amount of pollution. Chemical analyses of stormwater have been performed for the tributaries in the Maplewood, Madsen, Cedar Hills, Taylor and Peterson catchments. The chemical analyses showed that all of these tributaries had increased concentrations of total suspended solids, total phosphorus, and lead during storm events, but there were much lower concentrations in Peterson Creek. This indicates that the tributaries with higher calculated pollutant loadings than Peterson Creek are likely to have a water quality problem. These include the tributaries in Ginger Creek, Fairwood, Cedar Grove, and Jones Road/Orting Hills catchments.

Table 6-12 Ranking of Current Pollutant Loadings by Tributary

Tributary	Percent Contribution of Pollutant			Cumulative Contribution	Overall Ranking
	TSS	TP	Pb		
Fairwood	10.5	9.1	24.8	44.4	1
Ginger Creek	12.2	13.2	16.0	41.2	2
Maplewood	8.5	10.0	10.7	29.2	3
Madsen	8.6	10.0	9.4	28.0	4
Cedar Grove	8.2	9.9	5.4	23.5	5
Jones Rd/Orting	7.6	9.6	4.7	21.9	6
Taylor	6.5	8.3	6.0	20.8	7
Peterson	5.4	5.9	4.0	15.3	8
Maple Valley	5.2	6.4	2.7	14.3	9
Rock Creek	4.6	4.2	4.7	13.5	10
Cedar Hills	7.1	2.2	4.0	13.3	11
Webster Lake	5.7	4.4	2.6	21.7	12
Summerfield	5.6	4.2	2.7	12.5	13
Walsh Lake	4.0	3.8	2.0	9.8	14

SEDIMENTS

Sediment is less transient than water and can therefore represent a long term record of pollutants associated with nonpoint runoff. Additionally, for some types of pollutants (e.g., pesticides, PCBs, and organics) detectable concentrations are easier to obtain in a sediment matrix than in water.

The chemical composition of the sediments was analyzed at eighteen locations throughout the BPA. These sites were selected based on existing land-use, potential for nonpoint pollutants, field reconnaissance, and stormwater quality sampling results. The chemical analysis performed on each sample reflected the land use that the site was characterizing. Variables included: base, acid, and neutral extractable compounds; total phosphorus; oil and grease; total petroleum hydrocarbons; pesticide scan; herbicide scan; PCBs; aluminum, copper, lead, and zinc; and total organic carbon.

Most sites sampled, with the exception of the Logan Street outfall, showed sediment contaminant concentrations within the range termed "not polluted" to "moderately polluted" when compared to the DOE review of criteria and guidelines for contaminated freshwater sediments (DOE, 1991). The Logan Street sediments had consistent concentrations within the "heavily polluted" range. Table 6-13 shows the results for site 4, Logan Street outfall, in comparison to the levels considered to be heavily polluted. Automotive repair shops are suspected to be the primary sources of this contamination.

Table 6-13 Comparison of Sediment Analyses for Logan Street Outfall with Criteria for Heavily Polluted Sediments

Parameter	Logan Street outfall	Heavily Polluted
Total Phosphorus, mg/kg	2,158	>650
Oil & Grease, mg/kg	4,470	>2,000
Total petroleum hydrocarbons, mg/l	2,428	
Percent Volatile Solids	16.45	>8
Copper, mg/kg	1,835	>50
Lead, mg/kg	10,616	>60
Zinc, mg/kg	3,722	>200

Herbicides were analyzed for sites 1, 2, 3, 5, 7, 8, 11, and 18 and were detected at low concentrations, just above detection limits, at the Renton Municipal Airport outfall, I-405 outfall, river mile 2.9 of the mainstem, and at the Maplewood Creek outfall. 2,4-D was detected at the Renton Municipal Airport outfall (21 μg/kg) and on Madsen Creek below the Fairwood Golf Course (66 μg/kg). 2,4-D is an extremely soluble pesticide and would not be expected to be found in sediments. This indicates that either the herbicide was applied close to the time of sampling or it was applied in a very large dosage.

Pesticides and Polychlorinated biphenyls (PCB) were analyzed at sites 1, 2, 3, 5, 7, 8, 10, 11, 12, 15, 16, and 18. The only PCB detection was 200 μg/kg Aroclor-1262 at the Boeing Company outfall. No criteria guidelines exist for this PCB. However, sediment guidelines for a similar compounds, PCB-1260, defines chronic, long-term effects on benthic organisms and sets 5 μg/kg as the lowest-effect level and 24,000 μg/kg as a severe-effect level. Aroclor-1262 was detected at a level between these two effect levels; therefore there is an indication that this may be a problem.

Semivolatiles were analyzed for the Boeing Company outfall and the Renton Municipal Airport outfall (sites 1 and 3). Several coal tar derivatives and pthalates (plasticizer) were detected at both sites. This could be caused by the fuel usage or contributions from the asphault.

6.6 FUTURE WATER QUALITY CONDITIONS

Land use in the Cedar River is changing from largely agricultural and forested to residential, non-commercial animal keeping, and light commercial development. This change in land use has resulted in, and will continue to result in, increased stormwater flows and increased concentrations and transport of nonpoint pollutants to the basin's streams, lakes, and wetlands. The increase in quantity and decrease in quality of the water is of concern now, and will become an even greater concern in the near future.

Current water quality analysis (see Section 6.5) indicates that solids (TSS), fecal contaminants, nutrients, and metals are the major nonpoint pollutants in the basin. These pollutants will continue to increase in the future as urbanization and associated impervious surfaces increase throughout the basin. The quality and quantity of water that all water bodies receive will be impacted by development. Proper implementation of BMPs can significantly reduce the impacts of nonpoint pollutants, but even with mitigation, some degree of beneficial use (i.e., fisheries and wildlife, recreation, and aesthetic) impairment is likely to occur.

POLLUTANT LOADINGS

Loading estimates were made for four representative water pollutants—total suspended solids (TSS), total phosphorus (TP), lead (Pb), and fecal coliform bacteria (FC)—in surface runoff under current and future conditions. These four contaminants are representative of important pollutant classes that are likely to degrade water quality in the future. Pollutant loading estimates were made by multiplying land area in each land use by a pollutant yield coefficient appropriate for the land use. These yield coefficients were derived from published literature (Horner, 1991) and have considerable uncertainties. Therefore, the coefficients are expressed as minimum, median, and maximum values. Analysis of the data is based on the absolute percent increase of each pollutant from current to future conditions.

Table 6-14 shows the pollutant loading coefficients (minimum) used for the analysis. In general, loadings for each pollutant increase as the land-use intensity increases. TSS and Pb loadings increase sharply at the higher development levels (i.e., multi-family and commercial) in contrast to TP loadings that increase at the lower development levels (i.e., conversion of grass/forest to low-density residential uses).

Table 6-14 Pollutant Loading Coefficients

Land Use	Total Phosphorus (TP)*	Fecal Coliform (FC)**	Lead (Pb)*	Fecal Coliform (FC)**
Commercial	242	2.2	1.6	1.7×10^9
Multi-family	133	1.4	0.35	6.3×10^9
High density	97	1.3	0.05	4.5×10^9
Medium density	78	1.2	0.04	3.6×10^9
Low density	60	1.1	0.03	2.8×10^9
Grass	80	0.02	0.03	4.8×10^9
Forest	26	0.22	0.01	1.2×10^9

* kg/ha-y
** number/ha-y

Current and future pollutant loadings were calculated for the entire BPA by catchment and for the Class 1 wetlands. It should be noted that loadings for catchment Summerfield may be over predicted. Water in this catchment infiltrates and the loading coefficients do not reflect pollutant removals due to infiltration. These calculations are a predictive tool used to assess the future conditions and are not intended to reflect future concentrations.

BPA

Figure 6-2 shows the predicted absolute percent increase of total suspended solids, total phosphorus, lead, and fecal coliform by catchment; basin-wide loadings were predicted to increase 39, 63, 103, and 32%, respectively.

Ambient lead levels currently exceed chronic toxicity levels; a doubling of lead levels could have a detrimental effect on beneficial uses. Lead concentrations in the more urbanized catchments, such as Maplewood, Fairwood (Molasses Creek), Madsen, and Jones/Orting Hills Road, are already high and increases of 92 to 148% could cause acute toxicity. Lead concentrations are currently low in the less developed catchments, such as Peterson and Rock creeks; however, increases of 115 to 149% could be enough to increase concentrations to toxic levels. These loading increases are estimated for development without mitigation.

Wetlands

Figure 6-3 shows the predicted absolute increase for total suspended solids, total phosphorus, and lead loadings to the Class 1 designated wetlands in the basin. It should be noted that these loadings were based on full build out conditions without mitigation. See *Chapter 7: Aquatic Habitat* for a detailed description of these wetlands. In general,

Figure 6-2 Predicted Pollutant Increase by Catchment

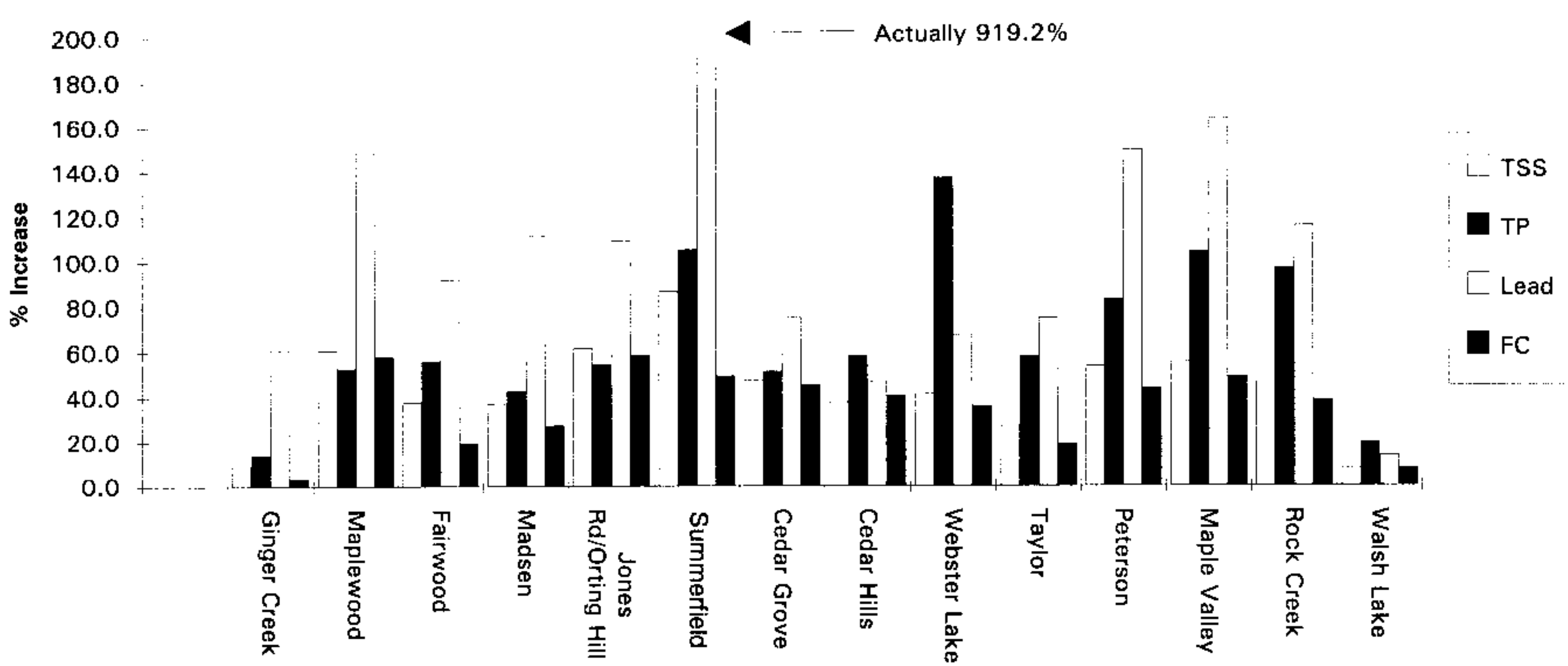
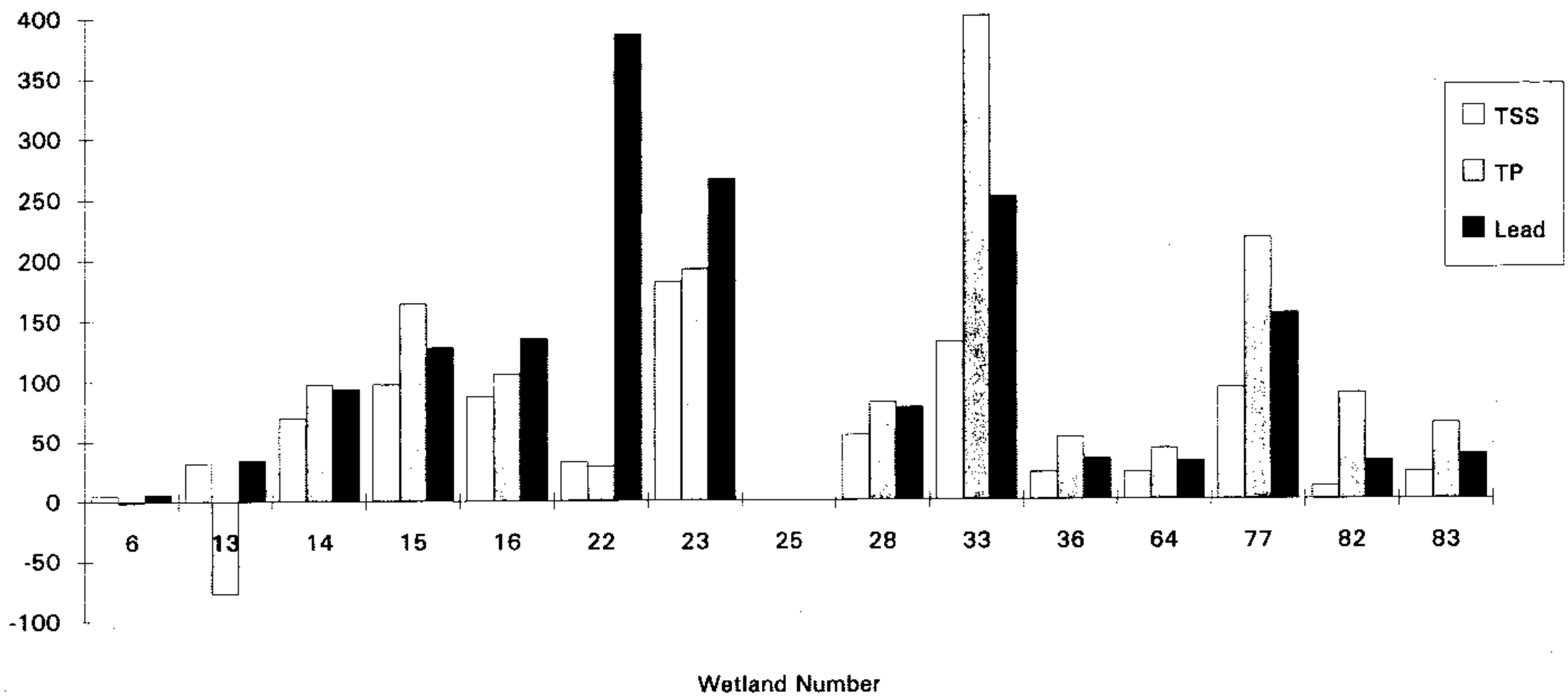


Figure 6-3 Predicted Pollutant Increase by Wetland



Lower Cedar River Class 1 wetlands that will experience the most increased pollutant loadings are located in the headwaters of tributary systems. For example, lead loadings to Wetland 16, located in the headwaters of Madsen Creek (Tributary 0305), are predicted to increase by 135% from current to future built out conditions. Additionally, solids and nutrients are predicted to increase by 87 and 106%. Increased inputs of pollutants of this magnitude will not only affect the wetland, but will have an effect on the water quality of Madsen Creek. The stormwater quality of Madsen Creek currently has increased pollutant concentrations due to urbanization. Pollutant levels in the headwater wetlands of Molasses Creek, including Wetlands 22 and 23, are predicted to increase up to 400% in future built out conditions. Many of these headwater areas are currently less developed and, under current land-use regulations, could be developed to high-density residential. Lake Desire, for example, is currently exhibiting signs of eutrophication and additional phosphorus inputs could be detrimental. Total phosphorus is predicted to increase 98 and 164% in Wetlands 14 and 15, respectively, located in the headwaters of Lake Desire. Webster Lake, Wetland 33, is currently in a pristine state, but future pollutant loadings could increase up to 400% in built out conditions.

6.7 WATER QUALITY PROBLEMS BY SUBBASIN

This section indicates significant water quality concerns or problems in the Cedar River Basin. Results from both the nonpoint pollution source identification and the chemical water quality analysis are discussed for the eight subbasins: Renton Reach, Lower Cedar River Mainstem, Lower Cedar River Subbasins, Middle Cedar River Mainstem, Peterson Creek Subbasin, Taylor Creek Subbasin, Middle Cedar River Subbasins, and Rock Creek Subbasin (Map 2, *Appendix B*).

RENTON REACH (RM 0.0 to 1.6)—Map 17

Mainstem water quality was measured at the Bronson Street bridge (RM 1.5), which is upstream of the commercial and industrial areas of Renton. Metal toxicity exceeded standards during one out of three storms and most parameters were within recommended levels. This reflects the dilution effects of the mainstem and does not include contributions from the high intensity land uses of Renton. However, fecal coliform bacteria concentrations exceeded criteria limits.

The commercial/industrial areas of the Renton Reach are significant sources of nonpoint pollution. During storm events, the Logan Street stormdrain outfall consistently contributes extremely high metal concentrations (in excess of the acute toxicity standards for copper, lead, and zinc), suspended solids, turbidity, total phosphorus, and fecal coliform bacteria. Sediments at this outfall are within the range of "highly polluted," which indicates that either this is a consistent source or there have been inputs of pollutants that were concentrated enough to be retained in the sediments. A survey of potential commercial and industrial sources has identified an auto maintenance shop as a possible source.

The Boeing Company and the City of Renton operate airport facilities along the Cedar River. Stormwater in a ditch between the Boeing Company and the Cedar River Trail periodically exceeded recommended levels of total phosphorus and fecal coliform bacteria standards. Elevated levels of fecal coliform bacteria are probably contributed by the large bird population at the mouth of the Cedar River. Acute and/or chronic toxicity standards were exceeded for copper, lead, and zinc. Volatile organics and PCBs were detected in the sediments at the Boeing outfall and volatile organics were detected in the sediments at the Renton Municipal Airport stormwater outfall.

LOWER CEDAR RIVER MAINSTEM (RM 1.6 to 16.2)—Map 18

Contaminant concentrations in the mainstem are typically low due to dilution. However, stormwater samples in the lower mainstem exceeded recommended levels or standards for solids, turbidity, total phosphorus, and fecal coliform bacteria during the higher intensity storms. Acute copper toxicity and chronic lead toxicity standards were periodically exceeded.

The Stoneway Batch Plant sediment pond outflow had extremely high pH; pHs of 11.9 and 11.3 were measured. Metal concentrations were also elevated, but due to the hardness of the water they did not exceed toxic standards. The pH of the sediments was slightly elevated (8.4) which indicates some buffering capacity within the system. The pH was not measured in the mainstem downstream of the outfall during the storm events.

The I-405 outfall includes highway runoff and residential/commercial runoff for adjacent areas. Water quality at this outfall showed levels of solids, turbidity, total phosphorus, and fecal coliform bacteria in excess of recommended levels and standards. Acute toxicity standards for copper, lead, and zinc were also exceeded.

LOWER CEDAR RIVER SUBBASINS

Stormwater samples were taken at Maplewood Creek, Madsen Creek, Orting Hills tributary, Cedar Hills tributary and at the old King County Shop tributary (unnumbered tributary). The land use in these areas are typically residential, with increasing densities downstream along these tributaries. Land-use based modeling indicated likely nonpoint pollution problems in Ginger Creek, Molasses Creek, and Cedar Grove tributary. In general, urbanization in the Lower Cedar River Subbasins is impacting the water quality in the tributaries.

Maplewood Creek (Tributary 0302)—Map 20

Bacteria and nutrient concentrations exceeded recommended levels and standards in Maplewood Creek. Septic failure rates for this drainage area were 13.2% and 4.8%, depending on the area studied. There are also several problem small noncommercial farms with poor management practices, some where livestock have direct access to streams in this drainage. This indicates that the potential bacterial source is from a combination of human and animal wastes. Acute and/or chronic metal toxicity standards were exceeded during storm events. Samples were taken at a tributary to Maplewood Creek, upstream of the sedimentation pond, originating from a residential area. Extremely significant levels of solids, turbidity, total phosphorus, and fecal coliform bacteria and acute copper, lead, and zinc toxicity were found during two storm events.

Land-use based modelling indicates that, in the future, without mitigation, pollutant loadings to Maplewood Creek should increase under future conditions.

Madsen Creek (Tributary 0305)—Map 22

The water quality in Madsen Creek reflects the subbasin's high-density residential land use. Acute and/or chronic standards for copper, lead, and zinc are often exceeded. Significant sediment and fecal coliform concentrations were found entering the sedimentation pond (RM 0.9). The Fairwood area sewer connection line runs down Madsen Creek. The potential of this sewer line to leak or break poses a threat to the downstream water quality. The herbicide 2,4-D was found in the sediments at the confluence of Tributaries 0305 and 0306. Sources include the Fairwood golf course and/or residential pesticide applications.

Land-use based modelling indicates that, without mitigation, pollutant loadings to Madsen Creek should increase under future conditions. Loadings to Wetland 16 at the headwaters of Madsen Creek are predicted to increase. This increase is due to the increase in commercial and high-density residential land use, and elimination of forest land uses in the catchment area. The land use in the catchment to Wetland 25 is currently high-density residential and will not change under future conditions, therefore pollutant loadings are not predicted to increase. However, the current urbanization threatens the wetlands.

Orting Hills (Tributary 0307)—Map 20

Stormwater samples taken above the confluence of Tributary 0307 showed high levels of nutrients and fecal coliform bacteria. Fecal streptococcus bacteria levels were measured and the fecal coliform/fecal stroptoccus ratio indicates a human source. The septic survey showed that septic tank failure rates within this drainage area were 13.1, 4.8, and

3.9%; the area with 13% failures is of particular concern. In addition, copper, lead, and zinc concentrations exceeded acute and chronic toxicity standards.

Copper concentration exceeded acute toxicity criteria in four out of five samples, chronic lead in four out of five samples, and acute zinc in one and chronic zinc in one out of five samples. This area is currently low and high-density residential, and is expected to become primarily high-density residential in the future.

Cedar Hills Tributary (Tributary 0316A)—Map 24

There are several activities with the potential to contribute to nonpoint pollution in the Cedar Grove tributary. Cedar Hills Landfill, Stoneway Gravel, Cedar Grove Composting, and Queen City Farms Superfund site are all located within the subbasin.

The headwaters of stream 0316A originate in a wetland adjacent to a residential area. An undefined channel passes through the corner of the Cedar Hills Landfill, which receives uncontaminated runoff from buffer areas. The stream is contained in a rock-lined channel around the perimeter of Cedar Grove Composting. Extremely high levels of nutrients and organic matter from the composting pile runoff, composted materials, and an overflow from stormwater (leachate) ponds enter directly into the stream at this point. The stream takes a direct route across the Stoneway Gravel mine, accumulates behind a natural berm, and infiltrates a short distance to a spring adjacent to Cedar Grove Road. Runoff from the gravel pit contributes high sediment loads; Tributary 0316A has highly eroded the area passing through the gravel pit and a hydrologic connection has been made connecting it to the process pond (Wetland 30), which contributes extremely high levels of fine sediment to stream 0316A. Excessive sedimentation and algal growth have occurred in downstream wetlands (Wetlands 31 and 32) due to the sediment and nutrient inputs from Stoneway Gravel and Cedar Grove Composting.

Stormwater samples were taken adjacent to Cedar Grove Road. Copper exceeded the acute toxicity standard and lead and zinc exceeded the chronic toxicity standard. These samples were impacted by road runoff from traffic to the landfill. In addition, solids, turbidity, total phosphorus, and fecal coliform exceeded the recommended levels or standard.

Uncontaminated runoff from Cedar Grove landfill enters Tributary 0316A or Wetland 13. The EPA has proposed a plan for the cleanup of soils and groundwater at this site, which includes the area surrounding Wetland 13. There is no surface discharge from Wetland 13 and groundwater flows towards the Issaquah Basin.

Unnumbered Tributary—Map 18

Toxic concentrations of metals were found in the unnamed tributary adjacent to the abandoned County vehicle maintenance site.

Ginger Creek (Tributary 0300A)—Map 19; Molasses Creek (Tributary 0304)—Map 21; Cedar Grove (Tributaries 0308-0310)—Map 23; and Webster Lake (Tributaries 0317-0319)—Map 24

There was no water quality data collected in these catchments. However, a comparison of water quality data from throughout the Cedar River Basin and land-use based pollutant modeling indicates that nonpoint pollution problems are likely to occur in Ginger Creek, Molasses Creek, and Cedar Grove tributary. Both Ginger Creek and Molasses Creek subbasins are urbanized. This land-use type threatens the water quality of both tributaries.

Wetlands 22 and 23 are both located in the headwaters of Molasses Creek. Land-use conversion is from forest and low-density residential to high-density residential. The water quality of these wetlands are threatened by increased development.

Septic tank failures within the Cedar Grove catchment were found to be 13% with an average age of 27 years, and 9% with an average age of 26 years. Failures are above the regional average and are a likely source of bacteria and nutrients and, due to the age of the systems, failures are expected to increase in the future.

MIDDLE CEDAR RIVER MAINSTEM (RM 16.2 to 21.2)—Map 25

Water quality in the middle mainstem is considered excellent. Water enters the subbasin from the City of Seattle watershed, which produces high quality drinking water. Nonpoint pollutants are contributed mainly toward the lower end of this subbasin as land use becomes more residential. The City of Seattle and Metro monitor the baseflow water quality at Landsburg Dam; the water quality at this point is excellent. Stormwater samples, taken at the Landsburg Dam to characterize the background stormwater quality, were of excellent water quality. However, copper exceeded the acute toxicity standard during one event. A specific source is not suspected other than metal concentrations reflect the natural soil content, solubility, and the influence of the soft water.

Future predicted phosphorus loadings to Wetland 83 are predicted to increase 60% without mitigation.

PETERSON CREEK SUBBASIN—Map 26

Stormwater samples were taken at the mouth of Peterson Creek at the Cedar River. Pollutant criteria were exceeded, but overall the water quality at the mouth of the tributary is good. The Peterson Creek Subbasin is currently less developed and so is able to provide a buffer to pollutant inputs. However, future development and urbanization is a definite threat to the future water quality of this subbasin. The area around Lake Desire is within the urban growth boundary, and high-density residential development is expected to occur.

The lake system of the Peterson Creek Subbasin includes Lakes Desire, Spring, Shady, and Peterson. Lake Desire is considered a eutrophic lake and Metro has classified the water quality as poor. The water quality of Lake Desire is currently being studied by KCSWM in a Phase One Restoration and Feasibility Study. Recent developments in the subbasin have contributed to degraded water quality in Lake Desire. Metro has classified the water quality in Shady and Spring Lakes as good. However, DOE has designated Shady Lake as being use impaired (fisheries) due to oxygen depletion; the listed causes are influences from pasture land, urban development and stormwater runoff, and removal of riparian vegetation. The current low-density residential pattern in this subbasin is rapidly changing to higher density development. These proposed developments will contribute additional nonpoint pollution to the wetland, lakes, and stream systems of the subbasin.

The septic survey showed failure rates of 15.8 and 11.5% for the areas surrounding Lakes Desire and Spring, respectively. In addition to these septic failures, there are a number of small noncommercial farms in the subbasin that have the potential to contribute nutrients and bacteria to the system. However, the stormwater samples taken at the mouth of the creek do not indicate current septic or agricultural nonpoint pollution problems.

Land-use based modelling indicates that future pollutant loadings in this subbasin and to Wetlands 14 and 15 will increase with forthcoming urbanization, without mitigation. Wetlands 14 and 15, at the headwaters of Lake Desire, are considered to be eutrophic, and any increased phosphorus loadings will increase the current water quality problems. Wetland 28 (Spring Lake) is valuable habitat area (see *Chapter 7: Aquatic Habitat*) and the water quality of this wetland is threatened by future development.

TAYLOR CREEK SUBBASIN—Map 27

Stormwater samples taken at three locations within the Taylor Creek Subbasin found acute and chronic metal toxicity in road drainage entering Taylor Creek. In addition, metal toxicity standards were exceeded intermittently in storm samples. Nutrient, total phosphorus, and nitrate and nitrite-nitrogen levels exceeded recommended levels at all sampling locations. Fecal coliform levels exceeded the standards and were among the highest in the basin, as high as 3960 organisms/100 ml.

The agricultural survey showed that the Taylor Creek drainage had the highest concentration of noncommercial farms in the BPA. Animals often have direct access to the stream, waste management practices are not in place, and many pastures are in poor condition. Septic failure rates in this subbasin were within the regional average. This indicates that the bacteria and nutrient source is from small noncommercial farm practices in the subbasin.

A relative comparison of pollutant loadings indicated that, with future unmitigated development, Taylor Creek contributed the highest lead loadings into the Cedar River. SR-18 is a current nonpoint pollution source for typical road-related pollutants such as metals and oils and grease. Unmitigated future expansion of this roadway will increase the pollutant loading to the Taylor Creek system.

MIDDLE CEDAR RIVER SUBBASINS—Map 25

Dorre Don (Tributary 0336)

Stormwater quality at the Dorre Don tributary showed one extremely high zinc concentration, more than 20 times the acute toxicity standard. However, this level is not consistent with the total suspended solids level and is believed to be an analytical error. During this same storm event, copper exceeded the acute criteria and lead exceeded the chronic criteria, total phosphorus and nitrate and nitrite-nitrogen exceeded the recommended levels, and fecal coliform levels also exceeded the standards. The septic system survey showed a repair rate of 6.7%, which is slightly above the regional average. The elevated nutrient and bacteria levels are consistent with the historical septic system repair rate.

Walsh Lake Diversion (Tributary 0341)

Historical mining and brick manufacturing activities in the Walsh Lake Subbasin may have affected the drinking water quality of Walsh Lake, but there is no current of historical water quality data to support this. In an effort to segregate this from the inlet at Landsburg Dam, the effluent was diverted, via the Walsh Lake Diversion, and routed back into the Cedar River below the intake at Landsburg. Acute copper and chronic lead and zinc standards were exceeded during one of the three stormwater samples. The cause of this is unknown but may reflect the natural metal content of the soils and hardness of the water. Fecal coliform standards were marginally exceeded during two of the storm events. These fecal coliform levels are not excessive and could be due to wildlife contributions from within the Seattle Watershed.

ROCK CREEK SUBBASIN—Map 28

Very little water quality data is available for Rock Creek Subbasin, but the water quality is thought to be very good. The subbasin is still very rural and there has been very little water quality degradation due to the low intensity land uses.

The outlet of Retreat Lake was monitored during three storm events. The stormwater quality was good with two exceptions. Acute copper toxicity standards were exceeded on one occasion. Fecal coliform levels were exceed twice, but were relatively low. Nutrients (phosphorus and nitrates) and sediments (total suspended solids) in the stormwater samples were far below recommended levels. A survey of septic tank failures showed that systems around Retreat Lake had a historical repair rate of 5%. This is consistent with the average failure rate in the Puget Sound area of 3 to 5%. The average age of septic systems around Retreat Lake is less than fifteen years and increased repairs are expected as the systems age. The low septic failure rate and low nutrient levels in the stormwater indicate that there is currently not a water quality problem at Retreat Lake.

The headwaters of Rock Creek originate in Lake No. 12. Metro has classified the water quality in Lake No. 12 as very good based on 1990 winter total phosphorus levels, summer Chlorophyll a levels, and summer transparency. Due to excessive macrophyte densities, King County SWM is currently studying the water quality of Lake No. 12 in an ongoing lake restoration feasibility study. Results of this study are expected late in 1993.

Most of the existing logging operations within the BPA are located in Rock Creek. If not controlled, these logging and land clearing activities could contribute to the nonpoint pollution load of the system, especially sediments. The subbasin is currently still very rural in nature and considered the most pristine subbasin in the BPA.

6.8 KEY FINDINGS

- ★ The Cedar River is considered to be the "clean water source" for Lake Washington. The Seattle Water Department manages the upper basin for high quality drinking water. Increased pollutant inputs downstream of the Landsburg Dam could threaten the water quality of Lake Washington.

- ★ The Cedar River is considered to be prime habitat for salmon rearing. Increases in toxic pollutants will threaten the productivity of the system.

- ★ Urbanization in the lower tributaries has degraded water quality. Increased urbanization without water quality mitigation will threaten the future water quality.

- ★ Solids, nutrients, and fecal coliform bacteria associated with surrounding land use are threatening water quality in the basin. These problems are especially severe in the higher density residential subbasins such as Maplewood and Fairwood.

- ★ Road runoff is threatening water quality throughout the basin. Toxic metal concentrations are found in road runoff and in tributaries that receive the runoff. Many roads throughout the basin drain into adjacent tributaries. These toxic metal concentrations threaten the aquatic fauna of the system.

- ★ Animal keeping, especially small noncommercial farms, is a potential source of nutrients and bacteria. Animal keeping is primarily on small lots and best management practices are rarely used. This is of particular concern in the Taylor Creek Subbasin.

- ★ Land clearing and the permanent conversion of forested land to residential or commercial use is the dominant forest practice occurring in the basin. The site clearing and grading for access roads and construction will result in increased water quality problems from runoff and erosion associated with these land uses.

- ★ Underground home heating oil tanks are a nonpoint pollution source. Many of these tanks have been abandoned and the remaining oil contents could leak.

- ★ The average onsite sewage disposal system repair rate exceeds the regional average. Nonpoint pollution from failing septic systems is of particular concern around Lakes Desire, Spring, and Shady; areas of Maplewood Heights; and along the mainstem.

- ★ Residential pesticide use and small quantity hazardous waste generators threaten the water quality of the basin. Herbicide applications at golf courses also pose a threat to water quality.

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- ★ Other nonpoint pollution sources that were found to pose a potential water quality problem include composting, metal recycling, and gravel mining activities.

- ★ The commercial areas in Renton pose significant water quality problems; extremely high metal concentrations were found at the Logan Street outfall, semivolatile organics were found in the runoff from both the Boeing Company and Renton Municipal Airport outfall, concentrations of PCBs were found in the Boeing Company runoff, and extremely high pH levels were found in the Stoneway Batch Plant R/D pond effluent.

- ★ Surface-water pollutants threaten the groundwater quality. This is particularly true in areas of high recharge. Surface pollutants threaten the Renton Sole Source Aquifer, the sole drinking water source for the City of Renton.

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Water Quality Appendix

TABLE 1 CEDAR RIVER Stormwater Samples

DATE	SITE	TSS (mg/L)	TURB. (NTU)	ALK (mg/L)	HARD (mg/L)	TP (ug/L)	NO3+ NO2-N (ug/L)	O/G (mg/L)	Fecal Coli (#/100mL) (* est)	Fecal Strep (#/100ml)	DO (mg/L)	Temp (C)	pH
12/04/9	1	93	37	--	18.7	171	84	< 1.0	* 380	--	--	9.6	6.37
02/19/9	1	4.6	16	11.8	17	59	65	1.4	1320	--	--	11.8	7.08
11/20/9	1	6.3	6.4	2.5	3.59	59	34		* 400				
12/05/9	1	21	8.6	7.3	10.8	74	33		* 1800				
12/04/9	2	1530	600	--	31.1	1610	39	< 1.0	1680	--	--	9	8.36
11/20/9	2	4.3	6.1		7.97	131	57		* 2500				
12/04/9	3	41.5	17	--	24.1	174	420	< 1.0	1840	--	--	--	--
11/20/9	3	9.9	4.1	24.8	24.7	38	336		* 300				
12/05/9	3	25	6	18.1	18.7	34	265		* 60				
10/16/9	4	53	--	--	36.2	98	427	1.6	* 3000	--	--	--	--
12/04/9	4	41.5	28	--	60.3	290	612	< 1.0	4600	--	--	10.6	6.63
02/19/9	4	310	330	25.6	38	400	526	1.5	* 1400	--	--	9.6	7.2
11/20/9	4	56	32	27.1	33.9	120	304		10				
12/05/9	4	95	38	23.7	31.5	120	275		* 1800				
12/04/9	5	285	128	--	255	980	215	1.2	* 1200	--	--	8.8	11.93
02/19/9	5	48	52	115	103	91	114	2.1	20	--	--	9.8	11.35
11/20/9	5	59	52	124	133	122	550		10				
12/05/9	5	45	49	68.2	65.4	91	274		* 20				
12/04/9	6	99	19	--	23.7	780	421	< 1.0	400	--	--	8	--
02/19/9	6	233	51	13.9	18.6	280	444	< 1.0	* 200	--	--	8.7	7.5
11/20/9	6	10	4.2	24.2	23.9	32	320		* 200				
12/05/9	6	31	5.5	16.1	17.9	28	264		* 140				
10/16/9	7	63	--	--	62.3	108	1690	1.3	420	--	--	--	--
12/04/9	7	316	63	--	30.4	220	910	< 1.0	740	--	--	8.6	7.5
02/19/9	7	643	240	19	28.7	880	782	1.6	1820	--	--	9.8	6.16
11/20/9	7	16	6.3	53.3	63.5	53	1330		* 920				
12/05/9	7	98	20	34.3	43.9	116	1420		* 1000				
11/20/9	7A	1022	56	9	5.98	1680	132		2300				
12/05/9	7A	1173	270	5.2	3.99	960	185		* 3200				
10/16/9	8	110	--	--	37.7	191	481	1.3	9600	--	--	--	--
12/04/9	8	510	74	--	26.9	350	1720	1.4	* 1800	100	--	9	7.37
02/19/9	8	633	170	9.7	25.2	710	1860	1.8	* 1900	1980	--	9	8.16
11/20/9	8	3	3.2	25.6	29.1	27	639		420				
12/05/9	8	8.3	4.7	17.8	23.9	35	774		900	920			
10/16/9	9	13	--	--	99.1	52	200	1.4	6800	--	--	--	--
12/04/9	9	2230	104	--	35	840	695	< 1.0	* 2400	--	--	--	--
02/19/9	9	2070	290	13.4	28.5	1960	688	1.4	2140	--	--	9.3	8.21
11/20/9	9	95	16	30.1	35.9	129	415		* 600				
12/05/9	9	112	14	28.8	15.2	114	526		520				
10/16/9	10	344	--	--	44.6	520	533	1.2	* 1600	--	--	--	--
12/04/9	10	1.5	2.8	--	30.4	13	989	< 1.0	* 28	--	--	--	--
02/19/9	10	216	320	15.4	24.9	420	437	< 1.0	* 600	--	--	9.4	7.17
11/20/9	10	48	63	29.1	39.9	102	433		* 1400				
12/05/9	10	61	55	26.3	37.1	89	337		* 2800				

TABLE 1 (cont.) Cedar River Stormwater Samples

DATE	SITE	TSS (mg/L)	TURB. (NTU)	ALK (mg/L)	HARD (mg/L)	TP (ug/L)	NO3+ NO2-N (ug/L)	O/G (mg/L)	Fecal Coli (#/100mL) (* est)	Fecal Strep (#/100ml)	DO (mg/L)	Temp (C)	pH
10/16/9	11	6.8	--	--	51.2	70	970	< 1.0	580	--	--	--	--
12/04/9	11	136	54	--	98.1	190	439	< 1.0	20600	--	--	--	--
02/19/9	11	56	31	79.8	81.4	152	378	< 1.0	* 80	--	--	9.7	6.96
12/05/9	11	5.1	4.5		54.6	27	48		* 20				
10/16/9	12	4	--	--	34.6	19	265	< 1.0	52	--	--	--	--
12/04/9	12	54	17	--	26.9	74	990	< 1.0	1240	--	--	--	--
02/19/9	12	174	33	10.3	17.4	270	975	< 1.0	3960	--	--	8.2	--
11/20/9	12	20	6.5	31.7	37.9	99	1200		* 1400				
12/05/9	12	44	13	21.8	29.1	94	1580		1120				
12/04/9	13	53.5	12	--	23	55	800	< 1.0	* 140	--	--	7.5	--
02/19/9	13	230	41	9.43	19.4	220	1017	< 1	* 300	--	--	8.3	7.43
12/05/9	13	21	5	17	8.37	43	1020		* 60				
12/04/9	14	8.5	6.1	--	19.7	19	222	< 1.0	* 10	--	--	--	--
11/20/9	14	2	2.8	20.5	21.5	13	414		10				
12/05/9	14	19	3.6	11.6	15.5	23	235		* 20				
02/19/9	15	108	26	10.4	19	201	999	2	2980	--	--	9	--
11/20/9	15	65	13	28.6	35.1	170	1090		* 800				
12/05/9	15	55	13	17.3	12	116	1520		1120				
02/19/9	16	119	23	6.67	15.4	167	2390	< 1	* 180	--	--	8	--
11/20/9	16	2	10	9.1	14.4	43	919		* 10				
12/05/9	16	186	6.4	9.2	5.98	446	1090		* 60				
02/19/9	17	53	19	10	17.8	133	984	< 1	2610	--	--	8.2	--
11/20/9	17	61	12	28.6	36.3	156	1260		* 1200				
12/05/9	17	48	11	21.4	12.8	115	1550		920				
02/19/9	18	99	19	8.2	16.6	187	954		1540	--	--	8	--
12/05/9	18	3	3.1	8.5	10	176	1750	1	* 240				
02/19/9	19	38	19	9.7	15	56	648		* 180	--	--	7	--
11/20/9	19	6.5	1.9	23.1	24.3	30	358	1	10				
12/05/9	19	12	2	21.1	23.2	30	534		* 200				
02/19/9	20	< 0.5	1.3	28.2	33.2	12	504		520	--	--	7.5	--
11/20/9	20	< 0.5	0.35	37	35.1	7	271	1	10				
12/05/9	20	< 0.5	0.5	34.2	34.7	6	510		* 160				
02/19/9	21	747	210	11.2	20.5	530	361		* 32	--	--	7.7	--
11/20/9	21	1	4	27	29.1	15	192	1	* 100				
12/05/9	21	5	4.9	21.7	24.3	16	153		20				

Table 2 CEDAR RIVER Stormwater Metal Toxicity

Note: * Shaded column is the MEASURED Copper (Cu), Lead (Pb), or Zinc (Zn) concentrations
* Acute and Chronic columns are the CALCULATED toxicity criteria based on hardness
* An underlined criteria means that the measured concentration exceeds either the acute or chronic criteria

Date	Site	Hardness (mg/L)	Toxicity Standard Acute	Toxicity Standard Chronic	Cu	Toxicity Standard Acute	Toxicity Standard Chronic	Pb	Toxicity Standard Acute	Toxicity Standard Chronic	Zn
901204	1	18.7	3.7	2.8	5.9	9.7	0.4	2.9	28.3	25.6	3.8
911205	1	10.8	2.2	1.8	69.0	4.8	0.2	53.0	17.8	16.1	54.0
910219	1	17.0	3.3	2.6	1.6	8.6	0.3	2.2	26.1	23.6	18.0
911120	1	3.6	0.8	0.7	1.0	1.2	0.0	4.4	7.0	6.3	32.0
901204	2	31.1	5.9	4.4	57.0	18.5	0.7	238.0	43.5	39.4	484.0
911120	2	8.0	1.6	1.4	1.0	3.3	0.1	6.0	13.7	12.4	139.0
901204	3	24.1	4.6	3.5	1.5	13.3	0.5	0.8	35.0	31.7	5.0
911205	3	18.7	3.7	2.8	4.3	9.7	0.4	1.4	28.3	25.6	40.0
911120	3	24.7	4.7	3.6	1.0	13.8	0.5	0.8	35.8	32.4	3.0
901016	4	36.2	6.8	5.0	6.5	22.4	0.9	14.7	49.5	44.8	57.0
901204	4	60.3	11.0	7.7	3.8	42.9	1.7	2.3	76.2	69.0	33.0
911205	4	31.5	6.0	4.4	17.5	18.8	0.7	31.8	44.0	39.8	106.0
911120	4	33.9	6.4	4.7	8.1	20.6	0.8	23.7	46.8	42.4	74.0
910219	4	38.0	7.1	5.2	19.6	23.8	0.9	38.4	51.5	46.7	56.0
901204	5	255.0	42.8	26.3	15.7	268.8	10.5	4.0	258.7	234.3	34.0
911205	5	65.4	11.9	8.2	12.4	47.6	1.9	6.2	81.7	74.0	28.0
910219	5	103.0	18.2	12.1	3.7	84.8	3.3	2.9	120.0	108.7	10.0
911120	5	133.0	23.2	15.1	24.0	117.4	4.6	9.2	149.0	135.0	42.0
901204	6	23.7	4.6	3.5	1.5	13.1	0.5	0.8	34.6	31.3	3.0
911205	6	17.9	3.5	2.7	4.7	9.1	0.4	1.3	27.2	24.7	15.0
910219	6	18.6	3.6	2.8	3.5	9.6	0.4	1.3	28.1	25.5	3.0
911120	6	23.9	4.6	3.5	1.0	13.2	0.5	0.8	34.8	31.5	3.0
901016	7	62.3	11.3	7.9	2.8	44.7	1.7	1.5	78.4	71.0	7.0
901204	7	30.4	5.8	4.3	4.8	17.9	0.7	2.1	42.7	38.6	15.0
911205	7	43.9	8.2	5.9	10.1	28.6	1.1	2.6	58.3	52.8	61.0
911120	7	63.5	11.6	8.0	1.1	45.8	1.8	0.8	79.6	72.1	3.0
910219	7	28.7	5.5	4.1	8.6	16.7	0.6	6.7	40.6	36.8	24.0
911205	7A	4.0	0.9	0.8	45.8	1.4	0.1	16.9	7.6	6.9	9.9
911120	7A	6.0	1.2	1.1	34.9	2.3	0.1	18.3	10.8	9.7	103.0
901016	8	37.7	7.1	5.1	7.1	23.6	0.9	6.7	51.2	46.4	25.0
901204	8	26.9	5.1	3.9	8.3	15.3	0.6	2.4	38.5	34.8	37.0
911205	8	23.9	4.6	3.5	5.9	13.2	0.5	4.0	34.8	31.5	88.0
911120	8	29.1	5.5	4.1	1.0	17.0	0.7	0.8	41.1	37.2	3.0
910219	8	25.2	4.8	3.6	11.4	14.1	0.6	9.8	36.4	33.0	26.0
901016	9	99.1	17.6	11.7	4.1	80.7	3.1	4.8	116.1	105.2	21.0
901204	9	35.0	6.6	4.8	9.1	21.5	0.8	0.8	48.1	43.5	54.0
911205	9	15.2	3.0	2.4	44.7	7.4	0.3	8.5	23.7	21.5	599.0
911120	9	35.9	6.8	4.9	7.6	22.2	0.9	3.4	49.1	44.5	55.0
910219	9	28.5	5.4	4.0	17.8	16.5	0.6	6.4	40.4	36.6	32.0

Table 2 (cont.) Cedar River Stormwater Toxicity

Date	Site	Hardness (mg/L)	Cu Toxicity Standard Acute	Cu Toxicity Standard Chronic	Cu	Pb Toxicity Standard Acute	Pb Toxicity Standard Chronic	Pb	Zn Toxicity Standard Acute	Zn Toxicity Standard Chronic	Zn
901016	10	44.6	**8.3**	**5.9**	14.7	29.2	**1.1**	5.9	59.0	53.5	28.0
901204	10	30.4	5.8	4.3	1.5	17.9	0.7	0.8	42.7	38.6	3.0
911205	10	37.1	**7.0**	**5.1**	12.7	23.1	**0.9**	4.0	50.5	45.8	31.0
911205	10	54.6	10.0	7.1	4.6	37.8	1.5	1.4	70.1	63.5	31.0
911120	10	39.9	7.5	**5.4**	6.9	25.3	**1.0**	5.9	53.7	48.7	31.0
910219	10	24.9	**4.8**	**3.6**	5.9	13.9	**0.5**	2.9	36.0	32.6	20.0
901016	11	51.2	9.4	6.7	1.5	34.8	1.4	0.5	66.4	60.1	3.0
901204	11	98.1	17.4	11.6	6.5	79.7	**3.1**	6.8	115.1	104.3	65.0
911205	11	54.6	10.0	7.1	3.2	37.8	**1.5**	2.3	70.1	63.5	18.0
910219	11	81.4	14.6	9.9	3.8	62.8	**2.4**	10.3	98.3	89.0	30.0
901016	12	34.6	6.5	4.8	1.5	21.1	0.8	0.5	47.6	43.1	3.0
901204	12	26.9	5.1	3.9	1.5	15.3	0.6	0.8	38.5	34.8	6.0
911205	12	29.1	**5.5**	**4.1**	7.7	17.0	**0.7**	2.9	41.1	37.2	35.0
911120	12	37.9	7.1	5.2	1.0	23.7	0.9	0.8	51.4	46.6	7.0
910219	12	17.4	3.4	2.7	2.3	8.8	**0.3**	5.5	26.6	24.1	10.0
901204	13	23.0	4.4	3.4	1.5	12.6	0.5	0.8	33.7	30.5	5.0
911205	13	8.4	**1.7**	**1.4**	6.9	3.5	**0.1**	1.9	**14.3**	**13.0**	25.0
910219	13	19.4	**3.8**	**2.9**	4.9	10.1	**0.4**	3.3	29.2	26.4	3.0
901204	14	19.7	3.8	3.0	1.5	10.3	0.4	0.8	29.5	26.8	4.0
911205	14	15.5	**3.1**	**2.4**	6.5	7.6	**0.3**	1.2	24.1	**21.8**	24.0
911120	14	21.5	4.2	3.2	1.0	11.5	0.4	0.8	31.8	28.8	3.0
911205	15	12.0	**2.4**	**1.9**	6.0	5.5	**0.2**	2.5	19.4	17.6	15.0
911120	15	35.1	6.6	**4.8**	5.6	21.5	**0.8**	2.3	48.2	43.7	20.0
910219	15	19.0	**3.7**	**2.9**	6.1	9.9	**0.4**	4.7	28.7	26.0	3.0
911205	16	6.0	**1.2**	**1.1**	14.6	**2.3**	**0.1**	9.6	**10.8**	**9.7**	40.0
911120	16	14.4	2.9	2.3	1.0	6.9	**0.3**	2.8	22.7	20.5	3.0
910219	16	15.4	**3.0**	**2.4**	3.3	**7.5**	**0.3**	27.6	24.0	21.7	3.0
911205	17	12.8	**2.6**	**2.0**	9.1	6.0	**0.2**	2.3	**20.5**	**18.6**	63.0
911120	17	36.3	6.8	5.0	3.5	22.5	**0.9**	2.1	49.6	44.9	17.0
910219	17	17.8	3.5	2.7	1.8	9.1	**0.4**	1.7	27.1	24.6	3.0
911205	18	10.0	**2.0**	**1.7**	5.2	4.4	**0.2**	0.9	**16.6**	**15.1**	401.0
910219	18	16.6	3.3	2.5	1.5	8.3	**0.3**	3.6	25.6	23.1	9.0
911205	19	23.2	**4.5**	**3.4**	11.1	12.7	**0.5**	1.8	**33.9**	**30.7**	34.0
911120	19	24.3	4.7	3.5	1.0	13.5	0.5	0.8	35.3	32.0	11.0
910219	19	15.0	3.0	2.3	1.0	7.3	**0.3**	0.9	23.5	21.2	3.0
911205	20	34.7	6.5	4.8	4.6	21.2	0.8	0.7	47.7	43.2	21.0
911120	20	35.1	6.6	4.8	1.0	21.5	0.8	0.8	48.2	43.7	3.0
910219	20	33.2	6.3	4.6	1.0	20.1	0.8	0.5	46.0	41.6	3.0

TABLE 3 CURRENT AND FUTURE POLLUTANT LOADINGS FOR CATCHMENTS

TOTAL SUSPENDED SOLIDS (min)

Subbasin	Current Total TSS kg/yr	Future Total TSS kg/yr	Absolute Increase	Percent Increase	Current Average kg/yr/ac	Future Average kg/yr/ac	Absolute Average Increase	Percent Average Increase
Ginger Creek	148110	165484	17374	11.7	230.6	257.6	27.0	11.7
Maplewood Cr	176355	283345	106990	60.7	161.1	258.8	97.7	60.7
Molasses Cree	224540	309121	84582	37.7	198.5	273.2	74.8	37.7
Madsen Creek	250974	313887	62913	25.1	176.9	221.3	44.4	25.1
Orting Hill	98539	159137	60598	61.5	144.3	233.1	88.8	61.5
Summerfield	14915	27820	12904	86.5	106.3	198.3	92.0	86.5
Cedar Grove	110981	163514	52533	47.3	155.2	228.7	73.5	47.3
Cedar Hills	104191	143225	39034	37.5	135.7	186.6	50.8	37.5
Webster Lake	59523	83953	24430	41.0	108.5	153.0	44.5	41.0
Taylor Creek	396372	502657	106284	26.8	124.0	157.3	33.3	26.8
Peterson Cree	382860	585939	203079	53.0	102.0	156.2	54.1	53.0
Maple Valley	83650	129592	45942	54.9	99.7	154.4	54.7	54.9
Rock Creek	710990	1038016	327026	46.0	87.7	128.0	40.3	46.0
Walsh Lake	299321	323322	24001	8.0	75.9	82.0	6.1	8.0
Total	3061321	4229012	1167691	38.1	-	-	-	-
Average/Basin	204088	281934	77846	38.1	127.1	179.2	52.1	41.0

TOTAL PHOSPHORUS (min)

Subbasin	Current Total TP kg/yr	Future Total TP kg/yr	Absolute Increase	Percent Increase	Current Average kg/yr/ac	Future Average kg/yr/ac	Absolute Average Increase	Percent Average Increase
Ginger Creek	1748.3	1975.9	227.6	13.0	2.72	3.08	0.35	13.0
Maplewood Cr	2258.8	3451.2	1192.4	52.8	2.06	3.15	1.09	52.8
Molasses Cree	2122.9	3308.1	1185.3	55.8	1.88	2.92	1.05	55.8
Madsen Creek	2589.8	3444.5	854.7	33.0	1.83	2.43	0.60	33.0
Orting Hill	1345.2	2075.7	730.5	54.3	1.97	3.04	1.07	54.3
Summerfield	121.5	249.3	127.8	105.1	0.87	1.78	0.91	105.1
Cedar Grove	1449.1	2190.4	741.3	51.2	2.03	3.06	1.04	51.2
Cedar Hills	344.9	544.3	199.4	57.8	0.45	0.71	0.26	57.8
Webster Lake	498.4	1178.8	680.3	136.5	0.91	2.15	1.24	136.5
Taylor Creek	5449.4	8578.2	3128.9	57.4	1.70	2.68	0.98	57.4
Peterson Cree	4534.9	8289.8	3754.9	82.8	1.21	2.21	1.00	82.8
Maple Valley	1107.3	2255.8	1148.4	103.7	1.32	2.69	1.37	103.7
Rock Creek	6952.9	13648.4	6695.5	96.3	0.86	1.68	0.83	96.3
Walsh Lake	3071.5	3670.2	598.7	19.5	0.78	0.93	0.15	19.5
Total	33595.1	54860.6	21265.5	63.3	-	-	-	-
Average/Basin	2239.7	3657.4	1417.7	63.3	1.37	2.17	0.80	58.0

LEAD (min)

Subbasin	Current Lead kg/yr	Future Lead kg/yr	Absolute Increase	Percent Increase	Current Average kg/yr/ac	Future Average kg/yr/ac	Absolute Average Increase	Percent Average Increase
Ginger Creek	151.7	244.3	92.6	61.1	0.24	0.38	0.14	61.1
Maplewood Cr	170.0	422.6	252.6	148.5	0.16	0.39	0.23	148.5
Molasses Cree	419.7	806.5	386.7	92.1	0.37	0.71	0.34	92.1
Madsen Creek	245.5	525.9	280.4	114.2	0.17	0.37	0.20	114.2
Orting Hill	45.1	94.2	49.2	109.1	0.07	0.14	0.07	109.1
Summerfield	5.6	57.3	51.7	919.2	0.04	0.41	0.37	919.2
Cedar Grove	59.8	104.6	44.8	74.9	0.08	0.15	0.06	74.9
Cedar Hills	42.4	62.2	19.8	46.7	0.06	0.08	0.03	46.7
Webster Lake	22.3	37.2	14.9	67.0	0.04	0.07	0.03	67.0
Taylor Creek	278.2	485.2	207.0	74.4	0.09	0.15	0.06	74.4
Peterson Cree	213.1	530.2	317.1	148.8	0.06	0.14	0.08	148.8
Maple Valley	34.0	89.3	55.3	162.7	0.04	0.11	0.07	162.7
Rock Creek	566.6	1218.2	651.7	115.0	0.07	0.15	0.08	115.0
Walsh Lake	105.2	119.3	14.2	13.5	0.03	0.03	0.00	13.5
Total	2359.2	4797.1	2437.9	103.3	-	-	-	-
Average/Basin	157.3	319.8	162.5	103.3	0.10	0.22	0.12	117.8

TABLE 4 CURRENT AND FUTURE POLLUTANT LOADINGS FOR CLASS 1 WETLANDS

TOTAL SUSPENDED SOLIDS (min)

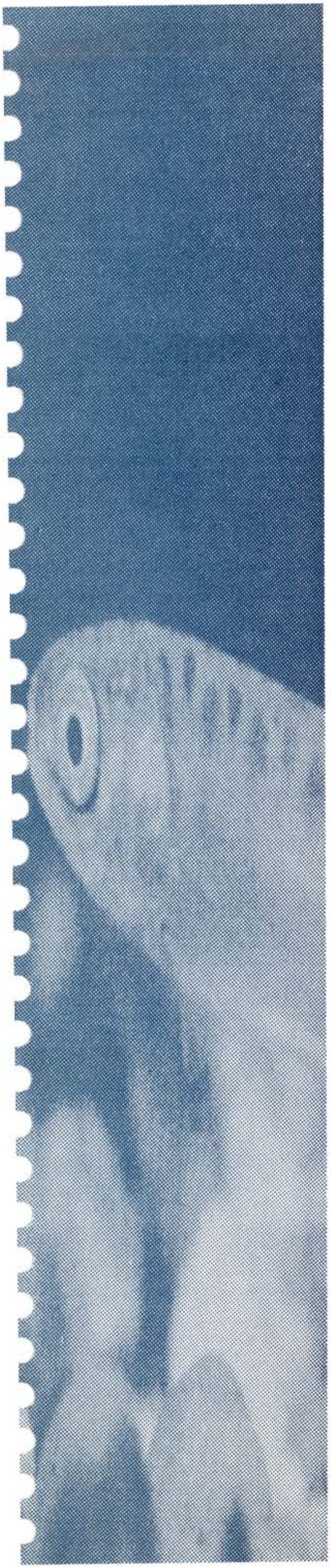
WETLAND	Current Total TSS kg/yr	Future Total TSS kg/yr	Absolute Increase	Percent Increase	Current Average kg/yr/ac	Future Average kg/yr/ac	Absolute Average Increase	Percent Average Increase
6	3574	3746	171	4.8	67.5	70.8	3.2	4.8
13	49044	64718	15674	32.0	151.5	200.0	48.4	32.0
14	23147	39265	16118	69.6	135.1	229.2	94.1	69.6
15	15441	30487	15045	97.4	102.5	202.3	99.8	97.4
16	22966	43042	20076	87.4	143.8	269.5	125.7	87.4
22	4699	6227	1528	32.5	185.0	245.2	60.1	32.5
23	1259	3538	2279	181.1	86.0	241.6	155.7	181.1
25	2282	2282	-1	0.0	132.0	132.0	0.0	0.0
28	51602	79537	27935	54.1	106.9	164.8	57.9	54.1
33	3409	7871	4462	130.9	64.0	147.8	83.8	130.9
36	21732	26641	4910	22.6	123.5	151.4	27.9	22.6
64	36852	45223	8371	22.7	110.1	135.1	25.0	22.7
77	14475	27803	13328	92.1	77.3	148.4	71.2	92.1
82	31442	34787	3345	10.6	123.3	136.4	13.1	10.6
83	21469	26344	4874	22.7	110.2	135.2	25.0	22.7
Total	303393	441510	138117	45.5	-	-	-	-
Average	20226	29434	9208	45.5	114.6	174.0	59.4	51.8

TOTAL PHOSPHORUS (min)

WETLAND	Current Total TP kg/yr	Future Total TP kg/yr	Absolute Increase	Percent Increase	Current Average kg/yr/ac	Future Average kg/yr/ac	Absolute Average Increase	Percent Average Increase
6	27.9	27.5	0	-1.4	0.53	0.52	-0.01	-1.4
13	71.2	16.3	-55	-77.0	0.22	0.05	-0.17	-77.0
14	221.6	438.7	217	97.8	1.29	2.56	1.27	97.8
15	163.2	430.5	267	163.8	1.08	2.86	1.77	163.8
16	198.8	409.1	210	105.8	1.24	2.56	1.32	105.8
22	59.3	76.5	17	29.0	2.34	3.01	0.68	29.0
23	16.2	47.2	31	191.5	1.11	3.22	2.12	191.5
25	27.1	27.1	0	-0.2	1.57	1.56	0.00	-0.2
28	744.5	1350.0	606	81.3	1.54	2.80	1.26	81.3
33	28.8	143.6	115	399.2	0.54	2.70	2.16	399.2
36	320.2	486.0	166	51.8	1.82	2.76	0.94	51.8
64	504.9	717.8	213	42.2	1.51	2.15	0.64	42.2
77	160.9	507.2	346	215.2	0.86	2.71	1.85	215.2
82	284.5	532.4	248	87.2	1.12	2.09	0.97	87.2
83	214.5	349.4	135	62.9	1.10	1.79	0.69	62.9
Total	3043.7	5559.4	2516	82.7	-	-	-	-
Average	202.9	370.6	166	82.7	1.19	2.22	1.03	86.6

LEAD (min)

WETLAND	Current Lead kg/yr	Future Lead kg/yr	Absolute Increase	Percent Increase	Current Average kg/yr/ac	Future Average kg/yr/ac	Absolute Average Increase	Percent Average Increase
6	1.1	1.2	0.1	5.6	0.02	0.02	0.00	5.6
13	17.0	22.9	5.8	34.2	0.05	0.07	0.02	34.2
14	9.6	18.6	9.0	93.8	0.06	0.11	0.05	93.8
15	22.1	50.4	28.3	127.7	0.15	0.33	0.19	127.7
16	58.1	136.6	78.5	135.0	0.36	0.86	0.49	135.0
22	2.2	10.7	8.5	385.5	0.09	0.42	0.34	385.5
23	0.5	1.8	1.3	265.2	0.03	0.12	0.09	265.2
25	1.0	1.0	0.0	-0.2	0.06	0.06	0.00	-0.2
28	21.9	38.7	16.8	77.0	0.05	0.08	0.03	77.0
33	1.1	3.7	2.7	249.5	0.02	0.07	0.05	249.5
36	9.4	12.6	3.2	33.8	0.05	0.07	0.02	33.8
64	15.7	20.7	5.0	31.6	0.05	0.06	0.01	31.6
77	5.2	13.2	8.0	153.1	0.03	0.07	0.04	153.1
82	11.7	15.5	3.7	31.9	0.05	0.06	0.01	31.9
83	8.2	11.3	3.1	37.3	0.0	0.1	0.0	37.3
Total	184.9	358.8	173.9	94.0	-	-	-	-
Average	12.3	23.9	11.6	94.0	0.07	0.16	0.09	123.9



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Chapter 7: Aquatic Habitat

7.1 INTRODUCTION

The Cedar River Basin below the Landsburg Water Supply Diversion Dam has a variety of riverine environments ranging from mainstem habitats to small headwater stream systems. Peripheral to the mainstem is a network of valley-floor habitats, such as side channels, oxbow lakes, and spring-fed "wall-based" tributaries. These habitats exist in a wide range of conditions from the near pristine reaches of Rock Creek (Tributary 0338) to the dramatically altered reaches of Madsen and Maplewood creeks (Tributaries 0305 and 0302, respectively), and the constructed "Renton Reach" of the lower mainstem (RM 0.0-1.6). The wetland habitats of the Basin Planning Area (BPA) are also extensive and highly varied and include bogs, swamps, marshes, ponds, and lakes in the riparian zone along the river and on the plateaus above.

This chapter examines the conditions of the different types of habitats in the BPA, describes the relationship between the Cedar River landscape and its aquatic features, and explains the influences of habitat changes on salmonid populations.

7.2 LANDSCAPE AND HABITAT CONCEPTS

INTRODUCTION

Aquatic habitats form as a result of complex interactions among water, soil, and riparian vegetation. The nature of these interactions is determined locally by physical features such as valley morphology, stream substrates, and vegetation, which create local variations in hydraulic complexity and by landscape processes that affect the storage and transport of water and sediment. The biological condition of aquatic habitats, such as the presence of diverse plant communities and fish populations, is determined in large part by many of these physical processes (Schlosser, 1991).

Land use throughout much of the Pacific Northwest has reduced the quality and abundance of aquatic habitats due to increases in storm runoff volumes and velocities and the loss of hydraulic complexity in stream channels, riparian areas, and wetlands. These changes tend to transform stream systems from a complex mosaic of pools and riffles to streams of relatively lesser complexity, dominated by riffles (Hicks, 1991; Ralph, 1992).

Landscape Age and Habitat

The Cedar River habitats are susceptible to damage by many land uses in part because they are situated in a geologically "young" landscape. The basin is characterized by large areas of highly erodible soils and dissected by numerous high-gradient stream systems that flow through deeply incised ravines. As a result, much of the landscape remains susceptible to considerable further erosion before a relatively stable geologic base is achieved. This natural process is aided by seasonally intense storm events common to the west slope of the Cascade Mountains, resulting in periodic high surface-water energy and aquatic environments that are naturally prone to frequent localized disturbance due to erosion.

On top of this geologic template is a landscape composed of diverse aquatic and terrestrial ecosystems including forested uplands, riparian areas, stream channels, wetlands, and lakes. Each of these systems is differentially affected by the frequency and magnitude of disturbances such as landslides and floods. The type and condition of buffering mechanisms surrounding these water bodies largely determines the extent of the effect of these disturbances. Often land development affects habitat by reducing or eliminating buffers and thereby changing the rate and magnitude of disturbances and the quantity and quality of aquatic habitat. Dramatic destruction of stream fish habitat and degradation of wetlands or lakes is often the most obvious effect of human development (Booth, 1991). In many instances, these changes parallel, or occur prior to, other problems, such as erosion of roads and utilities and damage to flood control structures.

BUFFERING ELEMENTS

Buffering in a landscape is provided by those elements that diffuse energy and thereby reduce the rate and magnitude of disturbance events. Jorgenson (1990) defined buffering capacity as the relationship between external variables (i.e., forcing functions) and internal (i.e., state) variables. In the case of stream fish habitat, the dominant forcing function is energy from runoff events, while state variables include factors such as well-vegetated riparian areas and stream channel roughness, which is created mainly by large bed materials, such as boulders, and large woody debris (LWD; see *Riparian Vegetation* below).

Soil, vegetation, and topographic features such as lakes, wetlands, and floodplains are the principal buffering agents of the landscape in the Cedar River Basin. Buffers modify the effect of disturbances and thereby create and maintain the hydraulic condition and aquatic habitats of the BPA. Loss or reduction of these buffering elements changes the rate, magnitude and influence of disturbances and contributes to physical damage of habitats and artificial structures.

Effects of Reduced Buffering

Within a landscape, buffering capacity is lost when elements such as vegetation, pervious soils, stream channel roughness, or volume of topographic depressions are reduced. Consequently, water energy is redirected and often increased as a result of reduced storage and/or diffusion of water in the landscape (see also *Chapter 3: Surface Water Hydrology* and *Chapter 2: Geology and Groundwater*). The net effect of reduced buffering is to overwhelm downstream aquatic habitats with excessive quantities of water and/or sediment. These flows can scour stream channels or dislodge and smooth stream channel and riparian roughness elements such as LWD, which are important in forming pool habitat and storing sediments.

Throughout the BPA, the effect of large-scale development is to reduce buffering, increase the rate and magnitude of disturbances, and reset affected areas to a geophysically and biologically immature condition. For example, streams become structurally simple and some wetlands become dominated by earlier successional stages: forested swamps revert to less structurally complex scrub-shrub wetlands and scrub-shrub wetlands revert to emergent systems.

Soil as a Buffering Element

Soils act as buffers by absorbing and storing much of the precipitation in our region, thus dampening the energy of stormwater runoff. Extensive areas of the BPA have high levels of glacial outwash soils, which have such high infiltration rates that many streams are present only during very wet seasons. Loss of soil permeability as a result of paving or soil compaction caused by lawns and pastures, often dramatically increases stormflow and subsequent erosional and flooding damage to habitat and, not coincidentally, to public and private property as well. Reduced infiltration of stormwater also results in less groundwater recharge and less water available for discharge during summer low-flow conditions. This further reduces fish habitat and possibly threatens the recharge of aquifers that provide baseflow to many aquatic systems.

Vegetation as a Buffering Element

Vegetation profoundly modifies the interaction between soil and water, and thus, it is another important buffering agent. The distribution, type, and quantity of vegetation are important in determining its buffering value and functions. Historically, the lowland valleys west of the Cascades were blanketed with an extremely high biomass of vegetation, much of it arranged in great structural complexity as a result of both standing and dead-and-down trees. This vegetation, dominated by ancient coniferous forests with deep duff layers, performed a variety of functions including dampening the impact of storm events by storing and slowing water movement through the landscape. In addition, vegetation was critical in directly stabilizing soils and creating much of the hydraulic diversity of stream environments. For many Pacific Northwest streams west of the Cascades, over 50% of the complex pool environment important for fish production is directly created by LWD recruited from riparian areas along stream channels (Franklin, 1992). Furthermore, stream channel stability is maintained and enhanced by this material, often seen in complex debris jams.

Topographic Features as Buffers

Lakes, wetlands, and floodplains are topographic features that are both important aquatic habitats on their own and serve as buffers for downstream aquatic habitat. Their value as habitat and in buffering is affected by changes in surrounding soil and vegetation buffers that lead to overwhelming increases in water inflow or inputs of sediments and other pollutants. Human development within these features often leads to infilling, which directly reduces the water storage and cleansing capabilities of these features. Allowing development in or adjacent to these features, particularly floodplains, can also put unsuspecting people in dangerous or high maintenance locations.

RIPARIAN VEGETATION

Historic Changes in Landscape and Riparian Vegetation

The vegetation of the Cedar River Basin has been changed dramatically in both type and quantity over the past 100 years. The primary change has been a conversion of the landscape from a coniferous-based, structurally complex forest to one dominated by deciduous trees and immature coniferous forests (Puget Sound Cooperative River Basin Team, 1992) with extensive clearings for agriculture and urbanization. Currently, approximately 56% of the basin below the Landsburg Diversion is forested, with only 37% of the large forested tracts are in a mature coniferous forest condition.

The majority of these "mature" timber stands are 55 to 70 years old, still too young to provide significant recruitment of LWD to the forest floor or stream channels (Franklin, 1992). Deciduous trees play a different role than conifers in long-term stream habitat formation and landscape stability because of their smaller size, faster decay rates, and loss of leaves during winter rainy periods. Nevertheless, deciduous trees are important in the nutrient cycling of landscapes and streams, adding organic material to both streams and forest soils. They are also important stabilizing elements in the early successional stages of disturbed patches of forests, particularly on landslide areas and along the margins of river channels large enough to meander, such as the mainstem of the Cedar River. The current prevalence of deciduous vegetation suggests that conifers were not replanted or did not take hold in much of the BPA following initial logging and is further indicative of the immature state and highly disturbed nature of the Cedar River Basin.

The Importance of Riparian Areas

Riparian areas are the interface between aquatic and terrestrial environments and often contain the greatest vegetative diversity and structural complexity in a landscape. Typically comprising a small portion of the land base in a watershed, riparian areas have a disproportionate influence in moderating soil and water movement, and thereby in creating and maintaining habitat. Their value for fish habitat and role in maintaining a healthy (i.e., dynamically stable) stream condition includes input of LWD, storage of overbank flood flows, trapping of sediments and other pollutants, moderating temperature extremes, and provision of organic material for aquatic productivity. Riparian vegetation is especially important in the restoration of habitat following disturbance (Lisle, 1982; Gregory and others, 1991).

Healthy riparian ecosystems in the Pacific Northwest are typified by a complex matrix of live and dead vegetation often dominated by living and fallen large coniferous trees. Loss of this riparian vegetation results in stream and wetland systems more susceptible to erosion damage and water quality degradation. Consequently these systems are less capable of sustaining diverse populations of fish and wildlife. Due to the dominance of immature riparian conditions of the Cedar River Basin, many of the habitat functions and values have been significantly reduced from pristine conditions.

Role of Large Woody Debris

Large woody debris (LWD) is an important component of healthy streams and wetlands of the Pacific Northwest (Naiman and others, 1992). The dynamic stability and complexity of streams afforded by these structural elements provided the environment in which the historic community of salmonids evolved over thousands of years. Large woody debris in streams and riparian zones assists in stabilizing stream channels by diffusing water energy, storing sediments, and reducing the rates of channel migration and incision. Much of the hydraulic diversity of streams is formed around LWD as a result of localized scouring and depositional processes. This interaction typically results in a very complex array of pool and riffle environments suitable to a variety of salmonid and other fish species. In addition to formation of habitat, LWD increases the structural complexity of habitat allowing for higher fish densities, reduced velocities during storm flows, and improved protection from predators. Finally LWD is an important source of nutrients for primary and invertebrate production. It is becoming increasingly evident that the formation and maintenance of "good" fish habitat relies to a very large extent on the interaction of LWD, and other organic debris, with soil and water.

SALMONIDS AND THE HYDRAULIC ENVIRONMENT

There are eleven distinct species, and numerous unique populations, of naturally occurring salmonids in the Pacific Northwest, comprising the most diverse salmonid-based ecosystem in the world. Six of these species occur in the BPA. The evolution of stream fish communities is the result of adaptation to the hydraulic, chemical, and biological attributes of the aquatic systems and surrounding landscape. Under pristine conditions, the hydraulic condition of streams in Pacific Northwest is typically highly diverse with conditions ranging from complex patterns of small step pools and pocket-water common in headwater and peripheral stream channels to deep expansive pools and backwaters of larger, lower gradient rivers.

Wetlands, lakes, side channels, and spring-fed wall-base tributaries naturally form along many streams providing additional habitat complexity for many species and life history stages of salmonids. For example, wall-base tributaries, which are stable spring-fed habitats located along the margins of river valleys, are extremely important winter rearing areas for coho salmon and provide refuge for many fish from mainstem storm flows. Wetlands and small lakes are often highly productive environments for coho salmon and cutthroat trout when water temperature and oxygen levels are adequate. Side channels provide additional habitat complexity along low gradient areas of larger streams and are utilized by all species of salmonids for spawning or rearing, or both, depending on timing and availability of water and channel size. Each species and unique population of salmonids adapts and distributes itself along a gradient of these hydraulic niches within the aquatic environment.

Many of these peripheral or "fringe" environments are highly susceptible to human impact because they are closely connected with the surrounding land and because their small size or ephemeral nature makes them appear as insignificant to fish production or other aquatic functions. As a result, they receive less regulatory attention and public concern. However, they are often the most productive individual habitats in a river system and are critical for certain life history stages of many salmonids.

Theoretically, as a landscape ages following a disturbance, vegetational interactions will play an increasing role in buffering and shaping the landscape, and stream habitat patches will become increasingly stable, larger, and more complex. This successional process provides the habitat complexity to accommodate diverse biological communities and individual species with increasingly complex life histories, such as chinook salmon, which have relatively high life-history variability in freshwater and generally large adult body size. At the other end of the spectrum, younger, more dynamic landscapes are predicted to be dominated by small-bodied species with relatively low variability in freshwater life-history characteristics, such as pink salmon and cutthroat trout. These species require less hydraulic complexity for completion of their freshwater phases. Such a relationship helps to clarify the ecological implications of landscape-level changes on fish populations.

Invariably, the consequences of human development are reduced buffering and increased effects of disturbance. As a result the landscape and its biota reset itself accordingly, with the most dramatic and permanent changes in stream hydraulic environments and fish species compositions predicted in the urban environment. This relationship appears to be consistent with observed changes in stream fish populations in the Lake Washington drainage basin (Lucchetti and Fuerstenberg, 1993).

Salmonid Populations and Disturbance Stress

Ecological systems typically respond to stresses caused by significant disturbance by reductions in physical and/or biological complexity. When these stresses are sustained beyond the natural adaptive capabilities of the species or community, the system is replaced. Salmon populations throughout the Pacific Northwest have been subjected to high levels of sustained stress caused by human disturbances. Many of these stresses are different in magnitude and behavior from those to which local fish populations originally adapted. These stresses include the physical modification of habitat and landscapes described above, as well as overfishing, interaction with hatchery stocks, and acute and chronic pollution. While it is not possible at this time to sort out which of these factors has had the greatest influence, it is likely that land-use driven habitat degradation is a primary contributor (Hicks and others, 1991; Bisson and others, 1992). The cumulative response of salmonids to these stresses is manifested in the loss or near extermination of many specialized populations, and a concomitant reduction in the overall diversity of the aquatic community. Thus, a major concern with fish populations, whether in the Cedar River or elsewhere in the Pacific Northwest, is that continued sustained stress, from habitat modification or other pressures, will ultimately lead to further declines in fish species diversity, and possibly the complete loss, of unique salmon stocks.

7.3 METHODS

Aquatic habitats in the Cedar River BPA were evaluated to assess past and present land-use effects on fish use and quantity and quality of stream and wetland habitat. Stream habitat conditions were assessed by evaluating the extent and condition of riparian areas and the structural complexity of stream channels in combination with erosion problems and geomorphic and hydrologic impacts of past development, as noted in earlier portions of this report. Field work to assess stream habitat conditions in the Cedar River Basin was conducted from October 1991 through June 1992. All tributary streams known to have salmon or trout were walked to identify passage barriers, point problems, and general habitat conditions with relationship to riparian and in-channel characteristics. Surveys were often extended upstream of fish use to assess upstream fish habitat potential and threats from upstream land uses. The valley floor of the Cedar River from Landsburg to the City of Renton was surveyed to identify the extent and condition of existing aquatic habitat features and identify areas of potential habitat creation. Additional assessment of mainstem and valley-floor habitat features was made using aerial photographs and videography.

Information from the National Wetlands Inventory (US Fish and Wildlife Service, 1985) and the King County Wetlands Inventory (King County, 1990a) was used to establish priorities for examining wetlands in the field to assess current conditions and threats from future development. The locations of uninventoried wetlands noted in the 1987 SWM Basin Reconnaissance Program and during field work for this report were also recorded for later addition to the inventory. As shown in Tables 7-1 and 7-2, wetland field evaluations were conducted for the following categories of inventoried wetlands: all Class 1 wetlands, all 10-acre or larger Class 2 wetlands, and all Class 2 wetlands associated with the mainstem Cedar River. In addition, 15 smaller Class 2, 3, and inventoried wetlands (those with a "b" suffix in the King County Sensitive Areas Folio (King County, 1990b)) were also visited. In all, 52% of the inventoried wetlands (equalling 89% of the total inventoried wetland acres) were visited in order to gauge the status of the less conspicuous systems in the BPA.

Table 7-1 Wetland Field Evaluations

Wetland Class	Number of Wetlands Evaluated	Percentage of Wetlands Evaluated	Wetland Acres Evaluated	Percentage of Acres Evaluated
Class 1	15/15	100	321.5/321.5	100
Class 2	28/55	51	467.7/559.9	84
Class 3	2/16	13	1.2/ 10.9	11
All Classes	**45/86**	**52**	**790.4/892.3**	**89**

During these field visits, aerial photographs and topographic maps were used to analyze development and drainage patterns affecting the wetlands, and field notes and photos were taken to document current conditions and impacts. Wetland functions and values were assessed using a modified version of the Reppert and others (1979) wetland evaluation method. The above information will eventually be used to develop wetland management plans for selected wetlands that can benefit from protection, restoration, and enhancement measures beyond those provided in the King County Sensitive Areas Ordinance (SAO).

Table 7-2 Impacts to Several Small and Uninventoried Wetlands

No.	Wetland Class	Acres	Impacts
30	2	2.7	Impacted by gravel mining.
45	3	0.5	Buffer and former scrub- shrub habitat has been cleared and graded into a shallow pond.
47	2	2.1	Buffer and alder/willow swamp have been cleared and graded to form an ornamental pond planted with non- native vegetation. Blackberries and reed canarygrass are invading along the edges.
63	3	0.7	Wetland has been filled to create a grassy play field for a residential subdivision.
89b	*	*	Open water pond encircled by residential lawn.
102	2	7.0	Wetland has been severely fragmented by power line transmission corridor construction and maintenance.
108b	*	*	Wetlands associated with Lake Youngs have been
109b	*	*	impacted recently by pipeline construction.
115b	*	*	Wetland within power line transmission corridor has been filled.
122b	*	*	Wetland has been cleared, filled, and graded. Extensive trash dumping (furniture, appliances, abandoned car, etc.) has also occurred.
124b	*	*	Buffer clearing.
125b	*	*	Wetland was been cleared within the past 10 years; a new home was built within 25 feet of the wetland edge in 1991.

7.4 CEDAR RIVER FISHERIES

OVERVIEW

The Cedar River BPA produces five species of salmonids: sockeye (*Oncorhynchus nerka*), coho (*O. kisutch*), and chinook (*O. tshawytscha*) salmon, and steelhead (*O.mykis*) and cutthroat (*O. clarki*) trout, and Dolly Varden Charr (*Salvelinus malma).* It is believed that the Cedar River once supported spring-run stocks of chinook, as well as chum (*O. keta*) and pink (*O. gorbuschca*) salmon prior to its diversion into Lake Washington, but these species are no longer found in the system (Coccoli, pers. commun., 1992). Although the Cedar River is one of the few large river systems in the Puget Sound Basin without a permanent hatchery system, there is an extensive history of stocking hatchery origin salmonids in the system. For example, hatchery origin chinook and coho salmon were stocked over a long period of time and the sockeye run is believed to be the result of introduced fish (see below). For the past two years the Washington Department of

Fisheries has operated an adult collection, egg incubation, and fish release program for sockeye as part of an interagency interim relief program stemming from concern over recently declining Lake Washington sockeye populations. These facilities are located at RM 21.9 along the left bank of the Cedar River above the Landsburg pipeline crossing. A previous effort to enhance sockeye populations via an extensive egg-box program was attempted from 1975 to 1980, achieving a peak egg take of approximately 13 million eggs. However, this program was stopped because of persistent disease and maintenance problems.

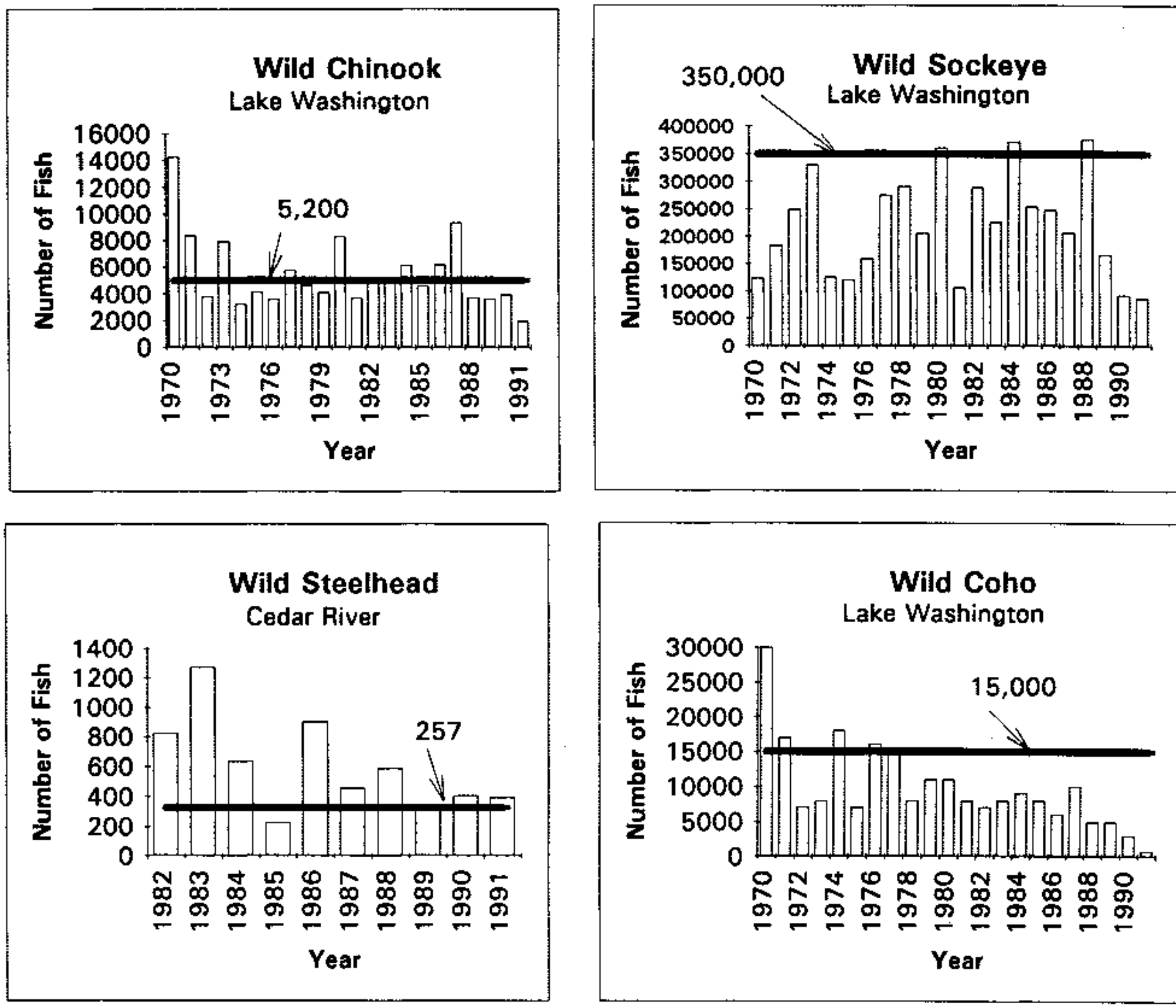
The history of steelhead plantings in the Cedar River is also extensive, with smolts from the Chambers Creek hatchery being planted between 1958 and 1991 by the Washington Department of Wildlife (formerly the Washington Department of Game). Between 1982 and 1991, steelhead smolts were planted at an average rate of 34,100 fish per year in the Cedar River. Over a six year span (1985-1990, except 1988), an additional average of 29,000 juvenile steelhead, derived from wild steelhead adults captured at the Ballard Locks, were stocked annually above the Landsburg Dam. Unfortunately, none of the salmon or steelhead stocking programs described above were rigorously monitored and assessed for their benefits to the fishery or their effects on the naturally producing stocks of the system.

Currently, the fisheries of the Cedar River Basin are managed, to the extent possible, for the natural production of salmonids. Salmon stocks are co-managed by the Washington Department of Fisheries (WDF) and the Muckleshoot Indian Tribe (MIT) while the MIT and Washington Department of Wildlife (WDW) jointly manage steelhead populations. In order to keep harvest rates relatively low, the south end of Lake Washington is not opened to commercial fishing except when sockeye are targeted. For example, naturally produced coho salmon from the Cedar River are harvested at relatively high hatchery rates in mixed-stock fisheries conducted in south Puget Sound, but once they enter the Shilshole Bay area they are harvested at considerably lower rates, more compatible with sustained natural production. Once they enter south Lake Washington they are not targeted for harvest although some may be caught incidentally when sockeye fisheries are conducted. Directed fisheries for Cedar River sockeye only occur when the Lake Washington runs exceed the 350,000 fish spawning escapement goal.

The lowest spawning escapements on record for all species of wild anadromous salmonids returning to Lake Washington have occurred since 1989 (Figure 7-1; note: returns for chinook, coho, and sockeye are presented for the entire Lake Washington

Figure 7-1

Spawning Escapement of Wild Anadromous Salmonids in the Lake Washington Basin



Chinook, coho, and sockeye estimates are for the entire Lake Washington basin (see text for estimated contribution of the Cedar River).

Horizontal lines indicate escapement goals. No data were available for cutthroat trout.

Drainage because formal estimates for individual systems were not available at the time of this report). The most dramatic of these declines appears to be for wild coho salmon, whose spawning escapement in 1991 was only 800 fish for all of Lake Washington, as compared to escapement levels averaging 13,700 and 7,700 in the 1970s and 1980s, respectively. The escapement goal for Lake Washington wild coho salmon is 15,000 fish, with the Cedar River system contributing approximately 12-15% of the overall production, based on available habitat.

Wild chinook salmon have maintained steady escapement levels for the past 20 years, averaging 5,500 to 6,000 spawners per year, but declining to only 1,900 fish in 1991, well below the wild fish escapement goal of 5,200 fish for the Lake Washington Basin, of which the Cedar River is estimated to contribute approximately 40%. Sockeye salmon spawning escapements have dropped from an average of 261,000 fish per year throughout the 1980s to 93,000 and 87,000 in 1990 and 1991, respectively. In a typical year, the Cedar River is estimated to contribute about 90% of the overall sockeye production in Lake Washington, although in 1992 unexpectedly low runs of fish entered the river while Bear and Issaquah Creeks, two of the largest tributaries of the Sammamish River, had the highest returns on record. Today one of the major fish management objectives for the Cedar River is sockeye production.

Steelhead runs to the mainstem of the Cedar River have averaged 600 fish per year since 1980 (range: 224 to 1,272) with recent declines largely attributed to a combination of predation by California sea lions (*Zalophus californianus*) at the Ballard Locks and a loss of stream habitat (Pfeifer, pers. commun., 1993). Little is known about the life history of cutthroat trout in the Lake Washington system. Large migratory cutthroat may be individuals with extended rearing in Lake Washington rather than representing true sea-run stocks (Pfeifer, pers. commun., 1993). However, sea-run strains of cutthroat trout throughout Puget Sound are depressed and have been identified as stocks of concern (Nehlsen and others, 1991).

There are a host of other fish in the Cedar River system, including sculpins (*Cottus* spp.), mountain whitefish (*Prosopium williamsoni*), western brook lamprey (*Lampetra richardsoni*), speckled dace (*Rhinichthys osculus*), and three-spine stickleback (*Gasterosteus aculeatus*). A relict population of pygmy whitefish (*P. coulteri*) is found in Chester Morse Lake; no specimens have been collected in the BPA. Additional fish that reside primarily in Lake Washington but that make spawning or feeding forays into the river include longfin smelt (*Spirinchus thaleichthys*), peamouth chub (*Mylocheilus caurinus*), and largescale suckers (*Catostomus macrocheilus*). Longfin smelt are a particularly important species in the Lake Washington ecosystem. They have been identified by Edmondson and Abella (1988) as a major contributor to increased water clarity in Lake Washington since the mid-1960s because they feed heavily on *Neomysis*, a zooplankton predator that feeds heavily on *Daphnia*, a zooplankton that feeds heavily on small algae and as a result can reduce lake-water turbidity due to algal blooms. Longfin smelt are also the major competitor of juvenile sockeye in Lake Washington, and their recently increasing numbers have been suggested as contributing to the recent decline of sockeye in the lake.

The Cedar River delta, and several of the large lakes in the BPA, are inhabited by a variety of fish including northern squawfish (*Ptychocheilus oregonensis*), prickly sculpin (*Cottus asper*), and an array of nonnative warmwater fish species including smallmouth (*Micropterous dolomieui*) and largemouth bass (*M. salmoides*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), brown bullhead (*Ictalurus nebulosus*), common carp (*Cyprinus carpio*), bluegills (*Lepomis macrochirus*), and pumpkinseed (*L. gibbosus*) (Wydoski and Whitney, 1979). Many of these species are nonnative to the Pacific Northwest and readily prey on juvenile salmonids when they are available, typically during the spring outmigrations, creating additional mortality on salmonids produced in the Cedar River system.

Cedar River Sockeye

The Cedar River was diverted from the Duwamish waterway into Lake Washington over approximately a ten-year period, ending in 1916 (Chrzastowski, 1983). The Cedar River historically flowed into the Black River, the original outlet of Lake Washington, and then into the Duwamish River and finally into Puget Sound at Elliot Bay. The diversion directed the Cedar River into Lake Washington, drying up the Black River, and a new outlet from Lake Washington to Puget Sound was created via the Lake Washington Ship Canal, which emptied into Lake Union and then emptied into Puget Sound at Shilshole Bay via the Hiram S. Chittenden (Ballard) Locks. The full effect of the diversion of the Cedar River on salmon populations is not known (Ajwani, 1956), although this redirection of an entire river drainage must have been confusing for returning adult fish and migrating juveniles for some period of time. Subsequent to this diversion, Lake Washington has become well known for its runs of sockeye.

The current population of sockeye in the Cedar River is believed to be the progeny of those transplanted from the Baker Lake system (Skagit River, WA) in the late 1930s (Royal and Seymour, 1940; SASSI, 1993). A form of sockeye, however, were present in the lake prior to diversion (Seale, 1895). In the 1930s and '40s a dominant kokanee population in Lake Washington was observed spawning in the surrounding tributaries, while chinook salmon seemed to be the dominant spawner in the Cedar River during that time (Paul Olson, pers. commun., 1993). In 1948, Paul Olson observed approximately equal numbers of sockeye and chinook salmon spawning in the mainstem of the Cedar River.

In general, however, little is known of the population dynamics of sockeye runs in the Cedar River before the mid-1960s. In the mid-1960s the eutrophication trend of Lake Washington reversed dramatically as a result of the formation of Metro and removal of sewage effluent outfalls directly into the lake. Since that time, a complex change occurred in primary production, plankton production, and fish populations, especially sockeye salmon and longfin smelt (Edmondson and Abella, 1988; Edmondson 1990, 1991a, b). Sockeye production in Lake Washington burgeoned in the late 1960s, ultimately peaking at a run size of approximately 644,000 adult fish in 1988.

In recent years the production of sockeye in Lake Washington has declined. As a result of this decline the SASSI (1993) Report has listed the Cedar River sockeye as "depressed." The current cause is unknown but appears to be related to changing conditions in Lake Washington, perhaps due to changes in type and quantity zooplankton and population increases in either longfin smelt (a major competitor of juvenile sockeye), or predators, or both. Disease has also been implicated in these declines, particularly the IHN virus, which is quite common to sockeye and has been known to cause mortality, especially in juveniles under stress. In addition, infestation by parasitic copepods (*Salmincola* sp.) is common to sockeye in Lake Washington, and a major infestation was found to be associated with large numbers of dead sockeye that were part of a die-off in excess of 200,000 adult fish returning to Lake Washington in 1977.

In the late 1980s, prior to the current and unexplained decline, a spawning channel was proposed for the Cedar River. The purpose of the channel was to provide partial mitigation benefits to the Muckleshoot Indian Tribe and the Washington Department of Fisheries stemming from the 1901 construction of the Seattle Water Department (SWD) water diversion dam at Landsburg. This dam has blocked approximately 16 miles of mainstem and tributary habitat from use by anadromous salmonids since that time. A spawning channel was to have been completed by September 1993; however, current uncertainty over the cause(s) of the decline in sockeye have resulted in project delays. A series of evaluations to learn more about the decline of sockeye has begun. These include lake studies, riverine survival studies, and interim fry production studies.

TERRESTRIAL FLORA AND FAUNA

The Cedar River Basin is currently dominated by mixed deciduous and second-growth conifer forests but was once heavily forested with cedar, hemlock, and Douglas fir. These forests provided habitat for deer, bear, wintering elk, and other mammals. Deer are still prevalent in much of the basin, but elk, black bear, and mountain lion (*Felis concolor*) are mostly limited to the rural areas near Landsburg, and areas within the SWD watershed. Bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and great-horned owls (*Bubo virginianus*) nest and hunt among the trees and along the river. Songbirds such as the yellow-rumped warbler (*Dendroica coronata*), orange-crowned warbler (*Vermivora celata*), MacGillivray's warbler (*Oporornis tolmiei*), and Wilson's warbler (*Wilsonia pusilla*) inhabited the thickets and clearings, summering here and wintering in distant habitats to the south. The latter three species, for example, winter in Central/South American tropical forests. Due to development pressures on both summer and winter habitat, most of these species are found in the basin in reduced numbers compared to the past (Terborgh, 1989).

Logging and railroad construction began in the late 19th Century and accelerated in the early years of the 20th. Today, stands of second growth fir and alder are being harvested and the land converted to urban and suburban uses. As conversion occurs and forested lands are lost, the landscape assumes a broken, fragmented function and appearance. The large blocks of forest that are critical to the survival of many species are reduced in size and isolated from each other, reducing the volume and complexity of the habitat. Ultimately, the diversity and abundance of species fall as well, or species are replaced with opportunistic (and often less desirable) species that come to dominate the remaining patchwork of habitats. With the current rates of development, and the little attention given to landscape-level phenomena, loss of forest habitat and species endemic to such habitats will continue unabated in the BPA. The current and proposed management of the SWD watershed provides a westward extension of a contiguous lowland coniferous ecosystem to an elevation of approximately 600 feet. It is the most westerly extension of this contiguous forest of any adjacent basin in King County and is an important wildlife corridor.

7.5 SIGNIFICANT RESOURCE AREAS

Previous basin plans have designated certain habitats—particularly stream and wetland habitats—as Significant Resource Areas (SRAs). The Basin Plans for Soos Creek, Hylebos Creek and Lower Puget Sound, Bear Creek, and East Lake Sammamish Basin have all used this designation to identify habitats possessing characteristic features and functions that are of overriding importance to fish, wildlife, water quality, or aesthetic appreciation in a particular basin. These designations are also made in this report. Recommended management actions will be described in the Draft Basin/Action Plan. Systems not designated as significant resources will still receive protection by existing regulations, including those provided by the SAO.

DEFINITIONS

Regionally Significant Resource Areas (RSRAs) contribute to the resource base of the entire southern Puget Sound region by virtue of exceptional species and habitat diversity and abundance, when compared to aquatic and terrestrial systems of similar size and structure elsewhere in the region. RSRAs may also support rare, threatened, or endangered species or communities.

Although typically found together, any of the following criteria are sufficient to recognize RSRAs in the watersheds of King County:

1. Watershed functions are not appreciably altered from predevelopment conditions, as measured by corridor integrity, hydrologic regime, sediment movement, and water quality, **or**
2. The diversity and abundance of aquatic or terrestrial habitats are of consistently high quality and are well dispersed throughout the system, **or**
3. Aquatic and terrestrial life, particularly salmonids, exhibit abundance and diversity consistent with undisturbed habitats and make a significant contribution to the regional resources of Puget Sound.

Locally Significant Resource Areas (LSRAs) also contribute to the resource base of the region, but at a lower level of both abundance and diversity compared to RSRAs. LSRAs are, however, significant within a particular basin, providing habitat that is important for plants and animals.

Because aquatic systems require adequate functioning of all elements to contribute significantly to system productivity, all of the following criteria are necessary to recognize LSRAs in the watersheds of King County:

1. Watershed functions have been altered from clearing and filling, but corridor integrity, hydrologic regime, sediment movement, and water quality are adequate for spawning and rearing of salmonids or for maintenance of other plant and animal species, **and**
2. The diversity and abundance of aquatic and riparian habitats are good but not exceptional; instability, damage and stream alterations are evident but confined to localized sites, **and**
3. Aquatic and terrestrial life, particularly salmonids, are supported at one or more species and life stages at population levels that may be low but are sustainable.

For a list of specific stream and wetland significant resource areas refer to section 7.8.

7.6 AQUATIC HABITAT CONDITIONS

MAINSTEM AQUATIC HABITAT

Historic Changes

Over the past century, much of the 21.7 miles of mainstem aquatic habitat in the Cedar River below the Landsburg Diversion Dam has been dramatically altered by human activities, such as water-supply dams and land development. Changes in the condition of in-stream and riparian habitat were initiated by agricultural development, coal mining, railroad construction, and light rural development in the late 1800s. Land clearing associated with early agricultural and rural residential floodplain development was considered a main contributor to extensive erosion in the 1887 flood (Paul 1937). Beginning in 1901, diversion of approximately 30% of the river's mean annual flow and regulation of flood flows were conducted by the Seattle Water Department (Cascade Environment Services, 1991). Prior to this time, railroad construction operations had also built dikes and cutoff some river meanders to protect the track and lessen the need for bridges. By 1936, the mainstem average channel width was reduced by approximately 30% from the estimated 1865 average of 250 feet to 170 feet (see *Chapter 5: Erosion* *and Deposition*). It is believed that this reduction is largely due to water withdrawal and regulation, since constructed levees and dikes bordered only about 16% of the river length at the time.

Following the diversion of the Cedar River in 1912 into a 1.6 mile canal draining north to Lake Washington, the river's banks in this reach were intensely developed for industrial and commercial land uses within the City of Renton. In the 1930s, and culminating in flood control efforts by the US Army Corps of Engineers and King County in the 1960s, an extensive network of dikes and revetments along the river was constructed to control flooding and prevent bank erosion. This has resulted in 64% of the river in the BPA having a revetment along at least one bank. These flood control structures constricted the average channel width an additional 35% by 1989, when compared to the 1936 condition, to its present average of 110 feet. In all, surface area of the channel decreased by approximately 56% (320 acres) between 1865 and 1989. Following these flood control efforts, some pockets of urbanization and industrialization of the lower reaches and surrounding plateaus have been developed, although much of the valley floor upstream of Renton is still relatively rural in nature.

Riverine Structure and Function

Preserving and managing for riverine complexity and landscape interaction is being increasingly recognized as an important component of habitat management for production of salmonids and other natural biota in the Pacific Northwest (Naiman and others, 1992; Stanford and Ward, 1992). Stanford and Ward (1992) identify four dimensions that define river environments: 1) upstream-downstream connections; 2) channel-hyporheic (groundwater) connections; 3) channel-floodplain connections; and 4) time. The American Society of Civil Engineers (ASCE, 1992) Task Committee on Sediment Transport and Aquatic Habitats recommends maintenance of the physical heterogeneity at the reach and watershed scales in order to preserve and support diverse biological communities.

The net effect of modifications of the Cedar River flow regime and channel morphology has been a narrowing and simplification of the Cedar River mainstem channel and habitats. This mimics the response of alluvial systems to disturbance events (Lisle, 1982). As a consequence, the Cedar River has taken on the form and function of an ecologically young system (i.e., low complexity, low buffering capacity). What was once a highly braided complex river channel has now become predominately a single thread. Construction and maintenance of dikes and revetments has eliminated much of the historic connection between the river and its floodplain and in many areas precludes establishment of mature riparian areas that normally provide LWD, shade, food, and nutrients.

It should be noted that this lack of instream LWD and trees leaning over the river do provide a much safer environment for boating and rafting, two common recreational activities on the Cedar River, and reduce the amount of debris potentially available for transport under flood flows. Riparian and channel management to promote large riparian trees or LWD will need to consider these consequences.

Mainstem Riparian Habitat

Most of the past modifications to the Cedar River have been conducted without preservation of complex ecological functions as a goal. As a result, much of the mainstem is highly confined by dikes and levees making much of the existing channel hydraulically smooth and unable to regularly interact with its historic floodplain. Such a configuration has also perpetuated considerable past and on-going flood control maintenance measures, including vegetation clearing and removal of LWD, especially along revetments, to facilitate flood conveyance and reduce flood damage. As a result of these actions, the Cedar River is generally low in significant LWD accumulations (although the January 1990 windstorm has resulted in increased LWD inputs throughout much of the river) and approximately 45 to 67% of the riparian area is devoid of large trees (Figure 7-2). Where riparian forests do exist they are typically dominated by deciduous species or immature conifers, suggesting that recovery from earlier disturbances is still on-going. Riparian conditions improve (i.e., tend toward larger and more coniferous woody vegetation) toward the upper part of the BPA, near Landsburg.

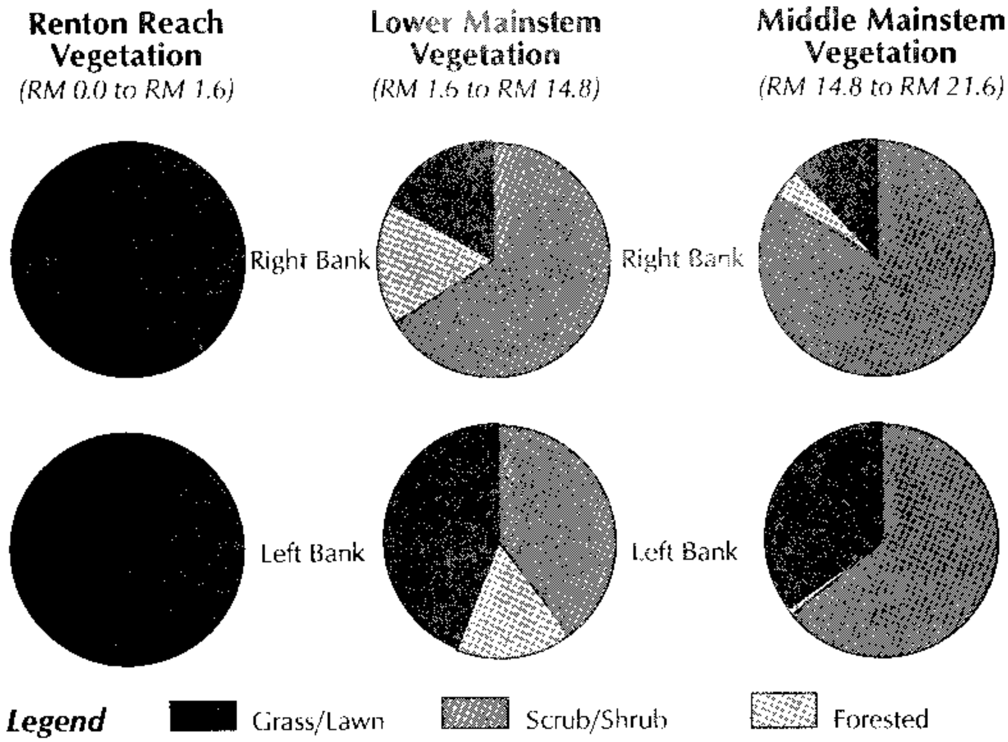
Mainstem Large Pool Habitat

Today much of the Cedar River is dominated by extended reaches of riffle. The mainstem channel has an average of 2.8 large (i.e., equal to or greater than one channel width in length) pools per mile based on a review of aerial video footage taken by SWD on February, 26, 1987 (Figure 7.2). James Sedell (pers. commun., 1993) estimates that an

Figure 7-2

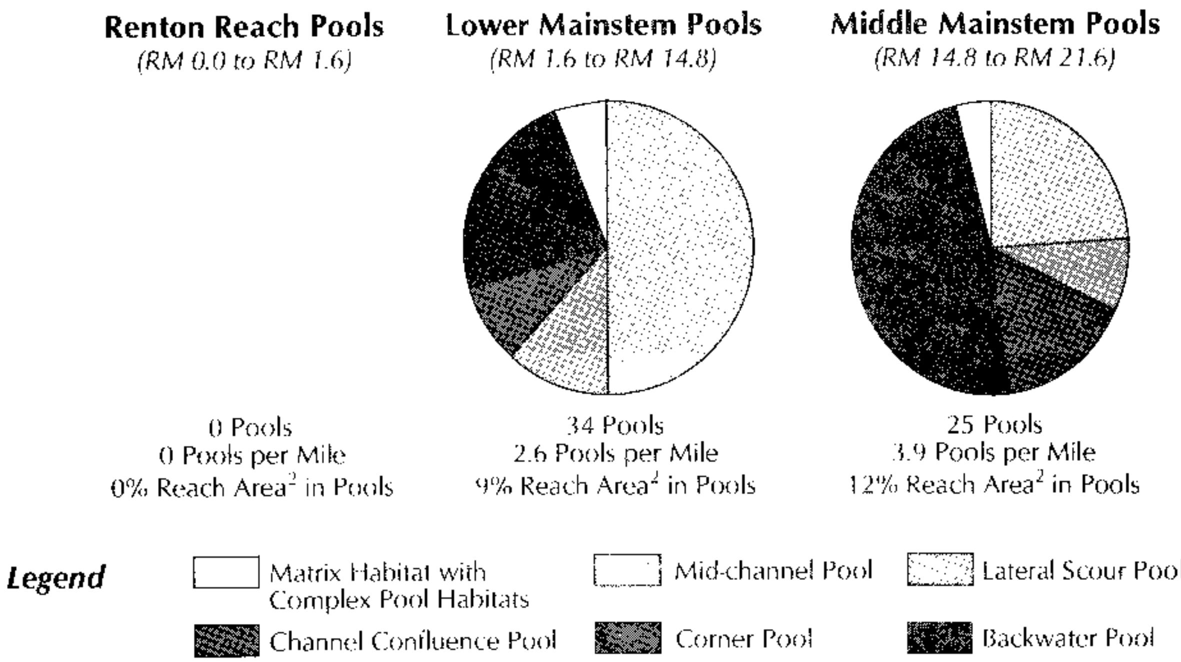
Riparian Vegetation Conditions

Cedar River Mainstem below Landsburg



Summary of Large Pool[1] Habitat Types

Cedar River Mainstem Below Landsburg



[1] Large Pools > one channel width in length [2] Average pool length is estimated 150 feet

unmanaged river the size of the Cedar River would have approximately one pool in every five channel widths. Therefore, under unmanaged conditions and assuming an average channel width of approximately 110 feet, the mainstem Cedar River channel would be expected to have approximately 9.6 large pools per mile below Landsburg. Based upon this expected pool ratio, the lower Cedar River has approximately 70% fewer pools than would be expected under unmanaged conditions.

The quantity and quality of large pool environments in other rivers of the northwest have been significantly reduced through various management activities. Sedell and Everest (1990) found that rivers in relatively undisturbed watersheds tributary to the Columbia River basin in 1937 had frequencies of large pools exceeding 15 per mile. Following timber harvesting activities, the present frequency averages less than 7 large pools per mile. Streams on agricultural lands also showed a steady decline, while streams in wilderness areas showed no decline

Many of the existing large pools, particularly corner pools (CCP) in the Cedar River occur at the base of major river bluffs. Smaller lateral-scour pools (LSPs) have formed along banks artificially hardened with rip-rap, providing some limited habitat but generally having reduced habitat quality in comparison to pools in natural reaches due to reduced formation of healthy riparian systems. Consequently, many riverine pools are lacking in internal habitat complexity normally provided by woody debris accumulations or fallen trees, and in overhanging woody vegetation, which can provide shade for cover and microclimate control, and terrestrial insect fallout for food. Many of these changes also make the Cedar River less capable of diffusing flood flow energy, and therefore more susceptible to substrate disturbance within the confines of the revetments than would be expected if the river were in a more hydraulically complex state.

Pool habitats in a variety of shapes, sizes, and internal structural complexity are critical in the life histories of salmonids. They provide adult holding habitat during spawning periods and juvenile rearing areas for coho salmon and steelhead and cutthroat trout, which have extended freshwater juvenile rearing periods. Species and stocks of salmonids that enter freshwater well in advance of spawning, such as spring and summer runs of chinook salmon and steelhead trout, are highly reliant on large pools as holding areas for adults prior to spawning.

Flood Flows and Habitat

It has been suggested that attenuation of stormflows from the Masonry Dam operations provides greater physical stability of the system. However, in the case of the Cedar River, both storm discharges and channel widths have been equally reduced (see *Chapter 3: Surface Water Hydrology*), thus possibly negating positive effects on habitat of peak storm flow reduction under current dam operations. Today, levees confine most flows to the active channel, increasing flow depths and frequency of scour, as opposed to undeveloped conditions when flood flows had greater access to floodplains. In addition, much of the existing channel has been hardened and smoothed as a consequence of flood control and for bank stabilization purposes, contributing to a condition of limited gravel supply and relative gravel instability that can affect productivity of the river for salmonids.

The relationship between stream bed stability and salmon survival was first detected by the US Army Corps of Engineers (Urabeck, pers. commun., 1993) in the mid-1960s and later reported on by Ames (1983) and Thorne and Ames (1987). They detected a high negative correlation in the survival to pre-smolt of sockeye salmon with Cedar River flood flows from 1967 to 1979. In recent years this trend appears to be overwhelmed or contradicted by another factor (Cascade Environment Services, 1991). Past sampling of downstream migrating sockeye salmon fry by WDF (Jim Ames, pers. commun., 1992) suggested that fry were dislodged prematurely from Cedar River substrates at flows as low as 1000 cfs, which, based on King County modelling (*Chapter 3: Surface Water Hydrology*), is approximately the mean monthly flow from December through February. In response to concerns regarding effects of flood flows on sockeye survival, the SWD contracted Cascade Environmental Services (1991) to conduct flood scour studies of sockeye salmon redds. Transmitters were buried in known sockeye redds in two reaches of the Cedar River and then monitored for displacement during subsequent flood events. Although data were variable, and authors cautioned against drawing broad conclusions, the data do offer useful and important information. These are 1) redd scour is initiated at a higher discharge than previously reported and 2) the level of impact on sockeye redds may occur regardless of the distribution of redds in the channel. Although this study was a good initial effort, many questions remain regarding the relationship between gravel stability, flood flows, and channel characteristics in the Cedar River. Increased information on this relationship would be helpful in guiding future flow and river management decisions that could affect fish production.

Positive effects of flood flows on habitat should not be overlooked. Benefits of flood flows include flushing of fine sediments from spawning gravels, redistribution of stored nutrients, and the creation of new habitats (Reiser and others, 1992; Stanford and Ward, 1992). Over-regulation of flood flows on regulated rivers can have serious consequences for achieving these functions. Future strategies for flood flows should account for both the positive as well as negative effects of such events.

Summer/Fall Low Flows and Habitat

Depending on their extent and duration, summer/fall low flows can be limiting for many populations of stream fishes in the northwest. During these periods, juvenile fish can be stressed by many factors including high water temperatures and crowding, leading to increased rates of disease, competition, and predation. Some species of salmon, such as sockeye and chinook, return as adults in the late summer and early fall when stream levels in the northwest are often at their lowest; low flows can create migration blockages at these times (see also Rock Creek Subbasin habitat description). Providing adequate baseflows during low flow periods for fish production needs has been the subject of much past and ongoing negotiation in the Cedar River Basin (Cascade Environment Services, 1991).

The current year-round minimum instream flows for the Cedar River were established under the Western Washington Instream Resources Protection Program, initiated by Washington State Department of Ecology in 1979, and are presented in Table 3-3 (*Chapter 3: Surface Water Hydrology*). Summer/fall low flow minimums during normal years ranges from 130 cfs from July 15 to September 10 with a linear increase to 200 cfs beginning September 10 and ending September 20. Another linear increase to 370 cfs begins on October 1 and ends on October 10. In critical water years, the summer low flows are decreased to 110 cfs by July 1 and remain at that level until approximately October 1, at which time flows linearly increase to 250 cfs by November 1.

In 1986 the Cedar River Instream Flow Committee was formed to apply the US Fish and Wildlife Service Instream Flow Incremental Method (IFIM) in determining necessary flows for the Cedar River. Cascade Environment Services (1991) summarizes the findings of that analysis, although no change in the current minimum instream flows has been formally adopted. Today the maintenance of instream flows requires an ongoing dialogue among resource agencies and tribes due to the uncertain nature of weather patterns and increasing pressures on water and fishery resources. During critical flow years, the Cedar River Instream Flow Committee is convened to review minimum flow needs and make recommendations when it appears that water supplies may be limited.

As described in *Chapter 3: Surface Water Hydrology*, current mean monthly low flows in the Cedar River are from 9 to 40% less than the pre-diversion levels, with the largest difference occurring in July. As with flood flows, the present effect of the SWD diversion on mainstem low flow habitat value may be somewhat reduced, perhaps even improved for some species (i.e., more water per channel width) because of the overall shrinkage of the active river channel. However, surrounding valley-floor habitats, such as percolation side-channels, which are linked to the mainstem by subsurface (hyporheic) connections, are likely reduced in their extent and low-flow habitat value from pre-diversion levels as a result of less available water under low flow conditions. When combined with fewer and lower quality large pools and degraded riparian areas, particularly in the lower reaches, the reduced water quantity during the summer and fall months has probably had the greatest effect on salmonids with extended juvenile stream rearing, such as steelhead and coho salmon. Chinook salmon, whose adult return is typically in late summer and early fall and who, as noted above, are reliant on large deep pools for extended holding prior to spawning, may also be affected by the combination of reduced water quantity and habitat quality at low flows.

Currently, the SWD is an active participant with MIT and several state and federal agencies in achieving the complex and difficult task of balancing municipal and industrial water needs with those of competing uses, especially fish and lock operations. However, a concern for the future is the ability to meet minimum instream flow needs under the existing claim by SWD of 300 MGD. As noted in *Chapter 3: Surface Water Hydrology*, the only way to meet all of these needs is to create additional storage in the system. Such an increase may have the added advantage of achieving enough flood benefits to significantly reduce flood related fishery problems, such as sockeye egg survival, and improved summer/fall low flows; however, the quantity and quality of habitat conditions below Landsburg must still be addressed.

The Hyporheic Zone

The hyporheic zone is an important regulator of ecological health in river systems due to its role in influencing energy and nutrient processes in riparian and surface water systems

(Naiman and others, 1992). This zone is defined as the interstitial river bed habitat penetrated by riverine animals, particularly benthic invertebrates (Stanford and Ward, 1988). It connects the surface water in the river channel with surrounding groundwater. As such, it is an important source of cold water and nutrients for biotic productivity in the river channel and serves as an important substrate for the production of benthic invertebrates. Recent investigations of gravel-bed rivers show that these habitats can extend throughout the alluvial gravels of riverine floodplains. For example, the average hyporheic habitat on the Flathead River, Montana, was estimated to be 3 km wide and 10 m deep by Stanford and Ward (1988).

The hyporheic zone of the Cedar River mainstem is an unseen but significant portion of the river, providing a connection with surrounding valley-floor aquatic environments. Water extraction, flow regulation, septic systems, land clearing, and many other human activities that occur on the Cedar River floodplain can potentially affect the quantity and quality of water in the hyporheic zone. The effect of past development on the Cedar River hyporheic zone is not known in part because it has not been clearly studied or delineated in the BPA by past development actions. It appears that this portion of the riverine habitat, while probably reduced in its extent, is still relatively well-functioning based on high riverine water quality, extensive subsurface connections with some valley-floor habitats (e.g., Cavanaugh Pond and the McDaniel Channel), and the relatively low levels of sands and silts in the river substrates, which allows for high porosity of substrate. Its importance in maintaining a healthy riverine ecosystem should be recognized in this and future planning efforts.

Mainstem Fisheries Value

The Cedar River mainstem is a fishery resource of regional significance. It persists as a good producer of salmonids, despite the changes and concerns noted above. This likely results from many positive elements of the river system that have persisted despite, or in some instances perhaps due to, the extensive historical modifications. These elements include relatively high water quality, a valley floor bedded with clean cobbles and gravel, and a hydrology that has not been adversely affected by extreme land-use changes due to an upper basin that has been managed as a municipal watershed (Williams and others, 1975; Washington Department of Fisheries, 1992). In combination, they have helped the riverine environment maintain a high degree of natural functioning. The fact that these elements are still present suggests that options exist for increasing natural system buffering and health through restoration of natural processes that other large river systems of King County, such as portions of the Duwamish, Green, and Snoqualmie rivers, may no longer have.

MAINSTEM HABITAT BY SUBBASIN

Renton Reach—Map 10

This reach is entirely artificial and was regularly dredged to prevent flooding from its completion in 1912 until the mid-1970s. It is essentially one long riffle with relatively little habitat complexity. It is affected by urban and industrial uses along the river bank that contribute to local water quality problems and eliminate the potential for connection with a natural floodplain or the establishment of a riparian corridor and significant LWD accumulations in the channel. This reach is the depositional area for many of the river's sediments, and as a result, the substrates tend to have higher levels of fine sediments than upstream substrates. Despite its limitations, this reach of river serves as a migration route for many fishes and is used extensively for spawning and limited rearing by sockeye, chinook, and coho salmon and steelhead and cutthroat trout as well as long fin smelt. A riverside park extends along much of this reach of river and is used extensively by the public for viewing fish spawning, especially the numerous and colorful sockeye salmon.

Lower Cedar River Mainstem—Map 18

There are 14.6 miles of mainstem habitat in this reach (also see section 7.8). Much of this reach is remarkable more for what is *not* happening rather than a set of specific or dramatic problems. The river channel throughout most of this reach is confined and stabilized by dikes and revetments contributing to a loss of connectivity of the river with its floodplain and poor riparian conditions. This has resulted in a mainstem channel dominated by riffle environments and riparian areas that are either devoid of large trees or, if forested, are dominated typically by large cottonwood, rather than conifers.

The King County Flood Hazard Reduction Plan (FHRP) has recommended abandoning or setting levees back into the floodplain at several sites in order to reduce flood damage and costs and to improve overall riverine health. An example of how the river could look if confinement was removed can be observed between RM 9.6 and 10.7. In this area the river is not confined and natural interaction with the adjacent floodplain and riparian vegetation exists. As a result, LWD accumulations have developed along the banks and a complex river braiding pattern reminiscent of historical conditions exists. Riparian areas are showing a mixed forest indicating that successional processes are proceeding in the desired direction of increasing conifer density.

Another habitat concern in this reach is the effect on long-term gravel recruitment and pool habitats caused by efforts to stabilize the toes of steep banks to prevent catastrophic landsliding. Large, deep pools tend to form at the base of many of these slide areas, often providing excellent habitat. For example, an active slide is located on the right bank at RM 9.3, about 0.3 mile upstream of the water intake for the proposed spawning channel. This slide contributes gravels and fine sediments and has added some LWD to the river channel. Habitat at the base of this slide is excellent due to LWD accumulations and a complex channel shape. Stabilization of the toe of this bank in order to reduce catastrophic inputs of sediment could eliminate a source of gravel and LWD and reduce local habitat quality.

In fact, two left bank revetments, one located directly downstream of Molasses Creek (RM 3.8) and another directly downstream of Peterson Creek (RM 13.9) have been constructed in recent years at slide areas to prevent future catastrophic failure. However, both sites were also potential sources of spawning gravel for the river, although the site at RM 3.8 was also adding much fine material that could potentially reduce spawning habitat quality in downstream reaches. Solutions for stabilization of steep banks along the Cedar River should incorporate evaluations of the function of these banks in gravel recruitment and in the formation of pool habitats for juvenile rearing and adult holding habitat for salmonids.

Middle Cedar River Mainstem—Map 25

This reach contains 5.5 miles of mainstem habitat (also see section 7.8) extending from the Dorre Don Tributary 0336 (RM 16.2) to the Diversion Dam at Landsburg (RM 21.6). The valley becomes more confined by natural bluffs in this reach than in the lower river reach; however, the river channel is much less constrained by revetments and floodplain encroachment by development is much less prevalent. Significant loss of floodplain has occurred in the Upper and Lower Dorre Don area ([1]RB; RM 15.8-17.0) and the Arcadia/Noble area (RB and LB; RM 18.2-18.8) resulting in degraded floodplain and riparian conditions for those reaches.

The primary mainstem habitat concerns in this reach are restoration of riparian vegetation and loss of floodplain connections at the developed areas mentioned above, and a channel constriction caused by a left bank dike at RM 19.7. Riparian conditions are primarily forested and conditions improve as one moves closer to Landsburg, with progressively more and larger conifers. The majority of large pools in the Cedar River mainstem occur in this reach, generally along the base of high bluffs. Several of these bluffs, especially in the vicinity of the mouth of the Walsh Lake Diversion Ditch, are important sources of spawning gravel. The water supply diversion dam at Landsburg (RM 21.8) is constructed so that Tainter gates can be opened during flood flows allowing gravel from the upper river to move past that point.

Future Mainstem Habitat Conditions

Much of the Cedar River mainstem habitat is on a trajectory of gradual degradation due to ongoing maintenance of flood-control facilities and gradual but steady pressures by encroaching rural development. Unless modified, these actions will contribute to a continued impairment of riparian and floodplain functions and reductions in the quantity and quality of spawning gravel substrates and instream habitat complexity resulting in reduced diversity and productivity of salmonids.

VALLEY-FLOOR HABITATS

The Cedar River valley floor contains a wide array of aquatic habitats outside of the mainstem channel (see also section 7.8). Some of these features, such as wall-base tributaries, are often the most productive salmonid habitats of river systems of the Pacific Northwest (Peterson and Reid, 1984). Typically they are formed in swales or channels left behind by past river migrations. In many instances they are small highly complex habitats out of the direct influence of mainstem flood flows, while others are important in the

[1]All right and left bank designations are made assuming the observer is facing downstream.

routing of flood waters across the valley floor. Such habitats are typically subject to some instability due to flooding. Although many such habitats have been damaged or lost to development in the floodplain, new valley-floor habitats are rarely created because revetments prevent river migration in most places.

A total of 68 individual aquatic habitats, including tributary streams and inventoried wetlands noted elsewhere in this report, were identified along the Cedar River valley floor (Table 7-3) in the summer of 1992. There are a total of 25 wall-base tributary (WBT) streams, making them the most numerous habitat feature, followed by percolation side channels (PSC;14 sites), and high flow side channels (HFSC), and riparian wetlands (RW), with six sites each. Many of the WBTs are part of larger wetland systems, reflecting their spring fed nature. Existing or potential fish use of many WBTs is limited by their steep gradients and short lengths, whereas PSCs typically provide much more existing habitat and have considerable potential for enhancement due to their larger size, lower gradients, and closer connection with the mainstem channel.

An evaluation of each site's habitat potential and existing limitations has indicated that lack of access limits fish production at nine sites while deficiencies of LWD and/or poor condition of the riparian environment are problems in 37 of the 68 sites examined. Other factors limiting salmonid use of valley-floor aquatic habitats include seasonally low or insufficient surface water, localized development, flood control structures, and concern over site stability due to flooding. A key issue in protecting and restoring these habitats and in developing new habitat is the need to identify sites and their restoration potential before development occurs. It is also essential to increase the public's awareness of the importance of these environments for natural river functioning as well as habitat for fish.

Table 7-3 Aquatic Habitat Features of the Cedar River Valley Floor and their Existing and Future Potential as Salmonid Habitat

Aquatic Feature (acre)	Location (RM/Bank)	Salmonid use	Limitations
PSC, UWET, WBT (0.2)	4.5/RB	Y/CO,CT,SO,ST	LWD, RIPN
HIGH FLOW SC (0.21)	4.5/RB	Y/CO,CT,SO,ST	STABILITY
PSC, UWET (1.38)	4.6/LB	Y/CO,CT,SO	ACC, LWD,RIP
MADSEN CREEK (beaver dam)	5.1/LB	Y/CO,CT,ST,SO	SED,LWD,RIP, ACC
TRIB 0307	5.4/RB	N	ACC,FLO,RIP,LWD

Table 7-3 (cont)

Aquatic Feature (acre)	Location (RM/Bank)	Salmonid use	Limitations
HIGH FLOW SC (0.48)	5.9/LB	N	FLO, PLS,STABILITY
PSC, SUMMERFIELD TRIB (0.02)	6.1/LB	Y/CO,CT	LWD
CAVANAUGH POND (WETLAND #6)	6.4/LB	Y/CO,CT,SO,ST	LWD, RIP
TRIB 0309	7.2/RB	?	NA
PSC, WETLAND #103	7.5/LB	Y/ALL	LWD,RIP
PSC (0.11)	7.8/LB	Y/CO,CT	LWD,FLO,STABILITY
WETLAND #37	8.3/LB	N	FLO,PLS
WBT	8.8/RB	N	RIP
WBT	9.0/RB	N	RIP
WBT	9.2/RB	Y/CO,CT,SO,ST	RIP
PSC (0.14)	9.5/RB	Y/CO,CT	
WBT	9.7/LB	N	
PSC (3.31)	9.8/LB	Y/CO,CT	FLO, LWD, RIP
WBT	10.1/LB	N	
WBT	10.1/RB	N	RIP, DEV
PSC (0.4)	10.1/RB	Y/CO,CT	
WBT, TRIB 0316	10.7/RB	Y/CO,CT	ESD,PLS
WBT	11.0/LB	?	
HIGH FLOW SC (0.02)	11.1/LB	N/CO,CT	DIKE, ACC
MAINSTEM BRAID	11.3/NA	Y/ALL	RIP
UWET	11.3/LB	N	
TRIB 0316A	11.4/RB	Y/CO.CT,ST,SO	SED,RIP,LWD,PLS
WBT, UWET (0.17)	11.5/LB	Y/CO,CT	FLO,LWD,RIP
WBT	11.8/RB	N	
WBT	11.8/RB	N	
WBT	12.1/RB	N	
WBT, UWET	12.4/RB	Y/CO,CT	FLO,LWD,RIP
PSC, UWET #116B (1.45)	12.9/LB	Y/CO,CT	ACC,DEV
TAYLOR CREEK, WETLAND #132	13.1/RB	Y/ALL	LWD,RIP, PLS
PSC (0.62)	13.2/RB	Y/ALL	LWD, FLO
HIGH FLOW SC, WETLAND #132 (0.09)	13.5/RB	N/CO,CT	ACC
PETERSON CREEK , WETLAND #118	14.0/LB	Y/ALL	RIP
WBT, UWET (1.15)	14.8/LB	Y/ALL	LWD,RIP,FLO
SC (0.28)	15.4/RB	Y/CO,CT,ST,SO	LWD,RIP
PSC (0.30)	15.6/LB	Y/CO,CT,ST,SO	LWD,RIP
HIGH FLOW SC (0.32)	15.7/RB	Y/ALL	LWD,RIP, DEV
TRIB. 0336	15.9/RB	Y/CO,CT,ST,SO	DEV,RIP,LWD,FLO
WBT, UWET (0.02)	16.2/LB	Y/CO,CT	FLO, RIP, LWD, PLS
PSC (16.3)	16.3/RB	Y/ALL	DIKE, STABILITY
WBT	16.4/RB	N	

Table 7.3 (cont)

Aquatic Feature (acre)	Location (RM/Bank)	Salmonid use	Limitations
MAINSTEM BRAID	16.6/NA	Y/ALL	RIP
MAINSTEM BRAID	17.1/NA	Y/ALL	RIP
HIGH FLOW SC (0.32)	17.2/LB	Y/ALL	LWD, RIP, FLO
WBT	17.3/RB	N	RIP
WBT	17.3/RB	N	RIP
WBT	17.4/RB	N	RIP
PSC (0.16)	17.6/LB	Y/ALL	LWD, RIP
WETLAND #79 (1.65)	17.8/LB	Y/CO,CT,ST	ACC, DEV, RIP
UWET (0.09)	17.8/LB	?/CO,CT	ACC
ROCK CREEK #0338	17.9/LB	Y/ALL	FLO
WBT, UWET(0.24)	18.2/LB	Y/CO, CT, ST	ACC, DEV
MAINSTEM BRAID	18.4/NA	Y/ALL	RIP
SC (0.11)	18.7/LB	Y/ALL	LWD, RIP, DEV
UWET	19.4/RB	N	
WBT, UWET (0.05)	19.4/LB	N/CO,CT	ACC
PSC	19.5/LB	Y/ALL	LWD,FLO
WALSH LAKE DIV. DITCH	19.6/RB	Y/ALL	LWD, RIP
WBT	19.6/RB	N	
PSC (0.09)	19.9/RB	Y/ALL	LWD, RIP, STABILITY
WETLAND #69 (2.89)	20.2/RB	?/CO,CT	ACC
UWET (0.23)	20.3/RB	N/CO,CT	ACC
WBT	21.1/LB	N	
WBT	21.1/RB	N	

KEY

Habitat Types
WBT=Wall Base Tributary
SC=Side Channel
PSC=Percolation Side Channel
UWET=Uninventoried Wetland

Salmonid Use/existing or potential
N=Not present
Y=Present
?=Undetermined
CO=Coho salmon
CT=Cutthroat trout
ST=Steelhead trout
SO=Sockeye salmon
All=all above+Chinook salmon

Limitations
LWD=Limitations in large wood debris and habitat complexity, RIP+riparian area lacking/immature condition
ACC=access to habitat is blocked
DEV=residental development has affected habitat characteristics
SED=sedimentation of existing habitat
DIKE=flood control structures such as dikes and levees are affecting site
FLO=surface flow inadequate for summer rearing
PLS=deep pool habitat lacking.

TRIBUTARIES

Tributaries of the Cedar River below Landsburg typically drain broad plateaus located one to three hundred feet above the valley floor (see also section 7.8). They then plunge through ravines of varying steepness, reaching the valley floor to enter the Cedar River. Some of these tributaries, such as Madsen and Taylor Creeks, meander for significant distances along the valley floor before joining the mainstem. Historically, coho salmon and steelhead and cutthroat trout were limited in their usage of these streams only by low flows and steep gradients. Coho are believed to have historically migrated to the tops of the plateau in order to utilize low-gradient stream and wetland habitats there. As the effects of urbanization have occurred, however, several of these tributaries are now used almost exclusively by cutthroat trout and sculpins. Sockeye and chinook utilize many of the low-gradient reaches of the larger tributaries.

Tributary habitat in the Cedar River Basin has largely been impacted by 1) changes in storm hydrology and sedimentation due to urban development in upstream plateau areas, especially in the Madsen, Molasses, and Maplewood drainages and 2) reductions in the structural complexity of stream channels, riparian areas, and wetlands.

Table 7-4 summarizes summer low-flow pool:riffle (P:R) ratio estimates and LWD loading rates for selected ravine reaches of several tributaries in the BPA. The relatively low P:R ratios of Maplewood, Madsen, and Molasses tributaries reflect their disturbed hydrologic and sediment conditions and generally indicate poorer habitat quality, while reaches in the other streams have a higher percentage, and generally a higher diversity, of pool types. Most stream reaches have LWD densities well below the range of approximately 2 to 2.5 pieces per channel width found in unmanaged small stream systems (Peterson and others, 1992). In many cases, the wood of these channels is derived from relatively small and highly decayed immature riparian vegetation that is of limited value in providing stable, long-lasting fish habitat.

Table 7-4 Pool:Riffle Habitat and Large Woody Debris in Selected Tributary Reaches

Stream System	Tributary	Reach (RM)	% Riffles	% Pools	LWD (#/CW)
Unnamed	0301	0.05- 0.25	60	40	2.0
Maplewood	0302	0.65- 0.85	70	30	1.7
	0302	1.1- 1.3	71	29	0.7
	0303	0.05- 0.25	81	19	0.4
Molasses	0304	0.25- 0.5	78	22	1.1
Madsen	0305	1.1- 1.3	80	20	0.6
	0305	1.6- 1.8	91	9	3.8
	0305	1.9- 2.1	86	14	10.7
	0306	0.05- 0.2	77	24	1.7
Taylor	0321	0.1- 0.3	49	51	0.3
	0321	0.5- 0.7	67	33	1.3
Peterson	0328	0.1- 0.4	55	45	0.2
Rock	0338	0.35- 0.65	49	51	0.6
Walsh Lake Div.	0342	0.2- 0.4	56	44	0.6
Average			**70**	**30**	**1.8 (1.1)***

* LWD density excluding Madsen Reach RM 1.9-2.1

There are nine major fish-bearing tributaries in the BPA: Maplewood (Tributary 0302), Molasses (Tributary 0303), Madsen (Tributary 0305) creeks, unnamed Tributaries 0316A and 0336, Taylor (Tributary 0320), Peterson (Tributary 0328), and Rock (Tributary 0338) Creeks, and the Walsh Lake Diversion Ditch (Tributary 0341). These systems comprise approximately 29.6 stream miles, of which approximately 18 miles are available to anadromous fish (Table 7-5). An additional six miles are utilized primarily by resident cutthroat trout. Numerous additional small steep channels may offer limited amounts of temporary winter habitat; such areas may provide critically important refuge from mainstem flood flows during storms.

Table 7- 5 Extent of Salmonid Use in Tributaries of the Cedar River Below Landsburg

Stream	WRIA Number	Total Length (mi)	Extent of Species Use (Confluence to RM X)					Comments
			Coho	Steelhead	Chinook	Sockeye	Cutthroat	
Maplewood Creek	0302	1.80	0.40				1.00	
Maplewood Trib	0303	1.60					0.40	
Molasses Creek	0304	2.60	0.80	0.80			2.50	Cutthroat intermittant above RM 0.8 to Wetland 22
Madsen Creek	0305	3.00	0.80	1.60			2.10	Steelhead to the confluence with Tributary 0306
Madsen Tributary	0306	1.00					0.25	
Unnamed Tributary	0316	0.50	0.30				0.30	Wall- based tributary
Unnamed Tributary	0316A	0.80	0.65	0.65		0.65	0.65	Utilization affected by water quality/quantity problems
Taylor Creek	0320	3.30	3.30	3.30	2.30	2.30	3.30	Chinook, sockeye potential to Wetland 58
Taylor Tributary	0321	0.80	0.80	0.80			0.80	
Taylor Tributary	0323	0.25					0.25	
Taylor Tributary	0326	0.70	0.25				0.70	
Peterson Creek	0328	2.60	2.60	2.60	1.20	1.20	2.60	Chinook, sockeye potential to top of plateau
Peterson Tributary	0328B	2.20	1.00				2.20	Coho to mouth of Lake Desire
Unnamed Creek	0336	1.60	0.17			0.17	0.17	Stream is dry most of year
Rock Creek	0338	2.65	2.65	2.65	2.65	2.65	2.65	Near pristine habitat limited by water withdrawls in fall
Walsh Lake Diversion	0341	4.20	4.20	4.20	4.20	4.20	4.20	To Walsh Lake outlet- chinook use marginal
Totals		**29.60**	**17.92**	**16.60**	**10.35**	**11.17**	**24.07**	

7.7 LAKES AND WETLANDS

INTRODUCTION

The planning area's nine major lakes and dozens of wetlands are critical elements of the Cedar River Basin. These areas provide habitat for a wide variety of flora and fauna, and they also have many other valuable ecological functions such as flood storage and biofiltration of storm runoff. Many of these systems have been altered by past development, although a number of the larger systems remain in surprisingly good condition. Except for Walsh Lake, all of the lakes in the planning area have been altered by development that encircles at least part of the shoreline. As mentioned in *Chapter 6: Water Quality*, a few of the lakes have moderate to severe water quality problems.

LAKES

The Peterson Creek Subbasin contains four sizeable lakes: Lake Desire, Spring (also known as Otter) Lake, Shady (also known as Mud) Lake, and Peterson Lake. Webster and Francis Lakes drain into Tributary 0317. The upper Rock Creek Subbasin contains Retreat Lake and Lake No. 12, while Walsh Lake (the largest lake/wetland complex in the planning area) enters the Cedar River below Landsburg via the Walsh Lake Diversion Ditch. All of the lakes are situated on the lateral plateau regions above the river. Refer to *Chapter 6: Water Quality*, for a discussion of specific lake conditions. Table 7–6 summarizes the fish species in the lakes of the BPA.

Table 7–6 Fish Species in Cedar River Basin Lakes*

Lake	Rainbow Trout	Cutthroat Trout	Coho Salmon	Yellow Perch	Largemouth Bass	Black Crappie	Pumpkin-seed	Brown Bullhead	Northern Squawfish	Sculpin species
Desire	X		X	X	X	X		X		
Spring	X			X	X		X	X		
Shady	X	X		X			X			
Peterson		X			X					
Webster	X									
No. 12	X			X			X	X		
Walsh		X		X	X				X	X

* Sources: Washington Department of Wildlife and Congleton and others (1977). Other species may also be present.

WETLANDS

Wetlands are defined as transitional areas between land and water that are typically saturated or inundated by surface or shallow groundwater for a significant part of the year in years with normal rainfall. Prolonged saturation of these areas results in the formation of soils with distinctive characteristics and communities of plants adapted to life in wet growing conditions. The wetlands of the Cedar River Basin include bogs, fens, marshes, forested swamps, and riparian areas, as well as shallow water areas near many of the lakes and ponds.

Wetlands store water in rainy periods and release it slowly during periods of dry weather. By acting as storage areas during rainstorms, wetlands help protect the Cedar River mainstem and its tributaries from excessive peak flows, erosion, and scouring. They also provide a source of sustained stream flow during hot, dry periods during summer and early fall. By filtering silt and pollutants, wetlands also help protect water quality throughout the basin and in its downstream receiving waters, including Lakes Washington and Union, and Puget Sound. The above wetland functions are vital in maintaining productive fish and wildlife habitat throughout the planning area.

Wetland Flora and Fauna

A great diversity of plants and animals utilize wetland habitats within the BPA. Specially adapted plants such as sphagnum moss (*Sphagnum* spp.), Labrador tea (*Ledum groenlandicum*), bog laurel (*Kalmia occidentalis*), and lodgepole pine (*Pinus contorta*) occupy the bogs and fens. Common marsh plants include cattail (*Typha latifolia*), yellow pond lily (*Nuphar polysepalum*), bulrushes (*Scirpus* spp.), sedges (*Carex* spp.), and rushes (*Juncus* spp.). Scrub-shrub wetlands are dominated by species such as hardhack (*Spirea douglasii*), willows (*Salix* spp.), and red-osier dogwood (*Cornus stolonifera*). The forested swamps are typically composed of dense stands of western red cedar, western hemlock, red alder, and Oregon ash (*Fraxinus latifolia*), and have shrub understories consisting of salmonberry (*Rubus spectabilis*) and vine maple (*Acer circinatum*), and forest floors carpeted with skunk cabbage (*Lysichitum americanum*), lady-fern (*Athyrium filix-femina*), and false lily-of-the-valley (*Maianthemum dilatatum*).

Among the mammals of these wetlands are the beaver (*Castor canadensis*) and river otter (*Lutra canadensis*); both are denizens of ponds, marshes, and riparian areas. Beavers have often been the agents of wetland formation on the plateau and valley floor, and several active beaver lodges currently exist in the basin, including one constructed in the late summer of 1992 near the mouth of Madsen Creek and another near Peterson Lake. Beaver subsist mainly on deciduous plants, including the bark of the trees and shrubs they use to construct their dams and lodges. Beaver dams—formed by sticks, mud, and brush—impound water, trap sediment and nutrients, and help moderate stream flows during storms and periods of low flow. Because of this, beaver ponds are among the most productive rearing environments for juvenile salmonids. Otters, which normally den in riparian burrows excavated by other animals, tend to range long distances along mainstem rivers and tributaries in search of food and other habitat requirements (Maser and others, 1981). Their diet consists primarily of aquatic species such as fish, crayfish, freshwater mussels, amphibians, some carrion, and occasionally berries.

The BPA's wetlands and buffer areas also support other small mammals such as porcupine (*Erethizon dorsatum*), mountain beaver (*Aplodontia rufa*), hares and rabbits (*Leporidae*), as well as several species of mice, voles, and rats. Predators such as black bear (*Euarctos americanus*) and coyote (*Canis latrans*) use wetlands in the less developed parts of the BPA, as do blacktail deer (*Odocoileus hemionus*) and members of the White River elk (*Cervus elaphus nelsoni*) herd.

Dozens of species of birds nest and feed in the wetlands of the basin. Among these are the great blue heron (*Ardea herodius*), osprey (*Pandion haliaetus*), red-winged blackbird (*Agelaius phoeniceus*), yellow warbler (*Dendroica petechia*), wood duck (*Aix sponsa*), bufflehead (*Bucephala albeola*), and hooded merganser (*Lophodytes cucullatus*). Chester Morse Lake, in the Upper Basin, is one of only three habitats in Washington that support nesting common loons (*Gavia immer*). The birds nest near the marshy upper end of the lake on floating wooden platforms provided by SWD. In this protected setting, they are relatively free from human disturbance, and the abundant emergent vegetation and overhanging willows along the lake shoreline provide cover and protection from terrestrial predators.

WETLAND CHARACTERISTICS

Wetland Functions

Wetlands are a critically valuable resource in the Cedar River Basin. Protection of wetlands is essential in order to maintain, and, where possible, restore valuable resource functions, including flood storage and stormflow attenuation, water quality purification, groundwater exchange, streamflow maintenance, and fish and wildlife habitat. As elsewhere in King County, many wetlands in the Cedar River Basin have been heavily damaged by a variety of human activities, including clearing, drainage, filling, and conversion to stormwater detention facilities. In the process, wetlands are often subjected to increased water level fluctuation, water quality fluctuation, and sedimentation, all of which can damage wetland plant communities and thereby decrease overall habitat quality. Even wetlands not directly impacted may become increasingly isolated from adjacent aquatic and upland habitats. Such isolation within the landscape almost invariably leads to loss of plant and animal species richness and/or replacement with other weedy and invasive species such as reed canarygrass (*Phalaris arundinacea*), the Norwegian rat (*Rattus norvegicus*), the bullfrog (*Rana catesbeiana*), and the brown-headed cowbird (*Molothrus ater*) (Richter and others, 1991; Terborgh, 1989).

Some wetlands such as Walsh Lake; Wetlands 92, 93, and 94, in the headwaters of Rock Creek; and Wetland 28 on Otter Lake remain in relatively good condition because up until now they have been relatively remote from intense development pressures. Such wetlands typically retain largely forested catchment areas and broad forested buffers that help preserve their hydrologic regime and provide habitat for species that depend on wetlands. Upland buffers also help protect wetlands from noise, light, glare, pollutants, and predation of their inhabitants by domestic animals.

Although buffer protection is essential, it is important to recognize that wetlands cannot be protected by simply focusing on solely on wetlands and their immediate buffer areas. Even protected wetlands can be degraded by levees, stream channelization, groundwater withdrawal, urbanization of upper catchment areas, water pollution, and other landscape changes. Therefore, as development continues efforts must be made to preserve adjacent upland habitat corridors and wetland hydrologic source areas, which often extend far beyond standard-sized buffers.

Bogs and Fens

Both the planning area and portions of the Cedar River watershed above Landsburg Dam contain an unusual array of peat wetlands, which can be broadly divided into two categories, bogs and fens. Poor fens are intermediate between mineral-nourished fens and precipitation-dominated bogs. Both types of systems generally form over a high water table and occupy areas of low relief within the basin. Fens differ from bogs in that they receive water that has passed through mineral soil. True bogs have developed peat layers higher than their surroundings and receive sparse concentrations of nutrients and other minerals exclusively from precipitation. The bogs and fens within the planning area have developed from aquatic ecosystems such as lakes or ponds that have filled in with woody vegetation.

Soil water chemistry is one of the most important factors in the development and structure of fens and bogs. A complex set of factors such as pH, mineral concentration, nutrients, and water flow rates interact to influence the vegetation types and biological productivity of peat systems. Decomposition rates and the pH of water tend to decrease with increasing organic content as peat wetlands develop. Bog and fen plant communities also influence the chemical properties of soil water. For example, the metabolic activity of *Sphagnum* mosses produces hydrogen ions. In acid neutral wetlands such as lakes, marshes, and riparian systems, water movement decreases acidity levels. In bogs, the opposite effect results from conditions of relative stagnation.

Bogs are extremely deficient in plant nutrients due to slow organic decomposition rates that limit nutrient recycling. As a result, the primary productivity of bogs is quite low compared to that of other wetland ecosystems (Moore and Bellamy, 1974). The flora and fauna in bogs have numerous, highly specialized anatomical and metabolic adaptations to low nutrient conditions. Fens, on the other hand, have considerably more nutrients than bogs because of their exposure to water from soil and external sources.

Bog plants must cope with exceptionally rigorous growing conditions, including low oxygen supply, due to prolonged saturation; relative nutrient deficiency; and desiccation of plant tissues during periods of summer drought. Because of these harsh conditions, overall primary productivity is low compared to other aquatic and terrestrial ecosystems. Moore and Bellamy (1974) described the productivity of a forested bog as about half that of a coniferous forest, and slightly more than a third that of a deciduous forest.

Mosses of the genus *Sphagnum* are the most important peat-forming plants in bogs and fens. However, these wetlands can also consist of *Sphagnum*-sedge, *Sphagnum*-shrub communities, bog forests, or other combinations of acidophilic (acid-tolerant) plants such as bog cranberry (*Vaccinium oxycoccus*), sundew (*Drosera rotundifolia*), Labrador tea, and bog laurel, as well as hardhack, which often occurs along the margins or in disturbed areas. The tree layer, where present, is typically dominated by stunted western hemlock (*Tsuga heterophylla*), although lodgepole pine (Pinus contorta), western red cedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), quaking aspen (*Populus tremuloides*), and occasionally Douglas fir (*Pseudotsuga menziessi*) occur in and along the edges of some systems.

Animal populations in bogs and fens tend to be low due to the limited productivity and relative unpalatability of vegetation. Herbivores include certain species of insects, birds, hares, and rodents, as well as large mammals such as elk and deer. Vertebrate predators include owls, frogs, and shrews; invertebrate predators include spiders and beetles. Deer and elk sign have been observed in some of the peat systems in the planning area.

Peat accumulation rates are quite low due to harsh chemical and physical conditions. Rigg (1958) has determined that peat in bogs and fens on the west side of the Washington Cascade Mountains accumulates at an average rate of one inch per 41 years, while the rate of accumulation east of the Cascades is much less—only one inch per century. Because of this, bogs and fens are considered unreproducible habitats: once destroyed, they cannot be recreated.

Wetland Classification, Inventory, and Regulation

The King County Wetlands Inventory (King County, 1990b) contains information about the presence, extent, and characteristics of wetlands within unincorporated King County. A total of 83 wetlands—10% of those described in the inventory—are located in the planning area. The inventoried wetlands occupy a total of 892 acres, or about 2% of the planning area, which also contains dozens of other wetlands that have not yet been inventoried. All classes of freshwater wetlands exist in the planning area: open water ponds, deep and shallow marshes, scrub-shrub wetlands, forested swamps, riparian systems, and peat systems. Most of the basin's Class 1 and large Class 2 wetlands are complex mosaics of several of these habitat types.

In order to prepare the inventory, several categories of data were collected on each wetland, including an aerial photograph, and information about the location, size, classification, habitat characteristics, observed plant and animal species, hydrology, and water quality. Based on these data, each wetland was assigned one of three ratings. The criteria used to assign the wetland ratings, as defined in the 1990 King County Sensitive Areas Ordinance (SAO, King County Ordinance 9614), are as follows:

1. "Class 1 wetlands" are those assigned the Class 1 rating in the 1983 King County Wetlands Inventory, or those that meet any of the following four criteria:

    a. The presence of species listed by the federal government or the State of Washington as endangered or threatened, or the presence of critical or outstanding actual habitat for those species;

    b. Wetlands having 40 to 60% permanent open water in dispersed patches with two or more classes of vegetation;

    c. Wetlands equal to or greater than ten acres in size and having three or more wetland classes, one of which is open water; or

    d. The presence of plant associations of infrequent occurrence.

2. "Class 2 wetlands" are those wetlands assigned the Class 2 rating in the 1983 King County Wetlands Inventory, or those that meet any of the following criteria:

    a. Wetlands greater than one acre in size;

    b. Wetlands equal to or less than one acre in size and having three or more wetland classes;

    c. Wetlands equal to or less than one acre that have a forested wetland class;

    d. The presence of heron rookeries or raptor nesting trees.

3. "Class 3 wetlands" are those wetlands assigned the Class 3 rating in the 1983 King County Wetlands Inventory; or any wetlands that are equal to or less than one acre in size and have two or fewer wetland classes.

In the past, many wetlands within the planning area were drained, cleared, and filled for conversion to agricultural land or other development. Innumerable wetland acres have been impacted by past road construction and extractive or renewable industries such as mining and logging. The King County SAO currently restricts development in and near wetlands, and requires mitigation for unavoidable impacts of public and private development projects. In spite of this law, wetland encroachment continues due to permitted and unpermitted activities. No estimate of the rate of absolute wetland loss is available at this time, but based on analysis of wetland impacts in other basins in King County (King County, 1990c) and in other parts of Washington (Puget Sound Water Quality Authority, 1986), it is possible that up to half the wetlands in the planning area have been lost or severely altered for development. Other studies indicate that even when required as a development permit condition, wetland mitigation projects are not always successful (Cooper, 1987; Kunz and others, 1988; Rylko and Storm, 1991). During field data collection for this basin plan, SWM staff noted that a high percentage of wetlands visited had undergone some degree of buffer removal, clearing, drainage, or filling since the 1983 inventory. Several wetlands were in the process of being altered at the time of the field visits conducted for this report.

Generalized Wetland Conditions

Table 7-1 summarizes characteristics of the inventoried wetlands in the Cedar River Basin. In terms of area, the basin has a high percentage (322 out of a total of 892 acres, or 36%) of Class 1 wetlands. The majority of the Class 1 and large Class 2 wetlands are a mosaic of freshwater wetland habitat types, including open water, emergent marshes, scrub-shrub systems, forested swamps, bogs, and fens. Many of the Class 2 wetlands are located in riparian areas (i.e., along streams and the Cedar River mainstem), reflecting a high degree of interconnectedness between streams and wetlands in the basin. Most of the Class 1 wetlands and the Class 2 riparian wetlands are considered to either Locally or Regionally Significant Resource Areas depending on their functions and values.

Many of the remaining Class 2 and Class 3 wetlands are relatively small, and typically consist of relatively homogeneous patches of scrub-shrub and/or emergent vegetation or constructed ponds; a number of these systems are relatively hydrologically isolated from other wetlands and streams. Nonetheless, these wetlands may carry out important functions in spite of their small size and apparent lack of habitat diversity. Results of the Puget Sound Wetlands and Stormwater Management Research Program indicate that multiple vegetation classes are not predictable indicators of high animal species diversity. Moreover, while wetland size is a factor in attracting breeding bird species, amphibian and bird diversity is determined more by the presence of plant species preferred for habitat and food. The research program has also found that wetlands that are low in amphibian and mammal richness tend to have poorer water quality, as evidenced by high conductivity and bacteria counts (Richter and others, 1991).

7.8 STREAM AND WETLAND HABITATS BY SUBBASIN

LOWER MAINSTEM TRIBUTARIES

Ginger Creek (Tributaries 0300, 0300A)—Map 19

Stream and wetland habitats in the upper reaches of this tributary are extensively degraded by urbanization. A 50 foot high bedrock falls prevents fish passage above RM 0.17. Below these falls fish use is limited by a high gradient, upstream urban impacts, and a culvert at the mouth.

Maplewood Creek (Tributary 0302,0303,0303A)—Map 20

Habitat conditions vary widely in this tributary. The lower half-mile is greatly affected by the Maplewood Golf course and culvert systems under SR-169 and the railroad grade. As a result the stream is in a large (72-inch diameter) culvert for its lowermost 800 feet. Through the golf course, the channel is largely barren of habitat and functions primarily as a drainage ditch. However, coho salmon have been reported to migrate through the culvert and into the golf course reach in recent years. Immediately above the golf course, habitat has been degraded by sediments transported from upstream and by efforts to control these sediments through two in-stream sediment ponds, the uppermost of which is an old water supply dam and not constructed for sediment control. Both of these structures effectively block fish passage; the old water supply dam has probably blocked anadromous fish since its construction, about 1930. However, there is a thriving population of cutthroat trout above these dams.

From RM 0.5 to the top of the plateau (RM 1.38), the stream is confined in a steep wooded ravine. The lower portion of this ravine (RM 0.5–0.75) contains some good habitat despite a riparian system that is still recovering from historic timber harvesting and effects of sedimentation and high flows due to upstream development. Much of the lower portion of the ravine, including Tributary 0303, is in the ownership of the Maplewood Homeowners Association, who have proven to be good stewards by protecting stream banks from development and by encouraging natural processes to dominate. Habitat in stream reaches in the upper part of the ravine is heavily affected by channel scour, a naturally unstable geologic condition, and lateral bank sliding. This latter problem is caused, in some instances, by stormwater discharge over steep banks (see *Chapter 5: Erosion and Deposition*). In addition, a large amount of trash, including old tires, appliances, and the like, has been discarded in the upper ravine area of Maplewood Creek. In both the east and west stream channels, habitat on top of the plateau is highly fragmented and degraded by development activities including housing and strip mall development, in-stream R/D ponds, localized filling of wetlands, and extensive networks of roads and related culverts.

Wetland 150

Current Conditions: Wetland 150 is an 11-acre Class 2 system in the headwaters of Tributary 0303. Approximately half of the wetland is forested. A cedar swamp at the south end of the wetland is an example of what the entire wetland may have looked like prior to alteration. The portion of the wetland north of SE 128th Street is well-buffered by a stand of Douglas fir and big leaf maple. However, about half of the original wetland area south of SE 128th Street appears to have been incrementally filled. As a result, the segment of Tributary 0303 that flows through the wetland has been confined to a narrow ditch, and alder saplings and weeds have colonized the fill. Several small commercial uses appear to have encroached on the oldest portions of the fill; other areas are littered with refuse and old tires. Filling of this wetland may have eliminated some natural storage within this subbasin. Frequent flooding occurs in the Puget Colony Homes plat downstream, and severe erosion has occurred where Tributary 0303 and mainstem Maplewood Creek descend to the valley floor in the Maplewood Golf Course. Other notable impacts are noise and glare from SE 128th Street, a four-lane arterial. Fortunately, road runoff is routed into a small R/D pond southwest of the wetland before release into Tributary 0303.

Future Conditions: If filling continues, the problems affecting this wetland and resources downstream could worsen. It may be possible to restore part of the wetland's former flood storage and biofiltration functions by removing fill and restoring portions of the wetland.

Molasses Creek (Tributary 0304, 0304A)—Map 21

This tributary originates in Wetlands 22 and 23 on the plateau south of the Cedar River valley. The upper reach of this tributary, including Wetland 2, is largely affected by Fairwood, a high-density development area. Beginning at RM 0.8 the stream flows through a deep, wooded ravine in which the habitat improves remarkably, before flowing through a gravel mining operation at its confluence with the Cedar River. Fish habitat is largely confined to the ravine (RM 0.0-0.8) and wetlands on the plateau. The reach separating the ravine and Wetland 2 has long stretches surrounded by highly landscaped lawns or is contained in extremely lengthy culverts (one approximately 0.25 miles long), which, in total, are anadromous fish barriers. However, Wetland 2, in the middle Molasses Creek subbasin, supports a significant population of cutthroat trout. Conditions promoting good stream habitat in the ravine include a well-vegetated riparian system, with a relatively high percentage of large conifer trees, and several pieces of highly functional LWD. Both of these elements appear to be providing relatively stable habitat conditions, at least for the moment, and some excellent pool habitat, in the face of cumulative urban effects. Three large wetlands in the upper and middle Molasses Creek subbasin have major flow-moderating effects on lower Molasses Creek.

Wetland 2

Current Conditions: Wetland 2 is a 37-acre Class 2 system in the middle Molasses Creek subbasin. Part of the wetland occupies Renton Park. Impacts to this wetland include two retention/detention (R/D) ponds built in the wetland and its buffer, one of which impounds Molasses Creek. Other impacts include filling, grading, and debris dumping in and near the wetland, and trash dumping and noise along Petrovitsky Road SE, which was recently widened to four lanes. Buffer encroachment and ongoing pet and human intrusion also occurs.

Although 5% of the wetland has been severely impacted, most of it consists of a healthy, moderately diverse forest plant community, consisting of alder, cottonwoods, and abundance of maturing conifers; many snags and fallen logs are also present. In addition to cutthroat trout, the wetland also provides a moderate amount of wildlife habitat.

In light of the degree of urbanization in this subbasin, Wetland 2 retains a surprising amount of interrelationship with other nearby habitats, including Soos Creek Wetland 2 to the south, forested habitat in a park and around the Fairwood Golf Course to the northeast, and the Molasses Creek ravine and mainstem riparian zones downstream. One of Wetland 2's most valuable functions is hydraulic buffering of flows in lower Molasses Creek. The wetland is also a valuable public education resource because of its location in a King County park near Renton Park Elementary School and Lindbergh High School.

Future Conditions: As currently forested headwater areas are converted to high-density single family residential development, future increases in stormwater volumes and flow durations, coupled with increased summer drying of this wetland, are inevitable, even with stormwater detention facilities. The ability of Wetland 2's forested habitat to withstand these changes will depend on the magnitude of change and on the resilience of its plant community. Mature trees are generally better able to tolerate flooding than seedlings (Azous, 1991), but very prolonged flooding could result in extensive tree death.

Wetland 22

Current Conditions: Wetland 22 is a 12-acre Class 1 system in the headwaters of Molasses Creek. It contains forested, scrub-shrub, and open water habitats, including a bog segment. Unfortunately, this wetland exhibits some of the most severe wetland impacts in the BPA. Habitat, water quality, and hydrologic functions were altered in the late 1980s by construction of a berm and stormwater outfalls for a nearby plat. Extensive siltation of the wetland and downstream areas occurred following these alterations. In addition, subdivision residents have deposited trash and debris in the wetland and maintenance of the R/D facility access road causes chronic buffer impacts. Stream channelization and sewer line construction inside the wetland, as well as additional filling have promoted the invasion of reed canarygrass, hardhack, and other weedy plants. Use of the wetland for R/D appears to be affecting its water quality, as evidenced by a thick brown foam observed in the creek near the pond outlet. 140th Avenue, SE bisects the north end of the wetland and is an ongoing source of noise, glare, and untreated surface runoff. The south half of the wetland is in much better condition, and is well-buffered by upland forest. This part of the wetland and the adjacent buffer contain several prominent snags and mature conifers.

Future Conditions: The planned widening of 140th Avenue, SE, if not mitigated, will increase surface runoff volumes, noise, and glare. At least one new subdivision, 77-lot Fairhaven, has been permitted in the upper subcatchment. Without mitigation of future flows, annual flooding of 140th Avenue SE and concomitant hydrologic and water quality impacts to the wetland will worsen. Increased water level fluctuations and further changes in water chemistry could damage or eliminate the wetland's remaining bog habitat.

Wetland 23

Current Conditions: This rather small (7.7 acres), mostly forested wetland was assigned a Class 1 rating because it contains a plant species of infrequent occurrence, Labrador tea, which indicates bog characteristics. Wetland 23 is located west of 140th Avenue SE, at the end of SE 187th Street, a quiet dead-end road. Because of its position at the upper end of subbasin, and the fact that it is surrounded by low-density residential development, this wetland has been spared many of the impacts from urbanization seen in the rest of the subbasin. The wetland is also protected by a broad forested buffer that affords a high degree of connectivity to nearby habitats. Portions of the wetland appear to have been logged approximately 50 years ago, and incremental filling has occurred along the northwest edge. In addition to its wildlife and plant habitat functions, this wetland is providing some degree of flood storage and flow maintenance for Molasses Creek.

Future Conditions: Although this wetland is presently in stable condition, it is slated to be encircled by development that will convert much of the upper subcatchment to impervious surface. Because of the existing flooding and erosion problems downstream, loss of existing natural flood storage in Wetland 23 could be problematic, as could direct impacts on the wetland due to increased water level fluctuation and an approximate doubling in loading rates of lead, phosphorus, total suspended solids, and fecal coliform organisms (for more information about water quality changes, see *Chapter 6: Water Quality*).

Madsen Creek (Tributaries 0305, 0306, 0306A)—Map 16

This stream can conveniently be broken into three reaches: the lower reach, which extends across the Cedar River floodplain; the middle section, which flows within a deep ravine; and the upper headwaters, which flow through the Fairwood subdivisions. Historically it was a major producer of coho salmon and steelhead and cutthroat trout and, in its lower reaches, sockeye salmon. Current fish utilization appears to be limited to cutthroat trout and occasional reports of steelhead. For their part, cutthroat are surviving throughout much of the system and extend into the heavily urbanized areas of the plateau.

The lower reach of Madsen Creek extends from RM 0.0 to 0.8 flows mostly through artificial channels of varying complexity and generally low habitat value, ranging from the roadside ditch along SR-169 to the newly created reach (RM 0.2-0.4). In 1992 beavers established a damsite on Madsen Creek approximately 200 feet from the mouth at a point where Madsen Creek drops from an older river terrace to the river channel. Habitat in this pond area is approximately two to three acres in size and should mature into an excellent wetland environment for coho and cutthroat trout. Habitat further upstream in this lower reach is being affected by many problems including SR-169 and residential development, high flows from urban development on the plateau, deposition of fine sediments, and the lack of channel complexity and a well-established riparian system. At RM 0.8, a sediment pond was constructed in 1974 by King County Division of Hydraulics (now KCSWM) to trap sediments from upstream erosional sources and to protect a mobile home park and SR-169 from flooding (see *Chapter 5: Erosion and Deposition*). While achieving success in this mission, the pond structure has not been successful in trapping fine sediments, however, and as a result, habitat structures placed downstream (RM 0.2-0.4) in the low-flow fish-habitat channel have been buried in sand, and the channel has become braided on the bank terrace immediately above its confluence with the Cedar River. The pond also connects with a high-flow bypass channel that has been observed to attract spawning adult fish and has the potential to attract and trap juvenile salmon, especially newly emerged fry, because of a lack of screening devices.

The middle section of Madsen Creek, from RM 0.8 to 2.15, flows through a deep ravine. This reach is characterized by an immature riparian area, moderate amounts of woody debris (mostly small and poorly positioned and therefore often ineffective), and a lack of deep, complex pool environments. Much of the habitat has been disturbed by high amounts of sediment from landslides on lower reaches of Tributary 0306 and systemic erosional processes triggered by changes in hydrology from upstream development. This condition is exacerbated by a lack of LWD, poor riparian conditions, and placement of sewer lines through the ravine. However, once away from the effect of the utility systems, the channel is in remarkably good condition, especially considering its proximity to Fairwood. Buried sewer utility lines throughout much of Madsen Creek ravine, especially on Tributary 0306, have contributed to habitat problems resulting from riparian and channel management activities that have hardened banks and removed LWD. While these activities create local stability of the pipeline, the stream reach and its habitat are increasingly prone to instability, with the potential to result in additional pipeline stability problems requiring ever increasing efforts to stabilize the pipeline through bank hardening and stream clearing.

The upper reach of Madsen Creek flows in very close proximity to the residential subdivisions of Fairwood. It is channelized through backyards almost the entire distance to the outlet of Wetland 16.

The primary tributary to Madsen Creek is Tributary 0306. This tributary has experienced the most severe habitat degradation in the entire basin due to landsliding and channel incision between RM 0.0 and 0.25. This is a very steep reach that had been extensively modified for a natural gas line crossing and impacted by large changes in storm hydrology; these problems are discussed in *Chapter 5: Erosion and Deposition*. Despite these problems, cutthroat trout continue to exist throughout this heavily damaged reach, although its value for coho or steelhead is questionable due to channel instability and a relatively high gradient. Above the highly eroded portions of this stream, there exists one patch of good salmonid habitat, but for the most part it is dominated by lengthy and otherwise impassable culverts under golf fairways, channelization through backyards, and headwaters that drain from Petrovitsky Road SE.

Wetland 25

Current Conditions: This small wetland received a Class 1 rating because, like Wetland 23, it contains a plant community of uncommon occurrence, a Labrador tea/hemlock bog. The major impact noted in the inventory was road fill and cross culverts placed during construction of the Lake Youngs Boundary Road in the 1920s. Since 1981, the entire buffer, and approximately three of the wetland's original five acres, were filled and an R/D pond (D-91023) for the Carriage Wood subdivision was constructed in the wetland. Tightlined drainage from the R/D facility flows into Tributary 0306, which flows into Wetland 18. The R/D system may be malfunctioning because the R/D maintenance access road is too narrow to accommodate a vactor truck to clean the outlet control structure. In addition to the hydrologic impacts of the R/D pond, other impacts include yard waste and trash dumping and intrusion by humans and domestic pets. A tree house and garden shed have been built in the wetland.

Future Conditions: Although some hemlocks in the remaining wetland still appear healthy, the overall size, species diversity, and habitat value of the wetland has been greatly reduced by filling and buffer removal. With ongoing additions of nutrient-rich stormwater, the bog's acidophilic plant community may eventually give way to one dominated by disturbance tolerant species such as hardhack and red alder, which appear to be spreading along the disturbed margins. Inability to remove sediment from the outlet control structure could eventually cause backwatering of stormwater into the portion of the wetland that still supports bog species and mature conifers, causing vegetation stress or death. Extreme backwatering could affect the storm drain system upstream in the Carriage Wood subdivision.

Wetland 18

Current Conditions: Although relatively small, Wetland 18 deserves mention because of past, current, and potential future impacts affecting its functions and resources downstream. The wetland inventory shows Wetland 18 as two separate forested areas totalling 1.7 acres along the stream corridor of Tributary 0306, the principal tributary to Madsen Creek. However, the wetland is actually a narrow, but continuous, 3200-foot-long riparian corridor between SE Petrovitsky Road SE and SE 175th Street. The size of this area is approximately four acres.

Past impacts to this wetland have been severe, and the present wetland is only a remnant of a once-larger system. The wetland receives flows from a combination of tightlined natural drainage and stormwater from the Carriage Wood plat upstream and the adjacent Candlewood plat in Fairwood. Between Petrovitsky Road SE and SE 179th Street, the wetland is confined to a narrow corridor of salmonberry, alder, and cottonwood, bordered by utility line fill and residences on the west and a narrow strip of upland forest on the east. South of SE 179th Street, the wetland broadens considerably but lacks a buffer because of the close proximity of 159th Avenue SE along the east side, a grass-covered utility easement used by the Youngs Lake pipeline, and a playground. An asphalt trail system and smaller unpaved foot trails criss-cross this segment of wetland, and several stormwater outfalls are also visible. Much of the understory vegetation and all woody debris within a half-acre area on both sides of the stream has been removed, possibly in order to "clean up" the wetland. An oil sheen and faint hydrocarbon odor were observed in the denuded area, possibly caused by stormwater contaminants. The cleared area had also been used in the recent past by a pileated woodpecker (*Dryocopus pileatus*), as evidenced by a freshly excavated hole in the surface of a tree. The stream appears channelized through most of the above reach. Downstream from the clearing, the stream and wetland are buffered by narrow patches of upland forest, including some mature conifers and bitter cherry (*Prunus emarginata*), which is somewhat unusual in King

County riparian areas.

Future Conditions: Although upper catchment areas that drain to Wetland 18 are fully developed, conditions may change as a result of a SWM capital improvement project scheduled to occur in 1994 that would improve detention in this segment of Tributary 0306. An environmental impact statement (EIS) will analyze project impacts and proposed mitigation. It is possible that stream and wetland enhancement can be incorporated into the project.

Wetland 16

Current Conditions: This 14-acre wetland was rated as a Class 1 system because it contains a bog component dominated by Labrador tea. In addition to its large size, Wetland 16 is unusually structurally complex including a bog and deep marsh components described in the inventory, and forested swamp, scrub-shrub, and shallow marsh habitats dominated by western red cedar and western hemlock; hardhack, red-osier dogwood, and willows; and a variety of emergent species. The deep marsh contains numerous snags and partially submerged logs that provide excellent habitat for a variety of animals, birds, and possibly warmwater fish. At present, the wetland is buffered by mature mixed deciduous forest to the south within Petrovitsky Park. The buffer along the southeast and east boundaries is much wider and consists of dense, mature second growth conifers and deciduous vegetation. Portions of the forested swamp and buffer areas contain accumulations of woody debris in volumes reminiscent of old growth forests.

Existing impacts include intrusion into the buffer from backyards and storm drains from subdivisions of Fairwood. Dredging has also occurred in this area in order to improve conveyance of untreated and undetained stormwater through the wetland to Madsen Creek. However, the flat gradient of the local terrain and scouring flows have caused this area to become a repository for sediment. In contrast, stormwater flowing into the southeastern corner of the wetland from Petrovitsky Park is cleansed and detained by a several hundred foot long biofiltration swale and an R/D pond before it enters the wetland.

Future Conditions: While the current condition of Wetland 16 is good to excellent in many respects, its future health is uncertain because of impending development to the south and east. This area, now forested, is currently being subdivided into 20-acre parcels with a new road system for the Lake Desire Estates development. If further subdivided into the 2.5-acre lots allowed under current zoning, some or all the smaller lots could be built out individually without formal drainage facilities. Non-commercial farm development of this tract would likely disrupt existing corridors to upland habitats and Lake Desire to the east, and greatly increase storm runoff volumes and pollutants in Wetland 16. Water quality monitoring indicates that Wetland 16 will undergo an approximate doubling in loading of lead, phosphorus, and total suspended solids (see *Chapter 6: Water Quality*). Construction of an outlet control structure to provide increased stormwater detention for Madsen Creek could also adversely affect Wetland 16. These impacts and possible mitigation will be analyzed in the EIS for the above-mentioned Madsen Creek channel stabilization project.

Tributaries 0308, 0308A, 0309, and 0310)—Map 23

Salmon use in these tributaries is limited by low, intermittent flows and erosion and deposition in transitional reaches where the streams flow onto the valley floor. As a result, fish use is largely restricted to valley-floor reaches. A culvert at RM 0.25 on Tributary 0310 blocks fish passage while high, heavy flows have eroded and deposited sediments around RM 0.1 on Tributary 0309.

Tributaries 0314, 0314A, 0314B, 0315, 0315A, 0316, 0317, and 0318)—Map 18

Fish habitat in these tributaries is confined to short reaches along the valley floor of the Cedar River due to high gradient, intermittent flows, and small size. Excellent habitat exists along Tributary 0315 where it merges with a wetland. Tributary 0316 is a classic example of a wall-base tributary with use by coho salmon and cutthroat trout. This tributary has been affected by encroachment and trash from the Rainbow Bend Mobile Home Park and, perhaps more importantly, by activities associated with gravel mining in the headwaters by Stoneway Gravel. This mining could lead to considerable loss of spring flows and turbidity problems as has occurred on Tributary 0316A.

Tributary 0316A

Stream and wetland habitat and water quality in this tributary have been severely degraded by extensive gravel mining and composting operations in headwater areas north of Cedar Grove Road. A local landowner has documented many changes to the stream system in the past ten years, including chronic and acute turbidity problems extending to the mouth, loss of summer base-flows, dramatic reductions in use of the stream by coho salmon and steelhead trout, and a complete loss of sockeye salmon utilization. These observations are consistent with our assessment. For ease of discussion, the stream is divided into a series of segments, starting with the upper headwaters.

Headwaters (RM 2.4-3.4) Tributary 0316A originates in wetlands (some of which are used as R/D ponds) in the Maple Hills plat northwest of the Cedar Hills Landfill. Water from the subdivision sheet flows through a broad corridor of forested and scrub-shrub wetlands before passing through similar habitats within the southwest corner of the landfill property.

Cedar Grove Composting reach (RM 2.0-2.4) South of the landfill fence line part of the water in Tributary 0316A enters the upper end of a rock-lined channel that initially flows east, then south along the composting facility perimeter. The remainder of the water backs up behind an earthen berm that separates the channel from the forested wetland, which extends south of the landfill and east of the composting facility. Mechanical screening of compost occurs atop several feet of fill, the side slopes of which form the stream's right bank. As a result, there is minimal vegetation between the stream and the facility throughout this reach. Both the streambed and channel side slopes are littered with composting residue, including plastic bags and organic debris. Compost and surface runoff from the facility appears to freely descend down the fill side slope and into the stream during storms. This runoff presumably contains partially decomposed yard waste leachate that collects in shallow pools along the base of the compost. Piles of loose soil stockpiled near the right bank for later mixture into compost products also appear to contribute sediment-laden runoff to the stream. South of the active composting area, overflow from the facility's leachate ponds is released into the stream through a buried pipe controlled by a valve. Thick accumulations of brown flocculent material—possibly algae—were observed in the bottom of the channel near the valve junction. Algae-coated rocks were observed elsewhere all along the stream adjacent to the facility. Flow from the south end of the wetland also merges with the stream just upstream from the valve. The air throughout this area had a foul odor during a field visit in early February. See *Chapter 6: Water Quality*, for information about water quality impacts.

Stoneway Gravel Mine to Cedar Grove Road (RM 1.2-2.0) Downstream from the valve, the stream lacks a defined channel. Instead, it braids for several hundred feet across an expanse of unconsolidated gravel. In this reach, thick growths of algae, pockets of oily residue, and ankle-deep accumulations of mud were observed at various locations in and near the stream. Vehicle tracks along and across the stream were also seen here. Below this area, the stream enters a rectangular pond apparently built to settle out particulates. However, the pond appears to be too small to serve this purpose.

South of the pond, the stream braids over unconsolidated gravel on the Stoneway gravel mine site. Near the lower end of this reach, an overflow channel from the Stoneway process water pond to the west is separated from the stream by a low gravel berm. A large accumulation of silt and sand was observed near the lower end of the overflow channel. At the lower end of this reach, surface flow from 0316A is directed to a bed of pervious gravels at the bottom of a large cut bank where the stream infiltrates into the ground. Approximately 450 feet to the southeast and slightly downslope of the gravel mine, Tributary 0316A emerges from a spring and flows south through a small ravine and thence under the Cedar Grove Road into Wetland 31.

It appears that the gravel mining operations have excavated into and essentially removed a large portion of the upslope glacial outwash gravels that historically served as the groundwater source area for 0316A. The existing berm between the gravel mine and the spring appears to be too small and too porous to filter out suspended particulates and dissolved pollutants from upstream areas. As a result, these substances are transported into downstream habitats.

Cedar Grove Road to Wetland 31 Outlet (RM 0.7-1.2) Below Cedar Grove Road, the stream flows through Wetland 31 before entering a short channel that flows into Wetland 32 (described below). The connecting channel has been dredged by the landowner in an effort to remove fine sediment from upstream areas. As a result, both the stream bed and the riparian zone lack diverse structure. The landowner has spent considerable effort revegetating the stream banks and adding gravel to the stream bed as mitigation for the dredging operation. While portions of the stream bed remain exposed to the underlying till layer, in other areas gravels are sufficient for spawning, such that during an early February field visit an estimated 15 to 20 coho were observed actively spawning in the channel between the wetlands.

Wetland 31 Outlet to Francis Lake Road (RM 0.7-0.6) A defined channel resumes west of the outlet of Wetland 32. This stream segment flows through a residential yard where the riparian zone has been cleared to create vehicle parking and a firewood cutting area.

Francis Lake Road to Cedar River (RM 0.6–0.0) Immediately below Francis Lake Road the stream enters a complex channel area surrounded by an uninventoried riparian wetland. The stream bed is composed of small side channels, braids, and islands with moderate amounts of LWD. At approximately RM 0.5 the stream begins its descent to the Cedar River via a short, moderately steep ravine. Within this reach the stream is relatively remote from human impacts and habitat conditions improve significantly because of dense riparian vegetation and ample LWD. Near the approach to the Cedar River the gradient flattens and excellent spawning gravels are present. In recent years local residents have observed sockeye congregating at the mouth of the stream, but, because of low flows, they were unable to migrate upstream.

Wetlands 31 and 32

Current Conditions: Wetlands 31 and 32 are Class 2 systems associated with Tributary 0316A south of Cedar Grove Road. Wetland 31, 10.5 acres in size, is composed mainly of scrub-shrub habitat but also contains patches of reed-canary grass wet meadow and an Oregon Ash swamp near the west end. In 1989, the landowner constructed a berm in the wetland in order to detain and biofilter sand, silt, and composting wastes from upstream areas. In addition, the stream was dredged in order to remove large volumes of fine sediment that had accumulated in the stream bed. As mitigation, the west end of the wetland was recontoured into shallow marsh habitat and enhanced with wetland and buffer plantings and bird nesting boxes.

Wetland 32 is a 1.5-acre pond excavated in the mid-1970s. In addition to open water, the pond is fringed along the south side by dense shrubs and a broad upland forested buffer. In contrast, the north shoreline has been denuded of vegetation by livestock. In the past, the landowner reared rainbow trout in the pond. The landowner reports that in recent years, attempts to stock the pond have failed because of low summer flows, high water temperature, and pollutants from upstream areas.

In spite of these impacts, both wetlands and the stream are magnets for wildlife because of their relative abundance of food, water, and cover. During a field visit in early February, SWM staff flushed a Bald Eagle feeding on a coho carcass near the inlet of Wetland 31. Deer and elk sign were observed in Wetland 31, as were several Mallards and Buffleheads. The landowner reports use of the area by coyote, weasel, mink, muskrat, beaver, Great Blue Heron, Red-tailed Hawk, Barn Owl, and seven other species of waterfowl, including Wood Ducks that hatched several broods of chicks in nesting boxes in the past two years.

Future Conditions: Following reclamation of the gravel mine, a portion of this area could be converted to low-density, single-family residential development. The effects of this on the stream's geohydrology are difficult to predict. The composting facility could expand to accept increased volumes of yard waste and possibly other materials, including food waste, storm drain catch basin waste, and sewage sludge. The Stoneway Gravel Mine is scheduled to close sometime before 1997. Unless upstream problems affecting water quality and the stream hydroperiod are corrected, current conditions in Tributary 0316A and Wetlands 31 and 32 are likely to persist and could possibly worsen.

Wetland 13 (Queen City Lake)

Current Conditions: Wetland 13 is a 28-acre Class 1-rated hydrologically isolated system in the headwaters of Tributary 0316. The wetland is bordered by the King County Solid Waste Division (SWD) Cedar Hills Landfill to the north, Cedar Grove Composting to the east, and the Stoneway gravel mine to the south. Wetland 13 is within a 320-acre former pig farm owned by Queen City Farms, Inc., which is now an EPA Superfund Site (see *Chapter 6: Water Quality* for further discussion of the Superfund cleanup).

Most of the wetland's water comes from stormwater that flows off previously filled and covered surfaces at the Cedar Hills Landfill. The wetland also receives lesser volumes of direct precipitation and overland flow from upper catchment areas. Subsurface leachate from the County Landfill is intercepted, pretreated, and pumped to a Metro sewage treatment plant via a pipeline along SR-169. In the past, the wetland received some runoff from contaminated areas to the east. In order to protect the lake from water quality degradation, King County SWD has entered into an agreement with EPA to monitor the rates and water quality of surface water flows from the landfill. Water from the wetland recharges the shallow aquifer directly underneath it.

Wetland 13 consists of a large open-water area surrounded by densely vegetated scrub-shrub and forested swamp habitats. An extensive upland deciduous forest forms a buffer around its boundaries. In the late 1980s gravel mining activities caused springs to form near the south side of the wetland. In order to prevent extreme water level fluctuations in Queen City Lake, and saturation of contaminated soils near the wetland that could interfere with cleanup efforts, an artificial outlet was installed near the center of the south side of the wetland to pipe lake outflows to the gravel pit lake north of Cedar Grove Road. The wetland has also undergone minor buffer removal and grading, apparently in connection with site investigation activities for the Superfund cleanup.

The significant habitat features of this wetland include its large expanse of open water, which is used by migratory waterfowl, numerous snags and logs, and some remaining interconnections with nearby upland habitats. The abundant deer and coyote sign found in the forested swamp north of the lake and in portions of the Superfund site to the east indicate that this area is heavily used by these wildlife species.

Future Conditions: The prospects for future protection and restoration may be improved because of its EPA's jurisdiction over the site, which will prevent future unsafe disposal of toxic materials and restore the onsite environment. The SWM Division has recommended that certain actions to protect and restore Wetland 13 be included in the Superfund cleanup plan. Water quality modeling indicates that although this wetland will receive approximately one-third more lead, fecal coliform organisma, and total suspended solids in the future, inputs of total phosphorus will decrease by 77% (see *Chapter 6: Water Quality*).

Wetland 33 (Webster Lake)

Current Conditions: This 25.7-acre system, which encompasses 16-acre spring-fed Webster Lake, is located in the upper headwaters of the in the Cedar Grove/Webster Lake subbasin. It was categorized as a Class 1 wetland because of its large size and unusually diverse structure, which includes forested swamp, scrub-shrub, bog, marsh, and deep water habitats. Water flows from south end of the lake into Tributary 0317, which in turn flows into Francis Lake. Among the lakes in western King County, Webster Lake is unparalleled because of its almost total lack of shoreline development. As such, it could be considered as a biological reference site for shoreline habitat restoration efforts on similar lakes in the central Puget Lowland. The wetland and adjacent buffer areas are virtually undisturbed except for three residences and four small docks. Motorboats are prohibited on the lake. The lake supports two small stocks of planted trout. It also provides some habitat for migratory waterfowl.

Future Conditions: 138 acres of forested land bordering the east side of the lake was recently subdivided into the Webster Lake Estates. The plat contains 26 lots averaging five acres. The seven wetlands inside this tract, including Wetland 33, are protected as sensitive area tracts through a private restrictive covenant under the Sensitive Areas Ordinance (SAO) requirements. These measures will likely prevent major alterations of the lake shoreline in this plat. However, additional subdivisions may eventually surround the remainder of the lake. Since non-commercial farming is common in the vicinity of the lake, wholesale lot clearing and livestock impacts could occur in the future, leading to substantial increases in runoff volumes and nonpoint source pollution in the lake. Future development could also disrupt the currently intact connections between Wetland 33 and adjacent habitats in upper catchment areas and downstream. Water quality monitoring indicates that this wetland will undergo the highest percentage increase—almost 400%—in total phosphorus of any Class 1 wetland in the planning area (see *Chapter 6: Water Quality*).

Wetland 36 (Francis Lake)

Current Conditions: Wetland 36 is a 31-acre Class 1 system surrounding Francis Lake, one-half mile downstream from Webster Lake. It consists of open water and scrub-shrub habitats bordered by agricultural land, scattered residences, and outbuildings. The wetland receives flows from Webster Lake to the northeast via Tributary 0317, and lesser flows from two other Tributaries, 0319 and 0318. Water flows out of the lake through partially impounded Tributary 0317.

In the past, much if not all of the wetland buffer was disturbed during conversion of formerly forested land to fields and pastures, many of which have drainage ditches. A segment of the main inlet has been diverted into a pair of ornamental ponds and a small portion of the wetland was filled. The lake's outlet, Tributary 0317, infiltrates into a demolition debris landfill at RM 0.6 near Francis Lake Road.

In spite of these impacts, Francis Lake and its associated wetland support an unusually large number of wildlife species, including migratory waterfowl, red-tailed hawk, Virginia rail, muskrat, and occasional mink. The lake's habitat value is enhanced by connections to large expanses of forested land in all directions and to Webster Lake.

Future Conditions: Given the existing land-use pattern near the lake, current impacts are likely to continue as forested areas are converted to low-density single-family residential development. Habitat fragmentation of upper catchment areas is also probable with future buildout of Webster Lake Estates and other development upstream. It will also undergo moderate—up to 50%—increases in four nonpoint pollutants (see *Chapter 6: Water Quality*).

Wetland 39

Current Conditions: Wetland 39 is a 10-acre Class 2 system located on a bench along the east valley wall in the lower Tributary 0317 subbasin. It consists of wet meadow (soft rush/cattail), scrub-shrub (willow), and forested (alder/ salmonberry) habitats. An uninventoried corridor of the wetland extends north from the mapped boundary and across Maxwell Road to the west; another uninventoried segment lies south of the boundary shown in the inventory. Wetland 39 receives water from wet areas along the steep valley wall east of Maxwell Road. Sheet flow that collects in a roadside ditch along the west side of the wetland is conveyed westward through culverts under the road. Older homes and outbuildings—including several that may be on fill—border the north, west, and south edges of the wetland. Recent impacts include clearing and driveway construction near the center of the wetland to provide access for two new homes, filling and construction of a garden shed along the north edge, and clearing of a wide swath of vegetation along the east side of Maxwell Road, possibly for road or power line right-of-way maintenance.

Future Conditions: Forested areas in the upper subcatchment areas that drain to Wetland 39 will likely be converted to low-density single-family residential development that could increase stormflows entering the wetland, as well as summer drying. Human encroachment will probably continue as this area becomes more populated.

PETERSON CREEK SUBBASIN

Peterson Creek (Tributary 0328)—Map 26

Peterson Creek is used by all species of anadromous salmonids indigenous to the Cedar River Basin. It contains generally good to excellent habitat that is well-buffered largely by an extensive lake and wetland network in its upper basin and a mostly undeveloped riparian corridor throughout much of its length. The riparian corridor varies in its state of vegetational succession and stability throughout much of the subbasin. Good to excellent habitat conditions exist in the lower 0.5 miles where there is also a high incidence of landsliding, delivering sediment and LWD to the channel. However, it is not clear that current conditions are significantly less stable than predevelopment conditions given the steepness of the stream and its valley walls and the geologic make-up of the area. Much of the vegetation in this lower ravine is dominated by relatively large conifer and deciduous trees nearing old growth in structure and function.

From RM 0.5 to RM 1.2, Peterson Creek is dominated by long riffle reaches. Some good to excellent reaches of habitat exist, especially where accumulations of stable LWD occur.

The riparian system of this reach is still recovering from past logging and is not yet naturally contributing significantly to the addition of LWD.

The reach of Peterson Creek extending from Peterson Lake downstream for approximately 0.4 miles (RM 1.6–1.2) has been straightened and channelized, creating a channel dominated by runs and glides with small alders along the banks. Despite this impact, salmonids do use this reach for spawning and rearing. There is a small dam at the outlet of Peterson Lake that has been noted as a fish blockage in the past, but is currently easily passable at almost all flows.

Above Peterson Lake, Peterson Creek splits into three channels, with the mainstem draining Spring Lake and a right bank tributary (0328B) draining Lake Desire. There is a third unnamed and unnumbered tributary that drains from the west and is largely contained in a pipe as a result of activities by the SWD to drain water away from Lake Youngs. This third channel does not have fish and is not examined further in this review.

Both of the larger channels are largely contained in a large Class 1 wetland system (Wetland 28) that dominates much of the valley area downstream of the lakes. The stream habitat in this reach is protected by the surrounding wetlands; banks are densely vegetated, mostly with deciduous woody plants. The channels are low gradient and substrates are dominated by silt with abundant LWD that contributes to habitat complexity.

Wetland 14

Current Conditions: Wetland 14, a 43-acre Class 1 system, lies in the extreme headwaters of the Peterson Creek Subbasin, where its outflow forms Tributary 0328B, 0.2 mile upstream from Lake Desire. Prior to peat mining, which began in the 1950s and ended in the late 1980s, Wetland 14 was a bog dominated by typical bog species, including hemlock, Labrador tea, cranberry, and Sphagnum mosses; at present, approximately six acres of pristine bog remain. Researchers from the University of Washington and elsewhere have found that the bog is approximately 15,500 years old (C. Hamilton, pers. commun., 1992). For a brief period during its mining history, Wetland 14 was the largest peat production site in Washington. Following peat excavation, much of the wetland was converted by means of an elaborate system of channels and berms into open water ponds, which are stocked with rainbow and cutthroat trout. In the more recently mined portions of the wetland, mineral soils formerly blanketed by peat deposits are being colonized by a variety of non-bog species, including alder, cottonwood, hardhack, a variety of shrubs, and emergent species. A number of large trees, including some conifers, remain within the buffer. Near the outlet, Tributary 0328 has been dredged to create a more defined channel.

Existing impacts include past wetland and buffer clearing, drainage, and filling to provide access to mined areas; equipment storage and stockpiling of topsoil in limited areas within the wetland; and invasion of the most highly disturbed areas along the wetland margins by reed canarygrass and blackberries. Clearing and access road construction within the Bonneville Power Administration powerlines north of the wetland have badly fragmented Wetland 102 to the north, and partially disconnected Wetland 14 from the upland forest to the northwest. Local residents report that the wetland suffers from increased volumes of runoff from a residential subdivision upstream. They also report that this may be affecting water quality and lake levels downstream in Lake Desire.

However, Wetland 14 is still generally bordered by large tracts of upland forest. It is also linked to Wetland 15 and Lake Desire by a broad riparian corridor along Tributary 0328A. In spite of peat extraction, Wetland 14 provides abundant habitat for many wildlife species, including great blue heron and migratory waterfowl. The wetland is frequently visited by deer, and is occasionally used by coyote, river otter, and bear. The exposed peat strata near the southeast corner of the wetland where mined area gives way to pristine bog provides a fascinating glimpse into the paleoecology of the Cedar River plateau. Although peat removal has altered its original hydrologic characteristics, Wetland 14 currently provides valuable stormwater detention of runoff from upper catchment areas, which were built out under less stringent detention standards than currently exist.

Future Conditions: Peat mining under a King County grading permit ceased in the late 1980s. Future conditions are expected to remain relatively stable, and could even improve as a result of buffer restoration and revegetation of the most recently mined areas. However, the future development pattern of the 500 acres of undeveloped land near Wetlands 14, 15, 16 and Lake Desire is a concern. This area is being subdivided for medium-density single-family development, as discussed under Wetland 16. If unmitigated drainage from development is allowed to enter the remaining Sphagnum bog area, increased surface water from upper catchment areas could alter Wetland 14's existing water chemistry and hydroperiod, thereby damaging the bog's peat substrate and acidophilic plant community.

Wetland 15 (near Lake Desire)

Current Conditions: Much of the land bordering Lake Desire is moderately steep and well drained, and thus it is not very conducive to the formation of extensive wetlands. Exceptions to this include the flat area along the north end of the Lake Desire, where Tributary 0328B flows through Wetland 15 before entering the lake, and another uninventoried riparian wetland that extends from the south end of the lake along Tributary 0328B to Wetland 28.

Wetland 15 is a 17-acre Class 1 system situated at the north end of Lake Desire. It is composed of forested, scrub-shrub, bog, and emergent habitats. Tributary 0328B, which receives flow from Wetland 14 and upper catchment areas, flows through the wetland and drains into the lake at RM 1.7. In addition to this riparian corridor, other significant habitat features include numerous snags and fallen logs, large hemlocks growing on the Sphagnum mat, and a patches of dense willows and cattails along the shoreline of Lake Desire.

Past impacts to the wetland include logging, impoundment of flows behind Lake Desire Road (which appears to flood frequently during winter storms), and minor buffer encroachment behind several residences. More serious wetland and buffer encroachment has occurred due to agricultural and residential clearing. Portions of the wetland have also been filled in recent years. South of Lake Desire Road, the state boat launch appears to have been built in the southwest corner of a wetland.

As mentioned above, an uninventoried riparian wetland exists between the south end of Lake Desire and Wetland 28. Both sheet flow and channelized flow in Tributary 0328B appear to be somewhat impeded by an old north-south oriented logging road a short distance south of the lake and adjacent to a 200-acre parcel of mostly forested King County open-space land. The steeper portions of the logging road are eroding into the stream and adjacent wetland. The open-space land contains public trails, most of the Wetland 28 swamp/fen complex (see below), and several small uninventoried wetlands. Over time, the upland forest on the open-space property will gradually regain old growth characteristics as the maturing hemlocks and cedars grow into large trees and early successional species such as alder become less dominant.

Future Conditions: Concerns about future conditions are similar to those stated above for Wetlands 14 and 16, namely the potential for adverse impacts on water chemistry and the wetland hydroperiod from piecemeal development in the upper watershed. The rezoning of the lake shore from low- to high-density, single-family residential development threatens water quality in the lake, and the physical integrity of Wetland 15 and its buffer.

Wetland 28 (Spring Lake)

Current Conditions: Wetland 28 is an 83-acre Class 1 system that encompasses Spring Lake. It is composed of a large (69 acre), extraordinarily high quality Sphagnum/Labrador tea fen and hemlock swamp situated near the southeast shoreline of the lake, as well as forested, scrub-shrub, emergent, and open-water habitats. The swamp is traversed by Tributary 0328, which flows from the south end of Spring Lake, and Tributary 0328B, which connects Lake Desire to Tributary 0328. From there, the combined flow of these two streams flows southeast to Peterson Lake. In addition to the usual assemblage of Sphagnum and Hypnum mosses, Labrador tea, cranberry, and hemlock, the fen contains unusual densities of mature lodgepole pine. Judging by the extreme depth of the peat deposits in the fen, portions of the wetland appear to be over 10,000 years old (Rigg, 1958).

Almost half of the lake shoreline is undeveloped. Because so much of the shoreline remains intact, Wetland 28 is in better condition than any of the other wetlands examined within the BPA. Indeed, it is arguably the most pristine wetland in the SWM service area. The only disturbed areas are those fringing the developed part of the shoreline, where road and single family residential construction has lead to localized wetland filling and removal of native vegetation. Small foot trails and a campsite are minor impacts to the peat in the hemlock swamp and fen segments of the wetland. A small portion of the Sphagnum mat near the lake is disintegrating and becoming colonized by acid-neutral species such as soft rush and sedges, perhaps due to increased nutrient levels and lake water fluctuations in recent years.

Future Conditions: While part of Wetland 28's immediate subcatchment area is protected as open space, the wetland itself has been platted under pre-SAO conditions. This means that large areas of the wetland could be cleared and filled for homesites, roads, and utility lines under the reasonable use provisions of the SAO. In addition, because of the sensitivity of its plant communities, this wetland is especially vulnerable to impacts from future development. Portions of the lake shoreline are slated for buildout at densities that will increase from single- to medium-density, single-family residential development. Increased water level fluctuations and nonpoint pollution from nearby and upstream sources pose a serious threat to the biological integrity of Spring Lake and other habitats within Wetland 28. Continued Sphagnum disintegration could lead to an undesirable release of nutrients into the lake, and possibly to wholesale and irreversible invasion of the fen by hardhack and cattails.

Wetland 42 (Peterson Lake)

Current Conditions: Wetland 42 surrounding Peterson Lake is a Class 2 system in the middle Peterson Creek Subbasin. It consists of approximately six acres of open water, extensive willow/hardhack scrub-shrub habitats northwest and southeast of Petrovitsky Road SE, as well as smaller emergent and forested areas. Although the wetland inventory lists its size as 14.5 acres, its actual size—including a four-acre segment near the SWD Lake Youngs pipeline and a larger area south of 192nd Avenue SE —appears to be closer to 23 acres. Wetland 42's major source of water is Peterson Creek. The lake shoreline is densely vegetated with hardhack, willows, red-osier dogwood, Douglas' hawthorn, and salmonberry and is lined in many areas with snags and partially submerged logs. The lake supports salmonids and warmwater species such as perch, black crappie, bass, and pumpkinseed. Abundant beaver sign was noted in areas on both sides of Petrovitsky Road SE. The wetland benefits from relatively intact habitat corridors extending to Spring Lake, Shady Lake, Lake Desire and associated wetlands to the northwest, and a large tracts of deciduous forested land to the north and east.

Impacts to Wetland 42 include Petrovitsky Road SE, which bisects the wetland and is a source of noise, glare, and litter; construction of the pipeline and access roads; dredging within the wetland and downstream in Peterson Creek; and small clearings and foot trails near the lakes, some of which contain trash. Wetland hydrology may have been altered in the past by placement of a concrete outlet control structure near the southeast end of the lake. When examined in November 1992, the structure appeared to be fish passable, but it could act as a barrier to upstream migration during summer low-flow conditions. Reed canarygrass and blackberries have invaded the more disturbed areas along the edges of the wetland.

Future Conditions: Future conditions could be affected by widening of Petrovitsky Road SE and 196th Avenue SE, by larger volumes of storm runoff entering the wetland from development in the upper watershed, and by fragmentation of adjacent upland habitats caused by future buildout. In addition, an area near the north end of the wetland has been designated for future commercial development. Without mitigation, increased volumes of nonpoint pollutants are likely to enter the lake. Unmitigated future flows could also damage fish habitat downstream in Peterson Creek.

TAYLOR CREEK SUBBASIN

Taylor Creek (Tributary 0320)—Map 27

The Taylor Creek system is a major producer of anadromous fish and, between RM 1.8 and RM 2.0, has a population of fresh water mussels. Much of the subbasin is composed of a comparatively complex network of relatively low-gradient stream channels containing habitat that is generally of good quality with some isolated pockets of excellent habitat. Riparian systems are generally well vegetated, although still immature. Habitat is further stabilized by patches of small to moderate sized boulder materials in high-gradient reaches. Hydrology of the system has not been greatly affected due to the relatively low level of development throughout the drainage. Habitat throughout much of the drainage has suffered somewhat due to the immature condition of its riparian system and limited quantities of LWD; these deficiencies suggest that the habitat could be significantly improved in complexity and stability over current conditions and that the system may be at risk of much more dramatic habitat degradation.

The mainstem of Taylor Creek drains a series of wetlands, many uninventoried, formed in a shallow valley between Carey Creek, a major tributary of Issaquah Creek to the northeast, and the Cedar River Basin. This valley also contains SR-18, which parallels much of the mainstem of Taylor Creek; generally wide buffers exist between the channel and the roadway. Two main fish-bearing tributaries (0327 and 0328) contribute to Taylor Creek prior to the mainstem's drop to the valley floor. Habitat throughout these systems is dominated by several wetlands, most notably Wetland 58, which is in the vicinity of the proposed Taylor Creek Golf Course, between RM 2.25 and 2.6. The golf course developer has identified extensive wetland and stream buffers for preservation and plans to construct "oversized" stormwater detention facilities in order reduce downstream flooding along Maxwell Road and improve habitat. Localized effects of agriculture, road crossings, and rural development along stream channels, especially on Tributary 0326 between RM 0.45 and 0.7, are the main impacts to habitat in these reaches of the creek.

From RM 1.8 to 1.2, Taylor Creek flows through a shallow ravine, which is much less steep in channel slope than ravines of surrounding Cedar River tributaries and has habitat problems much less dramatic to date. Potential habitat values in the ravine are reduced by low quantities of LWD and a largely immature riparian system. Stream crossings under SR-18 and two private roads constrict the stream channel, creating potential fish barriers at high flows, and may be contributing to the "clean" channel conditions as a result of stream maintenance to protect the crossings.

At RM 1.2, Taylor Creek reaches the Cedar River valley floor and parallels Maxwell Road where the stream is confined to a ditch. Habitat in this area has been affected by surrounding agriculture and rural development, and channelization and road maintenance activities conducted to reduce local flooding. The confluence of Taylor Creek with the Cedar River is contained in Wetland 132, a large riparian wetland complex with high quality fish habitat (see also Table 7-3).

Additional habitat in the Taylor Creek system is found in Tributary 0321, which enters Taylor Creek at RM 0.45, north of SE 206th Street. This tributary has excellent habitat between RM 0.2 and 0.8, where there is a riparian area of large second growth cedars and the channel has high-density LWD. Below this reach, the stream channel is relatively straight and clean and flows through a pasture, although a dense border of blackberries provides some protection from local grazing of banks. Above RM 0.8, Tributary 0321 and two others (0323 and 0323A) are degraded by a combination of agriculture and encroachment of rural development, resulting in poor quality riparian areas, or in some cases, a complete lack of streamside cover.

Wetland 49

Current Conditions: Wetland 49 is a 12.1-acre Class 2 system that spans SR-18 in the upper headwaters of Tributary 0326. It receives water from areas to the northwest, including Wetlands 48 and 38, and road runoff from the State highway and SE 200th Street. Flows from the wetland outlet near the southwest corner are conveyed in ditches along and under the highway into Wetland 50 downstream. West of the highway, a dense stand of willows and reed canarygrass screens a small but structurally diverse farm pond that contains dispersed clumps of shrubs and trees. East of the highway, the wetland was well vegetated with mature alder and cedar until several acres and much of the buffer were cleared in late 1992, substantially reducing wildlife habitat and water quality functions in this area.

Future Conditions: Existing forested upper subcatchment areas will likely be converted to low-density single-family residential development and non-commercial farms, which could increase winter runoff, summer drying, and nonpoint pollutants entering this wetland. Some of the recently cleared trees were over 100 years old. Even with replanting, the wetland will not regain its former habitat for many decades. In the short term, erosion and sedimentation are likely to increase because of loss of vegetation over approximately one-third of the wetland and buffer. Ironically, soil saturation and inundation could increase in the cleared area due to loss of interception and evapotranspiration by the trees. Future widening of SR-18 from two to four lanes will remove vegetation that currently screens the pond from the highway. It will also fill up to 5% of the wetland, thus further fragmenting wildlife habitat and decreasing natural flood storage. The road project will also increase surface runoff and noise levels.

Wetland 50

Current Conditions: Wetland 50 is a 13-acre Class 2 system in the upper headwaters of Taylor Creek. Although mostly forested with alder and salmonberry, it also contains a small open water pond near the intersection of SE 200th Street and SR-18. The pond has been planted with several species of warmwater fish and trout. Water enters the pond from Wetlands 48, 88, and 50 to the north, and exits near the west side of 258th Avenue SE. From there, flows enter the forested wetland through a culvert, and exit at the south end through another culvert under 258th Avenue SE. Local residents report occasional flooding where 258th Avenue SE crosses the north end of the wetland. Past impacts include logging, buffer clearing, and encroachment near three homes at the south end of the system. Additional clearing along the pond occurred during more recent construction of a nearby home. Road noise from SR-18 is audible near the pond. In spite of these impacts, Wetland 50 is in relatively good condition compared to many of the wetlands in BPA because most of it remains free of human intrusion. The pond and nearby areas are used regularly by waterfowl and deer, and are occasionally visited by river otter, elk, and bear.

Future Conditions: With SAO protection, the existing deciduous forest will eventually mature into a cedar and hemlock swamp. However, additional low-density single family residences and non-commercial farms could encircle the wetland, leading to increased stormwater and intrusion by pets and humans. Perhaps the most severe future impact will result from future widening of SR-18, which will generate more noise, eliminate the buffer along the north end, and route increased volumes of road runoff into the pond.

Wetland 52

Current Conditions: Wetland 52 is a 17-acre Class 2 system in the upper headwaters of Tributary 0326. It consists of wet meadow (soft rush/skunk cabbage), scrub-shrub (willow/hardhack), and forested (cedar/hemlock and alder/salmonberry) habitats. The western mostly forested half of the wetland is in relatively good condition. The eastern half has been altered by extensive buffer clearing and grazing, and a number of structures—including several homes—occupy the buffer. In the recent past, 2.5 acres of meadow and shrub habitat were cleared, graded and partially drained, leaving a large expanse of exposed soil. In addition, mature firs have been removed from the buffer along the southeast edge.

Future Conditions: The long term impacts from development of upper catchment areas and clearing will be similar or perhaps worse than those described for Wetland 49 because of soil compaction by heavy equipment, which typically retards revegetation.

Wetland 58

Current Conditions: Wetland 58 is a 9-acre Class 2 system along Taylor Creek south of the intersection of SR-18, 244th Avenue SE, and SE 208th Street. It contains a mosaic of habitat types, including a reed canarygrass wet meadow, several patches of shrubs, and a dense corridor of riparian vegetation along Taylor Creek. The wetland receives water from Taylor Creek and Tributaries 0325, 0326, and 0327, and from Wetland 53 and another uninventoried wetland (recently cleared of mature cedars) north of the highway. The principal functions of this wetland are wildlife habitat, flood storage, stormflow attenuation, and water quality protection. Portions of the wetland may serve as over-wintering habitat for juvenile salmonids, or could be altered to enhance this function.

Future Conditions: Current conditions in the east half of the wetland will probably remain fairly stable. However, the segment west of 244th Avenue SE will be affected by the future widening of SR-18. Filling, buffer removal, and increased volumes of surface runoff, noise, and glare are anticipated from this project. This same segment is within the future site of the Taylor Creek Golf Course. The golf course will be designed and operated in accordance with the SAO, which requires stream, wetland, and buffer protection. Other permit conditions include stringent erosion control during construction and water quality monitoring to ensure that fertilizers and pesticides do not enter Taylor Creek and its tributaries. As is the case with other headwater wetlands in this subbasin, existing forested areas will likely be converted to low-density single family residences and non-commercial farms without formal drainage facilities. Increased runoff volumes, summer drying, and nonpoint pollution are likely.

Wetland 73

Current Conditions: Wetland 73 is a 18-acre Class 2 system in the headwaters of Tributary 0326. Three segments of the wetland are separated by a cluster of houses situated on a knoll north of SE 216th Street and by the road. The south and east segments are densely vegetated with shrubs—mostly willows and salmonberry—but some alders and young cedars are also present. The west segment, a nine-acre area north of the road, is a grazed wet meadow. Other impacts include noise and runoff from SE 216th Street and invasion by blackberries along the edges.

Future Conditions: As is the case with other headwater wetlands in this subbasin, existing forested areas will likely be converted to low-density single family residences and non-commercial farms without formal drainage facilities. Increased runoff volumes, summer drying, and nonpoint pollution are likely.

Wetland 133

Current Conditions: Wetland 133 is a 10-acre Class 2 system in the headwaters of Tributary 0326. It contains emergent (reed canarygrass/soft rush), scrub-shrub (willow/hardhack), and forested (mostly alder) habitats. Much of the swamp has been heavily grazed, and contains large expanses of standing water; muddy, trampled soil; and dead and dying trees. Other impacts include noise and runoff from SE 216th Street, hydrologic modifications caused by driveways that extend completely through the wetland, and invasion by blackberries.

Future Conditions: As is the case with other headwater wetlands in this subbasin, existing forested areas will likely be converted to low-density single family residences and non-commercial farms without formal drainage facilities. Increased runoff volumes, summer drying, and nonpoint pollution are likely. In addition, current habitat conditions could worsen with further loss of trees.

MIDDLE CEDAR RIVER SUBBASINS

The Middle Cedar River has three main tributary stream systems: Rock Creek, which will be discussed in a separate section; Dorre Don Tributary; and the Walsh Lake Diversion Ditch.

Dorre Don (Tributary 0336)—Map 25

Although this stream has an extensive drainage network, its utilization by fish is limited because it is dry for extended periods of the year. Despite this ephemeral flow, rainbow and cutthroat trout were sampled by Washington Department of Wildlife (Muto and Sheffler, 1983) in pools below 244th Street (RM 0.8). Utilization by anadromous salmonids is further limited by a culvert under Upper Dorre Don Road at RM 0.17. Up to this point, the stream is surrounded by residential development along Lower and Upper Dorre Don Ways. This lower section of the stream runs through backyards, through two culverts, and over highly porous gravel that probably allows all but the highest flows from upstream to infiltrate. This lower reach is primarily used in the winter by anadromous salmon for spawning and refuge.

Wetland 77

Current Conditions: Wetland 77 is a 14-acre Class 1 system in the headwaters of Tributary 0336. The wetland is bordered on the south by a densely forested hillslope, and elsewhere by scattered rural residences. It is composed of forested, scrub-shrub, shallow marsh, and open water habitats. In addition to overland flow and direct precipitation, water enters the wetland through Tributary 0336, and from another small unmapped tributary draining into the north end of the wetland. Wetland 77's unusually diverse plant communities include coniferous (Sitka spruce) and deciduous (alder) forested components, and remnant patches of Sphagnum, bog laurel, Labrador tea, and cranberry, which indicate the former presence of a bog or fen.

Past impacts include clearing and logging. In addition to its wildlife habitat functions, Wetland 77 provides water quality protection and hydrologic support for Tributary 0336 downstream.

Future Conditions: With future conversion of forested upper subcatchment areas to low-density single-family residential development, total suspended solids and fecal coliform organisms are expected to nearly double, lead will increase 150%, and total phosphorus will more than triple.

Walsh Lake Diversion Ditch (Tributary 0341)Map—25

This channel is entirely artificial from its mouth to RM 4.2, having been constructed in the 1920s by the SWD to divert water of poor drinking quality away from the Cedar River drainage above the Landsburg Dam. However, all species of salmonids utilize Walsh Lake Diversion Ditch up to RM 4.2, where a series of beaver dams prevents passage of anadromous salmonids into Walsh Lake and above. It originates at Walsh Lake, located in the SWD watershed. The creek was originally connected to Rock Creek (Tributary 0342), a different Rock Creek than Tributary 0338 described below. However, at high flows the drainage ditch still spills over into Tributary 0342 at RM 3.6, thereby controlling the effects of high flows. The channel flows almost due west, paralleling the Cedar River on a high plateau to the north, until RM 0.65, where it begins a steep descent to the valley floor. Much of the channel on the plateau is a simple straight ditch, which is periodically maintained by the SWD. There is little instream habitat complexity in those reaches, although elements for good fish production are present due to constant flow and overhanging vegetation along at least one bank. There are reaches of fair to good habitat, including lateral and backwater pools, in areas where the channel meanders away from the SWD access road and has been allowed to flood and erode adjacent banks. Consequently it is able to achieve a natural meander pattern and capture LWD. A short portion (RM 1.1-1.2) of the Walsh Lake Diversion Ditch east of the Issaquah-Hobart Road was lined with an impervious material to reduce subsurface flow to the nearby Hobart Landfill. A leachate collection system was installed on the landfill, in part to prevent contamination of the surface water of the diversion ditch.

The high-gradient reach of the Walsh Lake Diversion Ditch (RM 0.18-0.65) is typified by steep, generally unvegetated banks as much as 40 feet high. These features indicate the extent of channel downcutting since flows were first diverted over the edge of the valley. Despite this instability there is some good pool habitat formed by LWD, apparently fallen into the channel from above. This LWD is also serving to create a stair-step channel profile and to stabilize and store sediments. A relatively high percentage of boulder and cobble substrates are providing a basic level of bed and habitat stability.

The lower reach of the Walsh Lake Diversion Ditch (RM 0.0-0.18) changes dramatically from the preceding reach, with gently sloping bank topography and vegetation dominated by deciduous forest with dense underbrush. Gravel deposits on the sediment fan in this reach are very permeable, and during low flows the stream often goes dry. The major habitats in this lower reach are pocket water, high- and low-gradient riffles, and only a few low-quality pools owing to an absence of LWD. Although surface substrates range from small gravel to small boulders, cobble-sized rock are dominant. There are a number of locations in which past meandering has taken place, including the presence of several well vegetated gravel bars outside of the present channel, indicating that habitat formation is still very dynamic.

Where maintenance is not occurring, habitat conditions in the Walsh Lake Diversion Ditch are still evolving and often are very good. There is some scattered residential development west of the Hobart Road, but otherwise habitat should continue to improve as riparian vegetation matures and interacts with the stream. The Walsh Lake Diversion Ditch may represent a unique opportunity to speed up the formation of habitat by adding structural elements, particularly LWD, that would otherwise require many more years before becoming naturally incorporated into the stream channel.

Wetland 64

Current Conditions: Wetland 64 is a 14.5-acre Class 1 system in the Walsh Lake Diversion Ditch subbasin. It is composed of forested, scrub-shrub, and open water habitats. This wetland is unusually long and narrow; in some places it is little more than 50 feet wide. Its sinuous shape and abrupt gravelly side slopes, which are especially visible near SE 226th Street, suggest that this wetland formed within an old glacial-age water channel carved by water flow between nearby bedrock hills. Water enters the wetland from an undefined source near the northeast end and as runoff from the subdivision that surrounds the southeast half of the wetland.

During a November 1992 field visit, SWM staff observed southwesterly flow over a gravel-filled area that connects the dead ends of SE 225th Street and SE 226th Street. However, no water was seen leaving the wetland through the culvert that acts as an outlet control structure. It is possible that the normal wetland inflow and outflow is entirely subsurface, helping to maintain streamflows in lower catchment areas. Wetland outflows are conveyed southerly in a drainage swale. During heavy storms, the wetland occasionally overtops SE 226th Street, flooding several yards and a residence south of the outlet. South of SE 228th Street, peak flows presumably enter the Seattle Watershed before reaching the Walsh Lake Diversion Ditch. Small uninventoried wet areas were observed near several homes in the subdivision. Seasonal water table fluctuations indicate that septic system problems are possible in this neighborhood. If septic system failures do occur, they could affect water quality in the wetland and downstream. Although encroachment by the subdivision has been intense around the south half of the wetland, its upper end is in very good condition and provides significant habitat for migratory waterfowl, other birds, and a variety of mammalian species.

Future Conditions: Because of the inadequate and, in some areas, non-existent buffer along the south half of the wetland, Wetland 64 is especially vulnerable to encroachment by unpermitted activities such as clearing and trash dumping. Alteration to improve detention capacity for the adjacent subdivision has been considered by SWM staff. However, the King County SAO discourages use of Class 1 wetlands as sub-regional R/D facilities. Barring such major future degradation, Wetland 64 should remain in relatively stable condition because of low-density rural zoning and the close proximity of protected habitats in the Cedar River Basin. Water quality modelling of future flows indicates that lead, fecal coliform organisms, and total suspended solids will increase moderately as forested land in upper catchment areas continues to be converted to low-density, single-family residential developmen (see *Chapter 6: Water Quality*).

ROCK CREEK SUBBASIN

Rock Creek (Tributary 0339)—Map 28

Rock Creek is outstanding habitat throughout most of its length and is among the best habitats in western King County. It is an important stream for all species of salmonids found in the Cedar River Basin. Habitat conditions, with few exceptions, represent a complex interplay between soil and vegetation, with relatively minor recent human intervention. These conditions contribute to a stable, diverse habitat even in the higher-gradient reaches. Natural system stability is enhanced by a relatively low gradient, a storm hydrology dampened by large amounts of glacial outwash soils in the subbasin, and a series of uninventoried riparian wetlands between RM 2.6 and 0.8. The drainage has been only sparsely developed. Much of the riparian vegetation, which has a high proportion of coniferous trees, is approaching old growth in size and structural complexity. Most of the stream has high volumes of LWD. In many reaches the habitat can best be typified as continuous "debris complexes," within which complex pool and riffle habitats have developed.

Existing impacts to Rock Creek include recent logging, which has left some reaches with immature riparian areas and relatively little LWD in some lower reaches of the stream. Other impacts to the stream habitat have resulted from localized agriculture and residential development at the headwaters and from water withdrawals by the City of Kent, which maintains a system of wells near the Summit-Landsburg road crossing (RM 1.7). Instream flow problems caused by the City of Kent's water withdrawals are particularly problematic during the late-summer and early-fall months when the diversion takes as much as three quarters of the expected baseflow. In mid-October, 1992, when many sockeye and chinook salmon were in the mainstem of the Cedar River, the lower reach of Rock Creek was estimated to have a flow of only 1.9 cfs, leaving many riffles and pools too shallow for the passage and holding of adult sockeye and chinook, which used to abound in the system, but are now relatively infrequent users. This lack of water during traditionally low-flow periods further crowds and stresses coho salmon and steelhead and cutthroat trout that use Rock Creek habitat for extended freshwater rearing. Hence it appears that some of the best habitat in King County is currently limited by lack of adequate stream flow rather than direct development impacts.

In addition to water withdrawals, future threats to Rock Creek include large-scale residential development and loss of mature complex riparian vegetation from logging. Residential development could be particularly harmful to Rock Creek because much of the channel's length is not intrinsically buffered by steep slopes from encroachment of houses and people. As a result of this relatively easy access to the stream, humans and their pets would have a higher potential for disturbing vegetation and fish populations.

Wetland 82

Current Conditions: Wetland 82, also known as Hidden Lake, is a 18.5-acre hydrologically isolated system in the upper Rock Creek Subbasin. It is composed of bog, scrub-shrub, shallow and deep marsh, and open water components. Judging by its appearance, this wetland, like Wetland 64, may have formed in an old glacial-age water channel. Dense brush and numerous partially submerged logs surround the lake shoreline along with several large snags. Past impacts to the buffer include substantial clearing and off-road vehicle trails. Warmwater fish reside in the wetland, and it may also contain some planted trout. Although hydrologically isolated, this wetland could carry out seasonal groundwater exchange. Separated from forested and riverine habitats within the

Cedar River Basin by only a single gravel road to the north, it undoubtedly provides important aquatic habitat for a variety of birds, amphibians, and mammals.

Future Conditions: Several lots have been platted along the west side of the wetland. However, with existing low-density residential zoning and SAO protection, wetland conditions should remain relatively stable and could even improve with regrowth of the logged buffer. Current forest practices requirements mandating wetland management zones should prevent wholesale logging of the buffer in the future. The King County Department of Corrections has proposed development of a "shooting park" on a site only a few hundred yards south of the wetland. Increased noise levels from firearms and paramilitary activities could disrupt utilization of wetland and nearby upland habitat by wildlife. Water quality modelling indicates that while fecal coliform organisms and total suspended solids will increase only slightly, lead will increase by almost one-third and total phosphorus by 87%, respectively (see *Chapter 6: Water Quality*).

Wetlands 91 and 92

Current Conditions: Wetlands 91 and 92 are associated with Lake No. 12 in the headwaters of Rock Creek. The wetland inventory shows these as two separate Class 2 wetlands. However, field inspection reveals a single 134-acre system composed of open water (Lake No. 12), emergent and scrub-shrub areas along the lake shoreline, and a large complex of cedar/hemlock swamp, scrub-shrub, marsh, and open water habitats east of the lake.

Lake No. 12 contains small, evenly-dispersed patches of water lilies and other macrophytes including Eurasian water milfoil (*Myroiophyllum spicatum*), which proliferates during the summer. The west shoreline is bordered by landscaped yards with minimal native vegetation. In contrast, the undeveloped east end of the lake is fringed by cattail, hardhack, willows, and cedar. Water from the lake flows sluggishly east, first through a maze of fallen logs and shallow pools in the swamp, and then through marshy areas and a small pond west of 290th Avenue SE. A short distance upstream from the road, the topography becomes steeper and Rock Creek begins in a defined channel at RM 4.5. From the area's peat stratigraphy (Rigg, 1958), it appears that a sedge-cattail marsh flourished at this location several thousand years ago, after which a forested wetland began to form, perhaps resembling the swamp that now exists.

Current impacts to Wetland 91 (Lake No. 12) include vegetation removal, filling, soil compaction in residential yards along three-quarters of the lake shoreline, and human disturbance from recreational use of the lake. The public boat launch near the southeast corner of the lake appears to have been built on fill in the wetland; trash dumping and invasion of blackberries are problems in this area. Since the lake is used by motor boats, oil and gasoline spills are possible.

Due to the lake's shallowness (maximum depth = 28 feet) and eutrophic state, algal blooms and excessive growth of macrophytes are problems during the spring and summer. As the plants increase and eventually die, masses of decaying plant material accumulate. While live plants produce oxygen in daylight, they consume oxygen at night, making the habitat inhospitable for trout and other organisms that require high oxygen levels. Additional oxygen may be consumed by bacteria and other organisms that ingest detritus and nutrients released by the decaying plant material.

A telecommunications cable installed in the southeast corner of Wetland 92 and its buffer has caused soil compaction, partial drainage and localized channelization of flow. Otherwise, the wetland is well buffered along the south and east edges by a mature conifer forest. In contrast, a large segment of the subcatchment to the northeast, including the buffer, has been logged within the past 10 years.

Future Conditions: Much of the upper subcatchment areas draining to these wetlands are in the forest production zone and have already been logged. With maturation of reforested areas, some nonpoint pollutants such as total suspended solids, lead, and fecal coliform organisms entering this wetland should decrease. On the other hand, continued conversion of residentially-zoned forested areas to residences and non-commercial farms without formal drainage facilities could increase total phosphorus entering the lake and its associated wetlands. Tacoma Public Utilities plans to build a water supply pipeline (No. 5) to convey water from the Green River to a distribution system in southwest King County. The pipeline would be constructed within portions of Wetlands 91, 92, and 93 and their buffers. Depending on how the project is designed, these wetlands could be severely damaged by erosion and hydrologic disruption during construction, and by permanent changes in hydrology and habitat structure caused by an access road and backfill for buried segments of the pipe and/or suspension pilings. Other potential impacts include invasion by non-native vegetation, increased human intrusion along the pipeline right-of-way, and disturbance of the steep slope south of Lake No. 12. An example of some of these impacts can be seen along SWD's Lake Youngs pipeline near Peterson Lake.

Wetland 93

Current Conditions: Wetland 93 is a 27-acre forested/scrub-shrub system bordering Rock Creek from RM 4.5 to 4.0. It is separated from the east end of Wetland 92 by the toe of the adjacent north slope west of 290th Avenue SE. The vegetation consists of dense thickets of willows, salmonberry, snowberry, hardhack, vine maple, and Pacific ninebark. Deer and elk sign were especially abundant in this wetland, and several songbird species were sighted. The King County stormwater and wetlands research project notes use of this wetland by 56 bird species. Judging by the relative paucity of stumps, this wetland could be an old beaver pond or pond that has filled in. Aside from partial buffer logging, the only significant impact is a six- to eight-foot-wide artificial channel that conveys flow from Rock Creek a short distance south into the Green River gorge. The diversion channel flows through two culverts. The upper culvert crosses 312th Way SE. The lower culvert, which is partially blocked with gravel, crosses a driveway and is suspended over a shallow pool formed by a concrete weir that appears to be the remains of an old domestic water supply. Below the weir, the diversion cascades down a steep slope toward the Green River. Given the summer low flow problems downstream in Rock Creek, the significance of this diversion needs to be investigated.

Future Conditions: Most of the upper subcatchment areas draining directly to Wetland 93 are in the forest production zone, and have already been logged. With maturation of reforested areas, some nonpoint pollutants such as total suspended solids, lead, and fecal coliform organisms entering this wetland should decrease. Without corrective action, a portion of the flows in Rock Creek will continue to be diverted into the Green River. Continued blockage of the driveway culvert with sediment, and/or upstream migration of nickpoints in the steep gorge sidewall could eventually damage or destroy the driveway, and possibly also the road.

Wetland 94

Current Conditions: Wetland 94 is a 20-acre scrub-shrub system adjacent to Rock Creek from approximately RM 3.4 to 3.2. The stream lacks a defined channel in this reach, and instead sheet flows through dense vegetation and several shallow pools, which were occupied by several species of waterfowl during a February field visit. Impacts include buffer logging along three sides of the wetland within the past ten years, regular vegetation removal along a power line right-of-way that crosses the north end of the wetland, and occasional noise from off-road vehicles and guns. Refuse and large numbers of empty gun shells were found along the east edge, which is bordered by a railway. Some areas of the wetland have been invaded by reed canarygrass and blackberries.

Given the location of this wetland in the forest production zone, future conditions are likely to remain stable and could improve if the buffer could be protected during the next timber harvest. As mentioned above, concentrations of many nonpoint pollutants entering the wetland should decrease with maturation of reforested upper catchment areas.

Wetland 87

Current Conditions: Wetland 87 is a 22-acre Class 2 system in the upper Rock Creek Subbasin. It is the largest of five hydrologically isolated wetlands south of Retreat Lake and northeast of Lake No. 12. It contains shallow marsh and scrub-shrub habitats dominated by alder, salmonberry, hardhack, and well dispersed patches of emergent species, and is circled by scattered homes. Minor trash-dumping and grazing by horses are problems near the southeast corner of the wetland. In spite of these impacts, most of the wetland is well protected by dense vegetation that probably limits intrusion by humans and pets. Several songbird and waterfowl species were observed during a December field visit.

Future Conditions: Given current zoning and land-use patterns, this wetland is likely to remain in its current condition and could improve with continued maturation of the buffer.

VALLEY-FLOOR HABITATS

Lower Cedar River Mainstem—Map 18

About half (36) of the 68 valley-floor aquatic habitats identified in our habitat survey were located below SR-18 at Maple Valley. Despite the relatively high level of floodplain development, many of these habitats are still important for salmonid production. At least two of these habitats, Cavanaugh Pond (also known as Wetland 6 at RM 6.4) and a wall-based tributary at RM 11.5 were created as a result of unintentional human actions but are used extensively by salmonids, including sockeye salmon. A similar opportunity for intercepting shallow surface water and developing new habitat is possible at numerous sites including Wetland 37 (RM 8.3-9.0), which is the largest riparian wetland along the Cedar River and also the site of the proposed spawning channel. Another notable habitat, composed of a percolation side channel, a wall-based tributary, and riparian wetlands is located across from the mouth of Madsen Creek (RM 4.5) and is largely protected by open-space land set aside by the Maplewood Heights Homeowners Association. The reach of river between RM 10.7 and 9.6 is largely unaffected by development and flood control structures and has several outstanding valley-floor habitats as well as excellent mainstem habitat.

Lower Mainstem Wetlands

The bed, banks, and floodplain of the Cedar River are composed of alluvium, materials transported and deposited by the river during current and past migrations across its floodplain. In some areas of the riparian zone, rapid peak flows of high velocity and short, infrequent duration result in constant reorganization and redeposition of unconsolidated sand and silt particles, which form sandy soils. Such soils are seldom in one place long enough to develop typical wetland soil characteristics such as distinctive colors and accumulations of organic matter (Washington State Department of Ecology, 1990; Federal Interagency Committee for Wetland Delineation, 1989; US Department of Agriculture Soil Conservation Service, 1975). For this reason, hydrology and vegetation are the most reliable indicators of riparian wetland boundaries.

Even using these indicators, seasonal and yearly changes in flooding levels, soil moisture, and vegetation makes the precise boundaries of riparian wetlands difficult to determine, particularly on the upland edge (Mitch and Gosselink, 1986). These factors may account for the discrepancies noted in the boundaries shown on some of the inventory maps.

Wetland 6 (Cavanaugh Pond)

Current Conditions: Fourteen-acre Cavenaugh Pond, located between RM 6.4 and 6.85, includes open water, along with forested, scrub-shrub, and emergent habitats. It is the only Class 1 system on the Cedar River valley floor. Wetland 6 has three sources of water: flows from Tributary 0312, which descends through a steep ravine on the south side of SR-169; occasional backwater from the mainstem Cedar River during high flow conditions; and groundwater upwelling from the river. Water leaves the wetland through a small outlet channel at the south end, which cuts through a gravel bar along the left bank of the river at RM 6.4.

Wetland 6 contains an exceptionally diverse array of habitats. The margins of the wetland are mostly dominated by alder and salmonberry, although a dense stand of willow exists along the southwest shoreline near the outlet. A marshy emergent zone dominated by water parsley covers an alluvial fan at the east end of the wetland formed by sediment from Tributary 0312. Another zone of marsh vegetation can be seen at the southwest corner of the wetland, which is densely vegetated by cattails and other emergent plants. The entire wetland is surrounded by an upland deciduous forest that also contains immature cedars and hemlocks. Perhaps Cavenaugh Pond's most unique feature is its large expanse of exceptionally high quality salmonid spawning, rearing, and refuge habitat. Because of groundwater upwelling and a sheltered location behind the adjacent revetment, water in Wetland 6 remains relatively clear and non-turbulent during flooding conditions. Under normal flow conditions the water along the north shoreline is crystal clear. SWM staff have observed large numbers of sockeye spawning at this location from December through January. The open water and large numbers of salmon carcasses found at this time also attract other animals, including raptors and large numbers of migratory waterfowl. SWM staff also observed a beaver lodge and other evidence of beaver activity, as well as signs of predation on salmon carcasses and birds during a 1991 field visit. As noted in the Wetland Inventory, the site forms excellent potential bald eagle habitat. As King County open space land, the area contains small foot trails and is an outstanding public resource for environmental education and passive recreation. Adverse conditions include ongoing sedimentation near the mouth of Tributary 0312, which causes at least occasional water turbidity, and a filled area at the west end of the wetland. The lack of mature conifers in both the wetland and in the surrounding upland forest has reduced the amount of wildlife cover that would otherwise be available in the winter. Blackberries and other weedy species have invaded the buffer in some areas.

Future Conditions: Future conditions should remain at least stable, and could improve because of protection conferred by the site's open space status. Ongoing sedimentation from Tributary 0312 is a concern, however. In addition, as public use increases in the future, the wetland's wildlife habitat value could be impaired. The buffer along with south side will be reduced and road noise will increase when SR-169 is widened in the near future. In spite of this, minimal change is predicted in loading rates of nonpoint pollutants such as lead, fecal coliform organisms, total suspended solids, and total phosphorus.

Wetland 103

Current Conditions: Wetland 103 is a 6-acre forested riparian system between the Cedar River trail and the mainstem between RM 7.3 and 7.6. The canopy vegetation consists largely of cottonwood and big leaf maple, although Pacific willow and a few immature hemlock and cedar are also present. The understory vegetation is dominated by salmonberry, hardhack, red-osier dogwood, and large monotypic stands of Himalayan blackberry and Japanese knotweed (*Polygonum cuspidatum*), a tall, cane-like, invasive species recently introduced from Asia. A grove of old fruit trees occupies the buffer along the eastern tip of the wetland. Significant habitat features include numerous deciduous snags, mounds of cobble covered by logjams, and large accumulations of river-borne woody debris near the northeast corner of the wetland. A debris-filled side channel loops out from the mainstem near RM 7.5. Elsewhere, the soils consist of sand and silt underlain by gravel and cobble. Overgrown scroll bars were observed in the wetland, attesting to past channel migration through this area. The active side channel may provide hydraulic refuge for fish during floods. Deer tracks were seen throughout the area closest to the river, and a few mergansers were flushed from the side channel during a December field visit. The wetland receives informal recreational use from foot trails that extend from the revetment and the main trail.

Impacts include road noise from SR-169, encroachment of the Riverbend revetment into the northwest edge of the wetland, and trash dumping along a gravel access road near the west edge. The highway and fill under the trail (formerly a railroad bed) appear to have altered the hydrology of this area of the floodplain by confining floodwaters within a narrow portion of the valley and concentrating drainage from the south valley wall through cross culverts.

Future Conditions: The invasive species will likely persist and could spread in the high disturbance zone close to the river. Without planting, the overstory will remain dominated by deciduous species because of a lack of nearby conifer seed sources. While deciduous vegetation provides substantial cover during the growing season and a pulse of nutrients into the aquatic food chain during autumn leaf fall, conifers offer better cover for wildlife in the winter. Noise levels and road runoff will increase significantly when SR-169 is widened from two to four lanes.

Wetland 37 (Cedar Grove Park)

Current Conditions: The 1990 inventory describes Wetland 37 as a 30-acre Class 2 forested/scrub-shrub system on the convex side of a meander bend between RM 8.3 and

9.1 in Cedar Grove Park. Three brief winter field visits revealed much of this area to be a low terrace with ridge and swale topography and several old percolation channels. The canopy vegetation in the wetter areas consists of cottonwood, alder, and big leaf maple, with an understory of salmonberry, snowberry, and patches of red-osier dogwood. A dense patch of scrub-shrub vegetation, mostly vine maple, is present south of the main percolation channel, which traverses the wetland northwesterly from approximately RM 9.0 to RM 8.4. Another wetland was found in an old chute cutoff near the Cedar River trail, outside the wetland area shown on the inventory map. Some of the higher portions of the site have predominantly upland vegetation, including a large stand of mature fir and big leaf maple near RM 8.8 and a magnificent grove of old growth cedars in the east interior of the site. In addition, several small areas vegetated with Scot's broom and grasses appear to have been graded and possibly filled in the past, perhaps as homesites or campsites. The left bank of the river is unarmored from RM 9.2 to 8.4, allowing overbank flows to traverse much of the site unimpeded. During the 1990 storms, this area was under several feet of water. Additional hydrology comes from seasonal upwelling into the percolation channels and swales. In addition to flow attenuation, water quality protection, and possible flood refuge for salmonids, this riparian area provides outstanding wildlife habitat. As the BPA's largest riverside park, it also has high recreational value.

Impacts to Wetland 37 include invasion of some areas by Japanese knotweed, Himalayan blackberry, and English ivy, which festoons some of the tall cottonwoods near the northeast edge along the river. Like Wetland 103, Wetland 37 has been partially cut off from hydrologic source areas at the base of the south valley wall by SR-169 and the old railroad bed. Several thousand square feet of the buffer were filled recently to create a staging area for construction of the trail.

Future Conditions: Part of the area mapped as Wetland 37 is within one of the sites proposed by the SWD for a future sockeye spawning channel. Impacts from this project would include clearing, grading, and filling to construct the channel and ancillary structures such as buildings, parking lots, and perhaps a visitor center. The exact extent of wetland and buffer impacts would depend on delineation of wetland boundaries by the applicant and field verification by several permit agencies. In the absence of this project, habitat conditions should improve as the more disturbed plant communities enter later successional stages. It might be possible to alter some of the meander scrolls to provide salmonid spawning and rearing habitat. Human intrusion could increase, however, when the Maple Valley trail becomes fully operational.

Wetland 105

Current Conditions: Wetland 105 is a 9.2-acre Class 2 system that spans the river between RM 10.5 and 10.6 and extends 0.2 miles south along the right bank of Tributary 0316, near the Cedar Grove Trailer Park. The left bank segment is dominated by alder, and right bank segment by mature cottonwood, alder, snowberry, and other shrubs. Garbage is scattered throughout the area near a trailer court and heavy trash dumping has occurred at a few locations. The stream, which contained three feet of slow-moving water during a winter field visit, has been channelized along the northeast side of the trailer court and downstream where it flows through the wetland. In spite of these impacts, the stream provides over-wintering habitat for juvenile salmonids. Beaver activity was noted near the mouth of the stream. A debris slide has occurred into the wetland edge and buffer near another unmapped tributary that enters the river just north of the wetland.

Future Conditions: Human disturbance is expected to continue.

Wetland 132

Current Conditions: The inventory describes Wetland 132 as a 25.9-acre Class 2 system. Its actual size is a few acres less because there are houses and a revetment within the boundaries shown on the inventory map. Two habitat types are present: a cottonwood/alder swamp, and patches of shrubs, mostly salmonberry, snowberry, vine maple, and Japanese knotweed. The more disturbed parts of the wetland, including the area along the revetment, are being invaded by blackberries and English ivy. Lower Taylor Creek flows north through the wetland, joining the mainstem at RM 13.1. The lower end of the creek appears to have been artificially enlarged by partial impoundment and excavation behind homes on 198th Place SE. As a result, the right bank has almost no buffer. The south end of the wetland contains a small side channel that flows into Taylor Creek at RM 0.3. A pair of coho and several sockeye were observed spawning near the north end of the channel during a field visit in early December. Both lower Taylor Creek and the side channel also provide good over-wintering habitat for juvenile fish.

Other impacts include runoff from Maxwell Road and several overgrazed pastures, use of the area by off-road vehicles, and several sheds within the wetland. Several thousand square feet of the wetland and buffer were recently cleared and graded.

Future Conditions: Current conditions are likely to persist, or worsen with continued encroachment.

Wetland 118

Current Conditions: The inventory describes Wetland 118 as a 5.3-acre Class 2 forested system that spans the river near RM 14.3. Field inspection of the right bank riparian zone revealed extensive clearing and grading since the 1990 inventory. Nevertheless, judging by the remaining grove of fir and big leaf maple, classification of this area as a wetland seems doubtful except immediately adjacent to the river, which is densely vegetated by Japanese knotweed and lesser amounts of alder and cedar. Local residents report that during the November 1990 storm, floodwaters swept through this area, flooding several homes. Much of the left bank area shown in the inventory as wetland is actually a steep slope blanketed by upland forest. There is, however, a small, flat wet area at the base of a bench south of this slope. The principal functions of the bona fide wetlands at this location are wildlife habitat, water quality protection, and flood attenuation.

Future Conditions: Future conditions could deteriorate if clearing continues along the right bank.

Middle Cedar River Mainstem—Map 25

Above Maple Valley the Cedar River is more rural and the valley more confined. Three significant habitats (RM 20.4, 19.4, 17.8) are isolated from the river by the abandoned Burlington Northern Railroad grade and would require construction of access to make them productive for salmon. Several outstanding habitats in this reach include wetland 69 (RM 20.4), which is a springfed oxbow lake located about one mile below Landsburg; the percolation side channel at RM 15.6; and the wall-based tributary at RM 14.8. There does not appear to be the same opportunity for large scale development of completely new fish habitat as exists in the lower subbasin, perhaps due to the confined nature of the valley and because historic habitats have not been as radically modified or lost due to floodplain development.

Middle Mainstem Wetlands

Wetland 83

Current Conditions: Wetland 83 is a 14-acre Class 1 bog along the Middle Cedar River Mainstem approximately one half mile south of RM 21.8 near Landsburg. In the center of the bog is a 2-acre pond surrounded by a dense mat of Sphagnum, Labrador tea, and hemlock. A rare insectivorous species, sundew, is also present. The wetland's remaining forested margins contain snags and fallen logs. Abundant deer sign, a Great Blue Heron, and several other song bird species.

Past impacts include clearing resulting in the invasion of undesirable species (blackberry and Scot's broom). Additional clearing, grading, and filling has occurred in the same area within the past year. Recent buffer clearing and slash deposition has also occurred.

Future Conditions: Ongoing buffer removal to maintain the adjacent power line corridor and pasture will likely continue. Additional encroachment as a result of residential development east of the wetland is also possible. Carelessly routed runoff from nearby single-family residential lots could convey sediment and excess nutrients into the bog, thereby harming its water chemistry and biota. The wetland is one half mile northwest of a proposed "shooting park" (see Wetland 82), which, if developed, could decrease wildlife utilization of the wetland and associated habitats. With maturation of nearby clearcuts and conversion of currently forested land to low-density, single-family residential development, moderate change is predicted in modelled nonpoint pollutants except for total phosphorus, which is expected to increase by 63% (see *Chapter 6: Water Qualtiy*).

Wetlands 69 and 70

Current Conditions: Wetlands 69 and 70 are two of the most interesting and least degraded wetlands in the basin. Both of these rather small (5.5 and 2.5 acres, respectively) Class 2 systems have formed on the valley floor in old river meanders near RM 20.0. Crescent-shaped Wetland 69 contains forested and open water habitats. It receives most of its flows from spring seeps that sheet flow down the walls of a short but deeply incised ravine near the center of the wetland. Additional water comes from seasonal changes in the water table and backwatering from the river, which connects with the wetland through a culvert under the Cedar River trail. Both the wetland and the surrounding upland forest contain many snags and fallen logs, and dense shrubs overhang much of the open water area. The 1981 inventory noted beaver sign and a river otter haulout area. Beaver sign and several bird species, including waterfowl, were observed during two winter field visits. Because of its extensive open water, this wetland probably serves as over-wintering habitat for juvenile salmonids.

Wetland 70 resembles Wetland 69 in some respects, but it is farther from the main channel, more overgrown with understory vegetation, and lacks open water. Its receives seepage from the valley wall, and its hydrology is strongly influenced by shallow groundwater and occasional floods. It might be possible to modify this wetland to provide over-wintering habitat for juvenile fish.

Future Conditions: The south end of Wetland 69 is relatively protected from encroachment because of its location at the base of a nearly vertical slope. The north end of Wetland 69 and all of Wetland 70 will lose all but 50 feet of their existing broad forested buffers when this part of the BPA becomes fully developed. As shown throughout the basin, this may not be enough to prevent these wetlands from increased human and pet intrusion, trash dumping, and nonpoint pollution.

SIGNIFICANT RESOURCE AREAS (SRAs)

Areas identified as RSRAs and LSRAs in the Cedar River Basin below the Landsburg Diversion Dam, based on criteria outlined in section 8.5 of this chapter, are listed below. Cedar River mainstem habitat from the mouth to the Landsburg Dam (RM 0.0 to RM 21.7) contributes to the River's status as a fishery resource of regional significance. However, it is withheld from this list pending a designation by the WMC that reflects both its productivity and highly managed state.

Tributary Reaches

RSRA

Rock Creek(Tributary 0338): RM 0.0 to 2.5
Peterson Creek (Tributary 0328): RM 0.0 to 2.6 (part of RSRA Wetlands 28, 42)
Peterson Creek Tributary 0328B: RM 0.0 to 2.2 (part of RSRA Wetlands 14, 15, 28)
Taylor Creek Tributary 0321: RM 0.2 to 0.8

LSRA

Maplewood Creek (Tributary 0302): RM 0.5 to 1.1
Maplewood Creek Tributary 0303: 0.0 to 0.2
Molasses Creek (Tributary 0304): 0.2 to 0.8
Madsen Creek (Tributary 0305): 0.8 to 2.15
Madsen Creek Tributary 0306: 0.0 to 0.25
Tributary 0316: 0.0 to 0.3 (part of LSRA Wetland 105)
Tributary 0316A: 0.0 to 0.45
Taylor Creek (Tributary 0320): RM 1.2 to 3.2 (Note: Taylor Creek below Maxwell Road RM 0.4 is part of Cedar River RSRA Wetland 132)
Taylor Creek Tributary 0326: RM 0.0 to 0.7
Walsh Lake Diversion Ditch (Tributary 0441): 0.0 to 4.0

Valley-Floor Stream Habitats

RSRA

[2]RB Percolation Side Channel at RM 4.7 to 4.8
LB Percolation Side Channel at RM 4.6 to 4.8
LB Percolation Side Channel at RM 7.5 (part of RSRA Wetland 103)
RB Percolation Side Channel at RM 9.5
RB Percolation Side Channel at RM 10.1
LB Wall-base Tributary (McDaniel's Side Channel) at RM 11.5
RB percolation Side Channel at 13.4 (adjacent to RSRA Wetland 132)
LB Wall-base Tributary at RM 14.9
LB Percolation Side Channel at RM 15.9
LB High-flow Side Channel at RM 17.2 to 17.4
LB Percolation Side Channel at RM 17.7
LB Side Channel at RM 19.0
LB Percolation Side Channel at RM 19.7
RB Percolation Side Channel at RM 20.0 (adjacent to RSRA Wetland 70)

[2]All right and left bank designations are made assuming the observer is facing downstream.

LSRA

RB Wall-base Tributary at RM 12.5
RB Side Channel at RM 15.7 to 15.9
LB Wall-base Tributary at RM 16.2
LB Wall-base Tributary at RM 18.3

Wetlands

***Class 1 Wetlands*:** Consistent with past basin plans, many of the Class 1 rated (i.e., "unique and outstanding") wetlands, including all bogs and fens, are categorized as RSRAs. The rest of the Class 1 wetland systems are categorized as LSRAs due to past land-use impacts.

In accordance with the SRA criteria, fourteen of the basin's fifteen Class 1 wetlands are designated as SRAs. Wetland 25, a Class 1 system in the upper headwaters of Madsen Creek, has been subjected to complete buffer removal and partial filling. It also serves as an R/D facility. As a result of these alterations, it no longer meets the SRA criteria.

Class 2 Wetlands: A number of Class 2 wetlands are within stream corridor SRAs. As such, they are assigned the same SRA designations as the adjoining streams. Their protection is critical in maintaining fish and wildlife habitat, water quality, and stormflow attenuation in these systems.

RSRA

Cedar River Mainstem: Wetlands 69, 70, 132, 37, 103, and *6
Peterson Creek Subbasin: Wetlands *14[B], *15[F] (and Lake Desire), *28[F] (encompasses Spring Lake), and 42 (encompasses Peterson Lake)
Madsen Creek Subbasin: Wetland 16[B]*
Webster Lake Subbasin: Wetland *33[B] (encompasses Webster Lake)
Taylor Creek Subbasin: Wetland 132 (also adjoins Cedar River mainstem)
Walsh Lake Subbasin: Walsh Lake
Middle Cedar River Subbasins: Walsh Lake and surrounding uninventoried wetlands, and Wetland *83[B]

LSRA

Cedar River Mainstem: Wetlands 118 and 105
Molasses Creek Subbasin: Wetlands *22, *23, 2
Cedar Grove Subbasin: Wetland *13
Webster Lake Subbasin: Wetland *36 (encompasses Francis Lake)
Walsh Lake Subbasin: Wetland *64
Taylor Creek Subbasin: Wetland 58
Rock Creek Subbasin: Wetland *82 (Hidden Lake); Wetlands 91 (encompasses Lake No. 12), 92[F], 93, and 94
Middle Cedar River Subbasin: Wetland *77

* = Class 1 wetland
[B] = Bog
[F] = Fen

7.9 KEY FINDINGS

MAINSTEM RIVER AND TRIBUTARIES

★ Landscape-level changes in the past century have significantly altered the quantity, quality, and stability of many fish habitats in the Cedar River Basin.

★ The surface area of fish habitat in the Cedar River mainstem has been directly reduced by approximately 56% due to water diversion and flood control activities in the past century.

★ All anadromous salmonids have declined to record low levels in the past three years. Sockeye salmon and steelhead trout in the Cedar River may be in a significant decline, and coho will be threatened by future development.

★ Most of the existing mainstem habitat has been hydraulically smoothed and confined, and is disconnected from historic floodplains by extensive revetments resulting in low structural complexity of habitat and a reduction in supply and stability of spawning gravels.

★ Existing mainstem habitat has an average of 2.8 large pools per mile, which is 70% fewer pools than would be expected under unmanaged conditions. Much of the mainstem riparian area is not forested. Where forests do exist, many are highly immature and lacking mature conifer trees. Significant accumulations of large woody debris (LWD) in the river channel are almost completely missing.

★ An extensive network of at least 68 individual habitats, including side channels, riparian wetlands, and wall-based tributaries, are currently distributed throughout the valley floor of the Cedar River. Some of these habitats exist in outstanding condition and are well utilized by fish. Many others are inaccessible to anadromous fish or are impaired by poor instream and riparian conditions and local land use.

★ Three major fish bearing tributaries, Madsen, Molasses, and Maplewood creeks, have been severely affected by urbanization. The upper reaches of these tributaries are highly fragmented by road and drainage networks in housing developments. Habitats in mid-reach ravine areas have been reduced in quality or destabilized due to urban runoff, high sediment loads, and low buffering capacity caused by low levels of LWD and immature riparian systems.

- ★ Madsen Creek habitats have also been, and will continue to be, degraded by the installation and maintenance of sewer and gas utility lines placed through the ravine area and by a sediment pond at the mouth of the ravine. These facilities have led to extensive stream channel and slope stabilization efforts that are contrary to the natural restoration processes and will continue to perpetuate poorer habitat conditions.

- ★ Fish habitats in Tributaries 0316 and 0316A are impacted by reductions in water quality and quantity due to gravel mining, composting, and landfill activities in their headwaters. Local landowner activities have also contributed to riparian and instream habitat problems.

- ★ Much of the mainstem of Taylor Creek is suffering early signs of habitat degradation due to immature riparian areas and low LWD levels.

- ★ Taylor Creek mainstem habitat along Maxwell Road (RM 0.4-1.2) is degraded by road maintenance activities conducted to reduce local flooding effects.

- ★ Peterson Creek, which exhibits generally good to excellent habitat conditions, has been degraded in the area of Peterson Lake by past channel maintenance activities.

- ★ Rock Creek, which exhibits some of the best structural habitat conditions in King County, is severely limited in its fish production capabilities by water withdrawals that remove approximately 75% of summer low flows. At times, this renders much of the channel inaccessible or unsuitable for chinook and sockeye salmon spawning and reduces rearing space for juvenile coho salmon and steelhead and cutthroat trout.

- ★ The Walsh Lake Diversion Ditch (RM 0.0-4.2), constructed by the SWD in the 1920s, represents new, and where unconfined and unmanaged, good habitat. It suffers from fish access difficulty at the mouth due to highly porous soils that create intermittent flow conditions.

WETLANDS

- ★ The Cedar River Basin has an unusually high diversity of wetland resources, including the Spring Lake Wetland, one of the largest fens in western King County. Most of the planning area's Class 1 and large Class 2 wetlands are complex mosaics of several habitat types. The functions carried out by these wetlands—including flood storage, peak flow attenuation, streamflow maintenance, and water quality protection—are vital in the long-term protection of the basin's fish and wildlife habitat.

- ★ Dozens of uninventoried wetlands exist in the BPA. Because of lack of awareness of their presence on the part of land owners and regulatory agencies, these systems are particularly vulnerable to damage and wholesale destruction as a result of permitted and unpermitted land-use activities.

- ★ A high proportion of the wetlands identified in the King County Wetlands Inventory have undergone some degree of buffer removal, clearing, drainage, or filling since the inventory was first conducted in 1983. In addition, several wetlands have undergone extreme hydrologic modification. For example, two of the basin's fifteen Class 1 wetlands have been converted to stormwater R/D facilities. In the urbanized areas of the basin, many wetlands have been partially or completely disconnected from previously interconnected aquatic and upland habitats.

- ★ Although direct protection of wetlands and their buffers is essential, the BPA's wetlands cannot be ensured by simply focussing on wetland areas. As development continues, efforts must be made to preserve adjacent upland habitat corridors and wetland hydrologic source areas, which often extend far beyond standard sized buffers.

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Aquatic Habitat Appendix

Table 1 Large Pool Habitats in the Cedar River Mainstem Channel.

	POOL TYPES						
River Mile	LSP	MCP	CCP	CRP	BWP	MAT	TOTAL
0.0- 1.0	0	0	0	0	0	0	0
1.0- 2.0	0	0	0	0	0	0	0
2.0- 3.0	3	0	0	1	0	0	4
3.0- 4.0	0	0	0	0	0	0	0
4.0- 5.0	0	0	1	0	0	0	1
5.0- 6.0	1	0	0	0	0	0	1
6.0- 7.0	1	1	0	0	1	0	3
7.0- 8.0	4	1	0	0	0	0	5
8.0- 9.0	0	1	0	0	0	0	1
9.0- 10.0	0	0	1	1	0	0	2
10.0- 11.0	1	0	1	0	0	1	3
11.0- 12.0	4	1	0	0	0	0	5
12.0- 13.0	2	0	0	1	2	0	5
13.0- 14.0	0	0	0	2	0	1	3
14.0- 15.0	1	1	0	0	0	0	2
15.0- 16.0	1	0	1	1	1	0	4
16.0- 17.0	0	0	1	1	1	0	3
17.0- 18.0	0	0	2	2	0	1	5
18.0- 19.0	2	0	0	4	0	0	6
19.0- 20.0	1	0	0	2	0	0	3
20.0- 21.0	1	1	0	0	0	0	2
21.0- 22.0	0	1	0	0	0	0	1

LSP Lateral Scour Pool
MCP Mid- channel Pool
CCP Channel Confluence Pool
CRP Corner Pool
BWP Backwater Pool
MAT Matrix Habitat with Complex Pool Habitats

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Public Agencies and Private Actions

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City of Seattle Watershed Management Plan
City of Seattle Water Department Water Supply Plan
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Chapter 8: Public Agency Response and Private Actions

8.1 INTRODUCTION

This Conditions Report raises many vital natural resource management problems affecting the Cedar River Basin Planning Area (BPA). The range of issues addressed includes flood damage to homes, habitat deterioration, and water quality degradation. The presence of these problems is the culmination of many years of development activity and life style impacts that are not compatible with the sensitivities of this system. In response, there are a number of local, state, federal, and tribal agencies, as well as tribal and community programs attempting to remedy these conditions and prevent further decline of the basin's valuable natural resources. These entities include the King Conservation District; the Muckleshoot Indian Tribe; US Soil Conservation Service; the Washington State Departments of Ecology, Fisheries, Wildlife, and Natural Resources; King County Cooperative Extension Service; US Environmental Protection Agency; county and city governments; citizen groups; and numerous other agencies and individuals.

Despite some gains made through these efforts, overall conditions in the Cedar River Basin have continued to deteriorate. From the standpoint of the responsible agencies and groups, there are several tools needed to reverse this decline. First, resource agencies have lacked a common interdisciplinary reference that documents conditions in the basin in sufficient detail to fully understand all its resource issues and their affects on each other. Second, there has not been a process available where the public and agency staff can jointly develop a single set of solutions. The Cedar River Basin/Action Plan provide both of these elements. The interdisciplinary information needed on basin conditions is provided in this Conditions Report, which all affected agencies have agreed is a factual basis for making resource management decisions for the BPA. In addition, the plan process enables all concerned and affected entities to share in developing a common blueprint of actions to redirect basinwide efforts toward more positive ends.

This chapter discusses the general affects of development activity on surface water conditions in the BPA, the problems that hamper the effectiveness of public agencies to remedy the conditions, and the agency activities underway that can be coordinated with the Basin/Action Plan to improve their response.

8.2 PRIVATE SECTOR ACTIONS

DEVELOPMENT ACTIVITY

Development activity, involving substantial clearing of vegetation and grading of soils, has significantly affected surface water conditions in the BPA. Site clearing and grading can allow large volumes of eroded soil to be washed into nearby streams in storm events if erosion and sedimentation measures or other Best Management Practices (BMPs) are not properly installed or maintained. As discussed in *Chapter 4: Flooding* and *Chapter 7: Aquatic Habitat*, eroded soil adds to the sediment from channel erosion, which increases the potential for flood damage and degrades fish habitat.

A recent study to assess the effectiveness of erosion-control BMPs on construction sites throughout King County was conducted by the King Conservation District (Tiffany and others, 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% having ineffective control included inadequate installation, poor timing of installation with respect to weather conditions, and insufficient maintenance.

Between 1980 and 1990, King County issued thousands of residential construction permits in the basin (King County Planning Division, 1991). On the basis of the King Conservation District findings, it can be concluded that the vast majority of these sites have contributed to the affects of accelerated erosion and sedimentation discussed in this report.

It is recognized that much of this problem may stem from insufficient knowledge on the part of developers and construction workers in the use of BMPs. In many instances, however, this information has been available but has not been implemented in practice due to inadequate enforcement staff, insufficient attention to land development permit conditions, or both.

LIFESTYLE IMPACTS

In addition to development-related activities, current conditions in the basin can be traced to smaller scale daily activities of the over 50,000 residents in the BPA. These actions can include filling of wetlands, rerouting of stream channels, removal of the habitat forming large woody debris from stream channels, removal of riparian vegetation, heavy reliance on automobiles, excessive use of fertilizers and pesticides, poor animal-keeping practices, and improper handling of toxic compounds or other contaminants. Although these activities may be inadvertent or even well-intentioned, their collective affects have significantly impacted the water quality and other habitat conditions of streams, lakes, and wetlands in the BPA.

8.3 ROLE OF PUBLIC AGENCIES

LOCAL GOVERNMENTS

Local surface water management programs are generally the first to respond to water resource problems. In the BPA there are four local governments that manage aquatic resources in the BPA. They include the City of Renton at the mouth of the Cedar River on Lake Washington, unincorporated King County, the City of Seattle, which operates a water supply and hydroelectric facility in the Upper Cedar River above Landsburg, and the City of Kent, which has a water intake on Rock Creek. Only Renton and King County, however, have the jurisdiction to regulate development in the BPA.

Both King County and Renton have surface water management programs that respond to existing drainage problems by evaluating conditions in the system and developing management options. These can include capital intensive projects such as stormwater detention ponds or water quality control facilities. Less intensive approaches can include land-use controls, public education, incentives to encourage improved stewardship, and development regulations. The effectiveness of existing and new regulations, however, depends on whether there is adequate funding for thorough permit review, development inspection, and code enforcement.

In King County, three primary means are used to prevent the harmful surface water affects of development: The 1990 King County Surface Water Design Manual, which has specific standards for managing the quality and quantity of stormwater runoff; the 1990 Sensitive Areas Ordinance, which protects stream, wetlands, steep slopes, and other sensitive natural resource areas; and the 1992 Water Quality Ordinance, which requires controls on existing new pollution sources such as degraded stormwater discharges, hazardous wastes, and failing septic systems.

The City of Renton Stormwater Management Utility has adopted the King County Surface Water Design Manual to regulate drainage discharges. In 1991, Renton approved new wetland regulations, adding to its other sensitive area requirements that protect streams and steep slopes. The City also has newly adopted regulations to safeguard the water supply in its sole source aquifer.

While King County and Renton strive to reduce flood damage and protect surface water resources, their approaches must be closely coordinated, especially where jurisdictions overlap, such as on Maplewood Creek. A principal function of the Basin/Action Plan is to cooperatively evaluate existing drainage standards and programs for their ability to reduce flood damage described in *Chapter 4: Flooding* and protect the Significant Resource Areas and the other natural resources discussed in *Chapter 7: Aquatic Habitat,* to ensure that sufficient protection is in place.

STATE, FEDERAL, AND TRIBAL AGENCIES

Table 8-1 identifies the many state, federal, and tribal agencies that make decisions about natural resources in the BPA. Most of these agencies have a role in protecting natural resources from the effects of development by granting permits according to agency policies and regulations, enforcing those regulations, and conducting programs to manage land and water resources. For example, the State Department of Ecology (DOE) and the US Environmental Protection Agency regulate water quality, while the US Corps of Engineers (COE) is responsible for regulating many of the development activities in streams and wetlands.

Several major problems, however, hamper the ability of these agencies to provide adequate oversight, which can lead to inconsistencies in resource management especially when agencies operate with divergent or conflicting missions. For example, some state and local agencies are mandated to provide road and utility services. Frequently, the most direct construction route for these facilities also crosses wetlands or streams where construction and maintenance activities can damage these resources that other agencies are mandated to protect. In other cases, agencies may not have sufficiently broad authority to protect resources. The Washington Department of Fisheries, for example, can only permit activities that occur directly in stream channels, although substantial damage to stream habitat results from the secondary affects of upland development. Other problems that limit public agency effectiveness in correcting and preventing resource damage can be caused by insufficient knowledge of the resources or the technical knowledge to mitigate for development impacts. Most often, however, resource management agencies are limited by insufficient staff and funding to keep pace with rapidly expanding development pressures. Finally, all agencies as well as the private sector are impeded by the lack of a consistent and unified direction for comprehensively managing the basin resources. A primary role of the Cedar River Basin/Action Plan is to establish this direction and the priority needs of the system.

Table 8-1 Government Agency Roles in Managing Resources of the Cedar River Basin

	Local Governments
City of Renton and King County	Administer within their jurisdictions development regulations for grading, drainage, and construction within and beyond shoreline areas; prepare and administer comprehensive plans and zoning regulations; prepare public works plans for stormwater, solid waste, and transportation; develop and implement plans to protect groundwater supplies.
City of Kent	Obtains a portion of its drinking water supply from Rock Creek.
City of Seattle	The Seattle Water Department operates a regional water supply and hydroelectric facility in the Upper Cedar River Basin above Landsburg.
	Regional Agencies
Metro	Monitors stream water quality in the planning area; monitors water quality in Lake Desire and Spring Lake; manages sanitary sewer facilities in the Cedar River Basin; prepares areawide plans for water quality priorities.
Seattle King County Health Department	Administers septic system regulations for small to medium scale development; administers pesticide regulations.
	Indian Tribes
Muckelshoot Indian Tribe	Co-manages all animal resource in the basin with state resource management agencies. The Cedar River and Lake Washington are also part of the Tribe's Usual and Accustomed fishing grounds.
	State Agencies
Department of Agriculture	Regulates the use, transportation, and disposal of pesticides.
Department of Ecology (WSDOE)	Administers state water quality regulations (including National Pollutant Discharge Elimination System permits for point sources), dam safety regulations, and the toxic clean-up program at Landsburg Mine and Mt. Olivet Landfill closing; provides technical assistance and oversight to local governments that administer the State Shoreline Management Act; reviews and comments on actions affecting wetlands; provides technical assistance to local governments in managing wetlands, nonpoint source pollution, and stormwater; approves nonpoint source action plans and local groundwater management plans.
Department of Health	Administers drinking water standards and septic system permit requirements for large developments.
Department of Fisheries	Administers regulations for activities within the ordinary high water mark of streams and lakes; manages and monitors salmon and smelt resources in the Cedar River and Lake Washington.
Department of Natural Resources	Owns and regulates activities in the aquatic lands of the Cedar River and Lake Washington; administers commercial forest practices regulations.

Table 8-1 (cont)

Department of Wildlife	Manages gamefish resources and wildlife in the watershed, including administering regulations to protect threatened and endangered wildlife species.
King Conservation District	Provides 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.
Department of Transportation	Constructs and maintains state highways, including I-405, SR-18, and SR-169.
	Federal Agencies
Federal Emergency Management Administration (FEMA)	Provides technical assistance on flood prevention and management to local governments; determines requirements for participation in the federal flood insurance program; administers flood insurance funds.
US Army Corps of Engineers	Administers regulations for activities in navigable waters, including the Cedar River and Lake Washington; administers regulations for projects involving placement of dredged or fill material in waters of the United States, including wetlands; provides assistance through a variety of authorities to local governments and agencies in addressing various water resource problems, including floodplain management.
US Environmental Protection Agency	Develops, and jointly enforces, federal wetlands regulations administered with the US Army Corps of Engineers; funds and manages Queen City Farms Superfund Clean-up; regulates federal pesticide laws.
US 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 the Cedar River and Lake Washington.
US Soil Conservation Service	Provides technical service and financial assistance to commercial agriculture operators for preventing and correcting soil erosion problems.
	Special Purpose Districts
Cedar River and Soos Creek Sewer & Water Districts	Provide sewer and water service to their service areas and monitor the quantity of their water supplies.
District 9 Sewer and Water District	Provides water service to its service area and monitors the quality of its water supply.

8.4 INTERAGENCY COORDINATION

It is essential to ensure that the preventive and corrective actions by all entities in the basin are well-integrated and coordinated to improve on historic approaches to surface water management. In addition to the Cedar River Basin/Action Plan, there are several major planning and action-oriented efforts now under way in the basin. Cooperatively implementing each of these planning efforts can provide important steps toward establishing a new level of integrated resource management among entities, the general public, and the private sector.

KING COUNTY GROWTH MANAGEMENT PLANNING POLICIES

In June 1992, the King County Council adopted policies to manage growth countywide. In accordance with the state Growth Management Act, the County approved an Urban Growth Area (UGA) boundary, defining the area in which urban growth would be allowed in the Cedar River Basin during the next thirty years and where urban level services, such as sewer and water, will be provided (Map 3, *Appendix B*). Those areas outside of this line are designated Rural and will be assigned commensurate low-density zoning. After thirty years, the UGA could be extended into the Rural designated areas to accommodate future growth. Local concurrence is required to permanently establish the UGA. As of this writing the Cedar Basin UGA is being considered by the Renton City Council for adoption.

The effects of the Urban/Rural designations on surface water are expected to be twofold. First, the increase in density within the UGA can greatly increase stormwater runoff and nonpoint pollution without appropriate mitigation. Conversely, it will delay somewhat the full affects of stormwater that would otherwise occur from intensive development of Rural designated areas. Second, the Growth Management Act mandates more cooperation between cities and the County, particularly in the UGA, to coordinate land use and surface water management plans and to provide services more efficiently.

KING COUNTY COMMUNITY PLAN UPDATES AND AREA ZONING

There are three Community Planning areas in the BPA. These include Newcastle, which covers a small portion of the BPA north of Renton; Soos Creek, covering a swath between the Cedar River valley and the south plateau, including Lake Desire and Shady Lake and extending outside the BPA to Lake Youngs; and Tahoma-Raven Heights, which crosses the plateaus north and south of the Cedar River and river valley in the eastern end of the BPA, including the Francis Lake, Maple Valley, and Wilderness Lake areas.

The Soos Community Plan was updated in 1991, with the exception of the area at 140th SE and Maple Valley Highway, which is currently being considered for a plan amendment. Community plan updates for Newcastle and Tahoma-Raven Heights are anticipated in 1994 or beyond. These updates will determine the future land use in these communities. The resources problems documented in this Conditions Report and possible land-use recommendations in the Basin/Action Plan will be incorporated into these planning processes.

KING COUNTY OPEN SPACE PROGRAM PLAN

The King County Parks Department is currently updating its 1988 Open Space Plan to identify new needs for public open space areas to keep pace with population growth. It is desirable to identify areas with significant natural resource features as acquisition candidates for this update. The Basin/Action Plan will be coordinated with the development of the Open Space Plan update to recommend appropriate open space and recreation areas.

KING COUNTY FLOOD HAZARD REDUCTION PLAN (FHRP)

In 1987 the King County Flood Hazard Reduction Plan (FHRP) was initiated to document the causes and impacts of flooding along the mainstems of the major river systems in King County: the Snohomish, Snoqualmie, Cedar, Green-Duwamish, and Sammamish (King County, 1990). In 1991 the recommended solutions to these problems were published in Draft FHRP. For the Cedar River Basin, the FHRP recommends a variety of flood management approaches to be evaluated in more detail in the Cedar River Basin/Action Plan. In general these strategies encourage management of the mainstem channel so as to recapture use of its floodplain for flood flow storage where possible. These recommendations would be accomplished by breaching, removing, or setting back levees and, in some cases, purchasing or floodproofing vulnerable structures. More specific recommendations for such projects will be made in the Basin/Action Plan.

CITY OF RENTON COMPREHENSIVE PLAN

The City of Renton is updating its comprehensive plan commensurate with the requirements of the state Growth Management Act. The Lane Use Element of the plan, and the proposed zoning to implement the plan, encourage intensive development in Renton's downtown area and industrial development in the Green River valley and North

Renton. Other commercial areas serving the neighborhoods are slated for increasing densities of both commercial and multi-family developments. Single family neighborhoods would have an overall density of 8-10 dwelling units per acre. Multi-family developments would occur in identified multi-family districts. Low density residential areas are slated for environmentally sensitive areas and urban separators. As of this writing, the plan is being considered for adoption by the City Council. The City also has a number of ordinances to protect its streams, wetlands, and steep slope sensitive areas. Due to the surface water problems in and around Maplewood Creek Subbasin, along the Cedar River, and in other areas within Renton's urban growth area in unincorporated King County, cooperative approaches to capital improvements and to changes in development codes in King County and the City of Renton are anticipated through the Basin/Action Plan.

CITY OF RENTON DREDGE PROJECTS

The continued accumulation of sediment at the mouth of the Cedar River enables birds to perch on the delta, which poses a hazard to airplanes entering and leaving the Renton Municipal Airport. In addition, sediment deposits in the lowest mile of the channel have contributed to flooding in this reach. Renton is currently seeking permits to dredge the delta and for maintenance dredging between the delta and the I-405 crossing. The result of the sediment transport study in this Conditions Report (*Chapter 5: Erosion and Deposition*) will be used to make short-term and long-term decisions regarding maintenance dredging in these areas.

CITY OF RENTON GROUNDWATER MANAGEMENT PLAN

The City of Renton Groundwater Management Plan is a cooperative effort between Renton and King County to evaluate the quality and quantity of groundwater in Renton's sole source aquifer located in the Cedar River valley, just east of the City of Renton. The Basin/Action Plan will identify the policies and programs needed to supplement Renton's current approaches to manage groundwater supplies and to protect their quality in the future.

CITY OF SEATTLE WATERSHED MANAGEMENT PLAN

The Upper Cedar River Basin represents approximately two-thirds of the total land mass in the Cedar River Basin (Map 1, *Appendix B*). Resource management practices in this area can have a significant effect on the quality and quantity of water in the lower reaches. In 1989 the City of Seattle adopted comprehensive resource management policies for this area. These policies stress protection of the water resource from this part of the basin for supplying high quality drinking water and hydropower to the Seattle metropolitan area (Seattle Water Department, 1990). The policies also guide the SWD toward a comprehensive strategy to manage its abundant forest and wildlife resources in a manner that both compliments and coordinates with the Basin/Action Plan. Since these two planning processes are being conducted in different time frames, it was determined that while the SWD management plan would continue to be coordinated with Basin/Action Plan process, the Upper Basin would not be included in the BPA.

CITY OF SEATTLE WATER DEPARTMENT WATER SUPPLY PLAN

The Seattle Water Department (SWD) Water Supply Plan is a regional strategy to provide a safe and dependable water supply for the growing SWD service area in the future. The Chester Morse Dam and Landsburg water supply complex in the Upper Cedar River Basin, upstream of Landsburg, are primary resources that will be used in implementing this plan. Due to the potential of the Water Supply Plan to affect low flows in the BPA downstream, this plan will be coordinated with the Basin/Action Plan.

WASHINGTON STATE DEPARTMENT OF FISHERIES (WDF) - SOCKEYE SPAWNING CHANNEL

WDF, in cooperation with the Muckleshoot Indian Tribe, the SWD, and other affected entities, is studying the potential of constructing a spawning channel to enhance the declining sockeye run in the Cedar River Basin. The Spawning Channel project was initiated in response to the loss of fish habitat above Landsburg that occurred when the SWD constructed the Landsburg Dam in the early 1900s. Since the Basin/Action Plan is also addressing aquatic habitat issues in the Cedar River, the Spawning Channel project is being coordinated with the plan process.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (DOT) - SR-18 AND SR-169 IMPROVEMENTS

DOT is upgrading portions of SR-169 (Maple Valley Highway) between Renton and Upper Jones Road (196th Avenue SE). SR-169 crosses the mainstem once and at several tributaries, including Maplewood and Madsen creeks. SR-18 traverses the eastern portion of the basin at Maple Valley and crosses several tributaries of Taylor Creek north of Maple Valley. The portion of SR-18 within the Cedar River Basin is proposed to be widened from two to four lanes. These projects will be coordinated with the Basin/Action Plan to ensure that quality and quantity controls are consistent.

US ARMY CORPS OF ENGINEERS (COE) DROUGHT PREPAREDNESS STUDY

The COE is currently studying the potential affects of drought in the Cedar and Green River basins as part of a national drought management study. The purpose of the study is to identify better ways to manage water supply conflicts under drought conditions in these systems. This study has direct implications for the Cedar River Basin/Action Plan due to the affects of low-flow conditions on reducing available aquatic habitat. When completed, in the Fall of 1993, the study will aid in determining how to minimize the effects of water shortages on habitat in the Cedar River.

8.5 KEY FINDINGS

★ Surface water degradation in the Cedar River Basin results primarily from development activities such as clearing of vegetation and grading. These actions accelerate stormwater runoff, erosion, and instream sedimentation that increases flood damage and deteriorate aquatic habitat. Secondarily, the life style preferences of residents contribute to this decline due to the resource damage that can be caused by excessive use of fertilizers, poor animal keeping practices, and frequent motor vehicle use.

★ Numerous local, state, and federal regulations and programs are in place to address surface water problems in the basin; however, insufficient staff and funding, lack of regulatory authority in some cases, and the rapid pace of development hamper their effectiveness.

★ The Basin/Action Plan process can improve coordination among public agencies with responsibilities in the basin by providing comprehensive technical information needed, by defining priority problems and solutions, and by enabling these agencies to use limited funds most efficiently.

PUBLIC AGENCY RESPONSE AND PRIVATE ACTIONS REFERENCES

King County Planning Division, 1991, 1989 annual growth report; King County, Washington

King County, 1990, Draft King County flood hazard reduction plan; King County, Washington

Seattle Water Department,1990, The Seattle Water Department water supply plan and draft environmental impact statement; Seattle, Washington

Tiffany, C., G. Minton; R. F. Thomas, 1990, Erosion and sedimentation control: an evaluation of implementation BMPs on construction sites in King County, Washington, January 1988 - April 1989; King County, Washington

Appendix A

Observed Conditions Summary

Appendix A

Cedar River Basin Observed Conditions Summary

RENTON REACH (RM 0.0 TO RM 1.6)			
River Mile	River Bank	Subject	Description
0.0-1.6		SED **	Current: Sediment deposited in the channel raises the river bed, which reduces channel capacity and causes more frequent flooding. The channel was last dredged prior to 1982. Future: Sediment will continue to deposit in the channel due to its low gradient.
0.0-1.6		HABITAT	Current: Habitat degraded by fine sediment deposition, poorly developed riparian area, and low habitat complexity. Future: As sediment accumulates, spawning habitat quality will be reduced.
0.0-1.6		FLOOD **	Operations at Renton Municipal Airport are impacted by the 5-year flood. During the November 1990 flood, the basements of City Hall and the Carco Theater received minor damage, and the Municipal Airport was prevented from operating. This problem will probably get worse as the channel continues to receive sediment.
0.1		WATER QUALITY *	Boeing Outfall; Sampling site CR1, S1: Stormwater: Cu, Pb & Zn exceeded acute and chronic toxic levels. FC levels of 380-1800 org/100 ml. Sediment: Detected several semivolatiles.
1.0		WATER QUALITY *	Renton Airport Outfall; Sampling site S3: Sediment: Detected several semivolatiles.
1.1		WATER QUALITY **	Logan Avenue Bridge; Sampling site CR2, S4: Stormwater: Cu, Pb & Zn exceeded acute and chronic toxic levels. FC levels of 2500 org/100 ml. TP exceeded recommended levels. Sediment: Levels of TP, FOG & %volatiles are in the "Heavily Polluted" range; Cu levels are 36 times, Pb levels are 176 times & Zn levels are 18 times the DOE guidelines for "Heavily Polluted."
1.5		WATER QUALITY	Bronson Way Bridge; Sampling site CR3, O438: Stormwater: FC levels of 60-1840 org/100 ml. All other below standards or recommended levels.
1.6		WATER QUALITY **	I-405 Outfall (& Renton urban areas); Sampling site CR4, S5: Stormwater: TSS, Turb & TP exceed recommended levels. Cu, Pb & Zn exceed acute and chronic toxic levels. FC levels of 1400-4600 org/100 ml. Sediments: Cu, Pb & Zn in "Moderately Polluted" range (DOE guidelines).

*** Extremely Significant
** Very Significant
* Significant

LOWER CEDAR RIVER MAINSTEM (RM 1.6 TO 16.2)			
River Mile	River Bank	Subject	Description
Entire Length		HABITAT	Current: Habitat in this reach is extensively affected by dikes and revetments and by degraded riparian conditions.
Entire Length		WATER QUALITY **	Septic tank failure rates (15.4, 13.8, 16.5%) indicate a likely water quality problem.
1.6-2.2		SED	Current: Sediment deposited in the channel raises the river bed, which reduces channel area and causes more frequent flooding. The channel was last dredged prior to 1982. Future: Sediment will continue to deposit in the channel due to its low gradient.
2.0	Right Bank	WATER QUALITY *	Stoneway R/D Outfall; Sampling site CR5, S6: Stormwater: pH levels of 11.3 and 11.9. Hardness was high, which reduced the metal toxicity levels. FC levels of 10-1200 org/100 ml.
2.0	Right Bank	FLOOD	Ten percent of the Stoneway Gravel processing site is inundated by the 25-year flood. About a third of the site is within the 100-year floodplain.
2.2	Right Bank	FLOOD *	The 100-year flood damages two apartment buildings, affecting an unknown number of units.
2.9		WATER QUALITY	Mainstem Wooden Bridge; Sampling site CR6, S7: Stormwater: TP & TSS above recommended levels. FC levels of 140-400 org/ ml. Sediment: 2,4,5-T (pesticide) detected at just above the detection limit.
3.5-4.2	Right and Left Banks	HABITAT	Current: No large woody riparian vegetation due to development on the right bank and a slike on th left bank, which is a potential source of sediment.
3.5-4.2	Right Bank	FLOOD	The HEC-2 model indicates none of the homes in Maplewood are within the 100-year floodplain. Several homes were reportedly threatened by the November 1990 flood.
3.9	Left Bank	SED *	Current: A revetment was constructed at the toe of this steep, slide-prone hillside in 1972 to prevent further undermining of the slope by the river. The hillside remains unstable, however, due to natural geologic conditions and runoff from upslope developments. The most recent failure, in 1987, released approximately 30,000 cubic yards of mostly sandy sediment into the river. Severe surface erosion of the landslide is still occurring, caused largely by subsurface flow. Future: Repairs to the slide have not adequately controlled subsurface drainage. Renewed landsliding is likely and could involve fill materials placed at the toe of the slide as well as the original hillside. (See also Lower Cedar River Subbasins, unnumbered channel at Cedar RM 3.9, left bank.)
4.2-5.0	Left Bank	FLOOD	A portion of the eastern part of the City of Renton's Maplewood Golf Course facility is within the 10-year floodplain; a small additional amount is within the 100-year floodplain. This area was flooded during the November 1990 storm, but suffered no major damage. The foundation of the eastern abutment of the abandoned railroad bridge at RM 4.2 was partly exposed, and the nearby bank suffered damage to its protecting rock. (See also Lower Mainstem Subbasins, Maplewood Creek: Tributaries 0302, 0303, and 0303A.)

*** Extremely Significant
** Very Significant
* Significant

4.4-5.0	Right Bank	SED *	In this reach, the river flows at or near the base of a slide-prone hillside. In 1968 a revetment was constructed at the toe of a large landslide between RM 4.9 and 5.0. Although no major slides have occurred in several decades, there is continued minor sliding and erosion. Future: River migration could potentially undercut the hillside and cause a major landslide; this is most likely at RM 4.4-4.6.
5.0	Left Bank	FLOOD ***	Two homes located on the left bank of the Cedar River and three on the right immediately downstream of the Elliot (Lower Jones Road) Bridge are within the 10-year floodplain and are subject to deep, fast flows during the 100-year event. Upstream of the bridge, there are 2 homes in the 25-year floodplain and a total of 7 in the 100-year floodplain. There are additional homes that are sufficiently elevated, but their access would be blocked by the 100-year flood.
5.3-6.5	Right Bank	FLOOD **	Twenty homes located on the right bank of the river and Jones Road are within the 25-year floodplain. A total of 45 homes are within the 100-year floodplain. Some have experienced ground subsidence, washouts, and the loss of bank armoring. Flood flows have eroded the rubble and concrete levees, and have overtopped and damaged Jones Road, beyond.
6.8	Right Bank	HABITAT *	Current: A wall-based tributary (approximately 0.25 miles in length) with salmon use has been impacted by development in the floodplain. Future: Local development threatens an existing natural channel and spring area.
6.8	Right Bank	FLOOD *	There is one home downstream from and opposite the Riverbend Mobile Home park that is at risk of flooding during the 100-year flood.
7.0	Left Bank	FLOOD	The November 1990 flood washed out the levee protecting this facility, undermining twelve mobile homes. The owner of the park has rebuilt the revetment.
7.4	Right Bank	FLOOD *	Two homes, apparently above the 100-year flood stage, were severely damaged by flood flows when the existing levee was overtopped and eroded during the November 1990 flood.
8.4 *Wetland 37 RSRA*		HABITAT *	Wetland and buffer filling in Wetland 37 at a King County construction staging area.
9.2		WATER QUALITY	Jones Road Bridge; Sampling site A438: METRO ambient sampling point. Data inconclusive but incicate possible metal toxicity during baseflow.
9.4 *RSRA from 9.6-10.7*	Right Bank	SED	Current: This is a chronic slide area; bedrock at the toe of the slope prevents massive landsliding. Future: Periodic sliding is likely, but the contribution of sediment will probably be relatively small compared to other landslides on the river.
10.6 *wetland 105 LSRA*		HABITAT *	Scattered garbage and localized trash dumping in Wetland 105.
10.6 *RSRA from 9.6-10.7*	Left Bank	FLOOD *	The river makes a 90 degree bend to the left downstream of the Rainbow Bend Mobile Home park. The 6 homes located within the bend are within the 100-year floodplain; all were damaged during the November 1990 flood.
11.2	Right Bank	FLOOD ***	Four permanent houses and 55 mobile homes are within the 10-year floodplain and are subject to deep, fast flows during the 100-year event. Flows have repeatedly overtopped and damaged the levee, causing significant damage to county roads and to numerous private residences. Flooding also prevents access to many residences.

*** Extremely Significant
** Very Significant
* Significant

11.3	Right Bank	WATER QUALITY *	Metal recycling facility.
11.4-12.2	Left Bank	FLOOD ***	The area between Cedar Grove Road's intersection with SR-169 and RM 12.2 floods during the 10-year. 15 homes and are subject to deep, fast flows during the 100-year event.
11.5 *this is an RSRA*	Left Bank	HABITAT	This wall-based tributary ("McDaniels Channel") is affected by grazing, but the impact is not severe.
11.6-11.8	Right Bank	SED	Current: The river flows against an unvegetated bluff of glacial sediments, which has eroded back through shallow landslides at average rates of up to 20 feet per decade since 1936. Future: Erosion will continue.
12.3	Right Bank	SED	Upstream left bank levees at RM 12.5 help direct flows into an eroding cliff with periodic landslides.
12.4	Left Bank	FLOOD *	This is a very tight bend in the river; momentum of the water has repeatedly caused overtopping of this levee and damage to roads and homes. Thirty homes are within the 100-year floodplain; 12 homes are inaccessible during the 25-year flood.
12.9	Right and Left Banks	HABITAT *	Current: A percolation side-channel (0.3 miles in length) has an artificial barrier to fish at the mouth. Habitat is affected by heavy equipment crossing the channel.
13.0	Right Bank	FLOOD ***	Flood flows leave the channel above Jan Road (SE 197th Place), damage residences and roadways with flooding and scour, then return to the mainstem at RM 12.1. There is one home within the 10-year floodplain, which is subject to deep, fast flows during the 100-year event. There are 3 homes within the 25-year floodplain, and 7 within the 100-year floodplain. Access is prevented to several homes during the 25-year event.
13.6 *Wetland 132 LSRA*		HABITAT **	Wetland and buffer clearing in Wetland 132.
13.6	Left Bank	FLOOD ***	Two homes are located within the 10-year floodplain and are subject to deep, fast flows during the 100-year event. 3 homes within the 25-year floodplain, and 21 are within the 100-year floodplain. Several residences and two roads were damaged by water and deposited sediment during the November 1990 flood.
13.8-14.7	Right and Left Banks	FLOOD ***	The SR-169 and SR-18 bridges may be restricting flows, raising the backwater elevations in portions of this area. There are 9 homes located in the 10-year floodplain, two of which are and are subject to deep, fast flows during the 100-year event. 16 homes are within the 25-year floodplain, and 21 are within the 100-year floodplain.
14.2-14.3	Left Bank	SED	Intermittent sloughing of valley wall where undercut by the river.
14.9 *this is an RSRA*	Left Bank	HABITAT	This extensive wall-based tributary is lightly affected by development and landscaping efforts.
15.7-15.9 *this is an RSRA*	Right Bank	HABITAT	This year-round side-channel is confined by development but is otherwise healthy.
15.8	Left Bank	FLOOD	The Coleman-Lotto levee suffered erosion during the November 1990 flood, but no serious damage resulted.
15.9 *this is an RSRA*	Left Bank	HABITAT	This percolation side-channel has low LWD levels and some runoff from pastures.

*** Extremely Significant
** Very Significant
* Significant

LOWER CEDAR RIVER SUBBASINS			
Tributary	River Mile	Subject	Description
0300A Ginger Creek	Entire Length	WATER QUALITY **	Comparison of land-use based modeling (for TSS, TP, and Pb) and monitored water-quality data from other catchments indicates that a water quality problem is likely to exist.
	0.0	HABITAT	Culvert is a partial barrier to approximately 0.2 miles of potential coho and trout habitat.
	0.2-0.4, 0.45-0.6	SED	Current: At these locations there is minor streamside landsliding and channel incision and widening that becomes severe between RM 0.2 and 0.3. Future: Relatively small future flow increases are predicted so the channel should eventually stabilize.
	1.3-1.6	FLOOD	Current: Localized poor drainage, yard flooding, basement dampness. Future: This condition is likely to continue.
0302 Maplewood Creek	Entire Length	WATER QUALITY **	Septic tank failure rates (15.4, 13.8, 16.5%) indicate a likely water quality problem.
	0.0-0.5	HABITAT	Current: Habitat is affected along the golf course and by an 800' culvert under SR-169 and an old railroad grade; there is also a complete fish blockage at RM 0.5 caused by sediment ponds used to protect the golf course. Future: The City of Renton is debating the creation of a low-flow channel and high-flow by-pass channel.
	0.2	FLOOD *	Current: Concrete culvert under SR-169 is now adequate for about the 50-year flow. Future: Approximately the 2-year storm will cause flooding under future unmitigated scenario, flooding the Maplewood Golf Course and possibly SR-169.
	0.2-0.4	FLOOD	Current: The Maplewood Golf Course floods during large storms, possibly due to an inadequate culvert parallel to the driveway and sediment in the channel. Future: These flows are projected to increase significantly, so this problem will only get worse. The City of Renton is planning to enhance the sediment ponds. As a separate project, they are also planning to add a low-flow (habitat) channel to divert some flows from the lowest reach of Maplewood Creek (RM 0.2) to the north, away from the driveway.
	0.3	WATER QUALITY **	Maplewood Golf Course; Sampling site CR7, S8: Stormwater: TSS, Turb, TP, NO3&NO2-N above recommended levels. FC levels of 420-3200 org/100 ml. Sediment: Dicamba (pesticide) detected.
	0.5, 0.6 *LSRA from 0.5-1.1*	SED	Current: Existing ponds are sometimes inadequate to trap the significant sediment load from upstream. The subsequent siltation of the channel downstream aggravates flooding. Future: The sediment load is likely to increase in response to flow increases from future development.
	0.55 *LSRA from 0.5-1.1*	SED	Current: Erosion and downcutting of a right-bank channel delivers fine-grained sediment to Maplewood Creek. Future: Continued fine sediment source.

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0302 (cont)	0.7 *LSRA from 0.5-1.1*	SED	Current: A small gully on the right bank is fed by culvert outfall and flow from springs. Future: The gully will continue to grow upstream, contributing to future sediment production.
	0.9-1.2 *LSRA from 0.5-1.1*	SED *	Current: Slow-moving landslides in glaciolacustrine deposits undercut by the stream are a chronic source of fine-grained sediment. Future: Not only is this condition likely to continue, but future flow increases could accelerate landslide movement by causing channel incision in this reach.
	0.95 *LSRA from 0.5-1.1*	SED *	Current: A large left-bank gully, fed by a culvert outfall, has deposited sediment in a fan in the creek. Future: The gully will continue to grow, contributing to future sediment production.
	0.95	WATER QUALITY **	Maplewood Creek: Sampling site 7A Stormwater: Extremely high TSS, Turb & TP levels. Cu, Pb & Zn above acute and chronic levels.
	1.0-1.4 *LSRA from 0.5-1.1*	HABITAT *	Current: Sediment deposition from gullies created by daylighted culverts and channel erosion are severely affecting habitat; trash, especially old tires and appliances in stream; low amounts of effective LWD in channel. Future: No change.
	1.05 *LSRA from 0.5-1.1*	SED *	Current: A large, right-bank ravine has eroded below the outfall of a culvert that overhangs a 40-foot-high scarp. The eroded material has collected to form a small sediment fan at the mouth of the ravine. Future: Erosion is likely to continue, but at a reduced rate.
	1.2	SED	Current: Left-bank landslide at culvert outfall. Future: Continued minor sediment production.
	1.25-1.4	SED *	Current: In this reach there is severe channel incision and bank erosion in outwash sand. Future: Future flow increases will worsen this condition.
0303 East Fork Maplewood Creek	0.0-0.2 *LSRA from 0.0-0.2*	HABITAT *	Current: Good habitat is threatened by channel erosion and sediment deposition Future: Sediment from upstream erosion will threaten this reach.
	0.2-0.4	SED *	Current: In this reach there is severe channel widening and incision in outwash sand and silt. Future: The affected area is likely to extend upstream through knickpoint migration; future flow increases would worsen this condition.
	0.2-0.6	HABITAT	Current: Heavy erosion of the stream channel degrades local habitat and exacerbates downstream habitat problems. Future: Problems will worsen as flows increase due to urbanization.
	0.4-0.8	FLOOD/ WATER QUALITY **	Current: The pipes that carry the creek through Puget Colony Homes are inadequate for storms above a two-year intensity. Yards and homes are damaged, roads are repeatedly flooded, and there are complaints that septic systems become saturated, allowing contaminants to enter the surface water. Future: There will likely be large increases in flows from upstream that will cause flooding and septic system failures to occur more frequently. Unfortunately, improved conveyance through Puget Colony would cause an increase in erosion downstream.
	0.6-1.2	HABITAT	Continued fragmentation of stream channels and wetlands by urban development will degrade local habitat and exacerbate downstream habitat problems.

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0303 (cont)	1.0-1.2	HABITAT *	Extensive wetland and buffer clearing, filling, and trash-dumping in Wetland 150 has reduced this wetland's natural flood storage, water quality, and habitat functions, thereby impacting a downstream RSRA.
0303A	0.4	FLOOD **	Current: A culvert carrying this small tributary under SE 132nd Street is inadequate for flows in excess of the two-year storm. Its backed up water regularly floods the SE 132nd Street /146th Avenue SE intersection, prevents access to homes on the east, and enters the Tributary 0307 catchment. Future: Flooding will increase with development; increasing the capacity of this crossing will add some flow in Tributary 0303 and contribute somewhat to the erosion there.
unnumbered channel Cedar RM 3.9, Left Bank		SED	Current: Runoff from this gully may have triggered a large landslide into the Cedar River in 1987. (See Lower Cedar River Mainstem, RM 3.9) Future: Continued erosion of the gully will occur, adding sediment to the landslide deposit and further destabilizing this naturally unstable slope. Revetment and sediment control structures have been built at the foot of the slide area to reduce sediment delivery to the Cedar River.
0304 Molasses Creek	Entire Length	WATER QUALITY **	Comparison of land-use based modeling (for TSS, TP, and Pb) and monitored water-quality data from other catchments indicates that a water quality problem is likely to exist.
	0.0-0.2	HABITAT *	Poor habitat (low quality riffle area, low LWD levels) in vicinity of gravel pit operations.
	0.2-0.8 *LSRA from 0.2-0.8*	SED *	In the future, severe channel incision could occur in this reach if flows increase.
	0.6 *LSRA from 0.2-0.8*	SED	Current: There is a gully and a landslide scar in the power-line corridor. Future: Continued minor erosion is likely as the slide scar ravels.
	0.65-0.8 *LSRA from 0.2-0.8*	HABITAT	Trash in stream; at RM 0.8 there is a blockage to fish passage where a culvert outfall is stranded above the streambed.
	0.8	SED	Current: There is erosion of the left bank at a culvert outfall. Several shallow landslides on ravine walls have now revegetated. Future: Continued minor erosion is likely.
	0.8-2.0 *Wetlands 2, 22, and 23 LSRA*	HABITAT	Current: Stream habitat is fragmented by culverts and channelization. Future: Habitat and buffering provided by Wetlands 2, 22, and 23 will protect the channel. Water quality may have an affect on the existing fish population.
	1.0	FLOOD *	Current: During 25-year and larger storms, water ponds between 132nd and 133rd Place SE, in an inadequately-sized detention area behind an access road in the SWD right-of-way south of SE Fairwood Blvd. Of two houses built lower than subdivision requirements, one suffered flood damage and another is threatened. Future: Projected increases in flows would make this problem worse.
	1.8	FLOOD **	Current: SE 180th Street floods at approximately the 5-year flow, preventing access to residences. Future: Flows will increase, making road flooding and access problems more frequent.

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0304 (cont)	2.0 *Wetland 22 LSRA*	FLOOD **	Current: The 140th Ave SE crossing spans Wetland 22, at RM 2.2. The low point in this arterial and the surrounding properties experience flooding almost annually. This crossing has a capacity of 26 cfs, or about a 5-year storm. Future: Most of the area above where 140th Ave SE crosses Wetland 22 is currently undeveloped, so future flows will probably be significantly higher, causing deeper and more frequent flooding.
	2.0 *Wetland 22 LSRA*	HABITAT *	Class 1-rated Wetland 22 has been converted into an R/D pond for a subdivision. The pond access road causes chronic buffer impacts and is a conduit for trash dumping. Thick brown foamy water was observed in Molasses Creek near the pond outlet.
	2.4 *Wetland 23 LSRA*	HABITAT	Filling near outlet of Class 1-rated Wetland 23. Future: This wetland will be encircled by a 77-unit subdivision.
0304A	0.2	HABITAT *	Extensive filling, grading, and debris dumping in Wetland 2 south of Petrovitsky Road.
0305 Madsen Creek	0.0-0.8	SED	Current: Fine sediment has been deposited in the channel, significantly reducing its capacity; the capacity of the sediment pond at RM 0.8 proved inadequate in 1990.
	0.0-0.8	HABITAT *	Current: An artificial "low-flow" channel here provides low habitat value. Also, fine sediment moves through the sediment pond at RM 0.8, and a high-flow by-pass channel traps fish. Future: Habitat will continue to function poorly.
	0.8 *LSRA from 0.8-2.15*	WATER QUALITY **	Madsen Creek (upstream from sediment pond); Sampling site CR9, S10: Stormwater: TSS, Turb, & TP exceeded recommended levels. Cu & Zn exceeded acute and chronic toxicity. FC levels of 520-6800 org/ ml. Sediment: No pollutants detected.
	0.8-2.15 *LSRA from 0.8-2.15*	HABITAT/ WQ *	Current: Ravine habitat affected by placement and management of METRO sewer line and sediment from channel erosion on Tributary 0306 (the east Fork of Madsen Creek.) Future: Habitat recovery from landslide on Tributary 0306 will be impaired by activities associated with METRO sewer line and ravine stabilization efforts.
	0.85-1.5 *LSRA from 0.8-2.15*	SED/WQ	Current: This channel reach is generally stable, although local bank erosion has exposed a METRO sewer line in a few places.
	1.5 *LSRA from 0.8-2.15*	WATER QUALITY *	Madsen Creek; Sampling site S11: Sediment: 2,4-D (pesticide) detected at 66 ug/kg, 7 times the detection limit.
	1.5-1.6 *LSRA from 0.8-2.15*	SED *	Current: There is downcutting and bank erosion in this reach.
	1.6, 1.8 *LSRA from 0.8-2.15*	SED	Current: Logjams on the east fork of Madsen Creek trap sediment and prevent incision from progressing upstream. Future: Removal or failure of these logjams would lead to rapid erosion and downcutting.
	1.85-2.1 *LSRA from 0.8-2.15*	SED *	Current: There is active widening and incision of the channel. Three recent landslides on the right bank may have been caused by disturbance from the sewer-line road. Future: Continued erosion is likely because the channel has not yet completed its adjustment to increased flows. However, the road crossing at RM 2.15 will prevent erosion upstream of that point.

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0305 (cont)	2.15	HABITAT	Culvert is a complete barrier; cutthroat trout exist upstream.
	2.15-2.5	HABITAT	Current: Habitat fragmented and constrained by development; some localized reaches provide good habitat for trout. Future: Habitat will be degraded if Wetland 16 is further affected by development.
	2.6 *Wetland 16 RSRA*	HABITAT/ WQ **	Dredging and filling near the outlet of Class-1 rated Wetland 16. .Water quality modelling indicates this wetland will undergo the highest percentage increase in future pollutant loads of any SRA wetland in the basin.
0306 West Fork Madsen Creek	0.0-0.1 *LSRA from 0.0-0.25*	SED/WQ **	Current: Over 15 feet of downcutting have occurred here, with associated landsliding and channel widening, which has left gas lines suspended in the air and has damaged a METRO sewer line.
	0.0-0.2 *LSRA from 0.0-0.25*	HABITAT *	Current: Habitat degraded by erosion from high flows and sewer failure and pipeline placement; impassable culvert at golf course at RM 0.2. Future: Habitat will be degraded by active incision and by efforts to stabilize the channel.
	0.1-0.2 *LSRA from 0.0-0.25*	SED *	Current: Here the channel is much narrower than downstream, with active incision and minor landsliding. Future: Further incision and substantial widening are likely as the channel adjusts to past changes.
	0.2-1.0 *LSRA from 0.0-0.25*	HABITAT	Current: Habitat fragmented and constrained by development; some localized reaches provide good habitat for trout. Future: No changes anticipated.
	0.3-0.45	SED	Current: Downcutting and widening have occurred in till. Future: Slow channel enlargement may continue to occur.
	0.7	HABITAT *	Extensive filling has severely reduced Wetland 18's natural flood storage, water quality, and habitat functions, resulting in a loss of buffering of a downstream LSRA. One half acre of the wetland and riparian zone was recently cleared as a neighborhood beautification project.
	1.3	HABITAT	Approximately 60% of Class-1 rated Wetland 25 and the entire buffer were eliminated during construction of homes and a subdivision R/D pond.
0306A		HABITAT	Habitat fragmented by golf course and development.
0307 Orting Hill	Entire Length	WATER QUALITY **	Septic tank failure rates (13.1%) indicate a likely water quality problem.
	0.0-0.2	HABITAT	Stream confined to long culvert blocking upstream passage.
	0.2	WATER QUALITY **	Jones Road Trib.; Sampling site CR8, S12: Stormwater: TSS, Turb, TP & NO2&NO3-N exceeded recommended levels. Acute and chronic levels of Cu & Zn. FC levels of 420-9600 org/100 ml. Sediment: No pollutants detected.
	0.2	SED	Current: In the past, a catch basin filled with sediment and plugged a culvert during major floods. Future: Inlet replacement and a bank stabilization project under construction upstream may reduce sediment problems. (See RM 0.4-0.0.5, below.)
	0.3	HABITAT	A culvert under a private driveway is a potential barrier.

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0307 (cont)	0.4-0.5	SED	Current: Bank erosion and discharge from daylight culverts have caused streamside landslides. Future: A left bank stabilization project currently under construction will protect some of the affected streambanks, but future flow increases could initiate channel incision and additional streamside landslides on the right bank.
	0.4-0.5	HABITAT	Current: Habitat is impacted by culvert failure of Orting Hill Road and past road management activities. Future: A channel stabilization effort by the County will increase quantity and stability of pool habitats.
	0.5-0.7	HABITAT	Current: There is very good habitat in forested park setting; an upstream channel is culverted under a large development.
0308, 0309, & 0310	Entire Length	WATER QUALITY **	Comparison of land-use based modeling (for TSS, TP, and Pb) and monitored water-quality data from other catchments indicates that a water quality problem is likely to exist.
		SED	Current: These channels are generally stable upstream from Jones Road, with some widening and only minor incision, with the exception of a short section of 0309 at RM 0.2. Future: If unmitigated, future flow increases could result in severe downcutting and erosion of steep reaches.
0309	0.2	SED	Current: There is a 100-foot-long, severely eroding channel with a headcut. Future: The headcut will progress upstream and threaten the SE 143rd St. road crossing, 60 feet upstream.
	0.8	FLOOD	The crossing under 175th Avenue SE appears to be undersized, causing nuisance flooding.
0310	0.1	FLOOD/ SED	Current: The channel here fills with sediment and changes course with larger flows, causing flooding of yards and possibly threatening homes. Future: No increase in flows, and therefore no increase in flooding, is expected.
0311 Summerfield	0.2-0.55	SED	Current: Sediment deposition problems at the mouth of the ravine have led to construction of a sediment basin. A debris flow occurred on this steep channel in 1990. The channel is deeply incised, with widespread bank slides and erosion. The major part of the flow has since been tightlined to the valley floor, bypassing the ravine. Future: Ravine walls should eventually stabilize.
0313	0.15-0.45	FLOOD/ SED *	Current: This channel has severe incision, bank erosion, and landsliding. Sediment deposition at the mouth of the ravine contributes to flood damage at a mobile home park. A debris flow reportedly occurred on this channel in the 1930s. Future: Continuous, severe sediment production is likely and could worsen if flows increase with future development.
0314	0.2-0.4	SED	Current: Channels are deeply incised and there is bank erosion on both the mainstem and 0314B. 0314A is stable except near its mouth, where a headcut is progressing upstream; riprap controls erosion at the downstream end of mainstem 0314. Future: Erosion is likely to continue on the mainstem and 0314B. The headcut on 0314A is likely to move upstream and could potentially destabilize a 600-foot-long reach of channel.
0315B	0.1	SED	Current: There is bank erosion and channel incision in one fork of this stream, with a sediment fan below.

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0316	Entire length *LSRA from 0.0-0.3*	HABITAT/ WQ *	Current: Water quality and quantity of this wall-based tributary is affected by the Stoneway Gravel Mine at the headwaters. Rainbow Bend Trailer Park confines habitat along the valley floor. This tributary flows into an RSRA Future: Unmitigated work by Stoneway will continue to threaten habitat. There is much potential for habitat improvement of this site.
0316A	0.0-0.2 *LSRA from 0.0-0.45*	HABITAT *	Current: The Stoneway Gravel Mine and the Cedar Grove Composting Facility are affecting water and habitat quantity and quality of the stream, including a downstream LSRA Future: No change is expected.
		WATER QUALITY **	Cedar Grove Road.;Sampling site CR10, S13: Stormwater: Elevated TSS, Turb & TP levels. Cu exceeded acute and chronic toxicity. FC levels of 28-2800 org/100 ml.
		WATER QUALITY **	Cedar Grove Road, Runoff diversion.; Sampling site S13: Sediment: No pollutants detected.
		WATER QUALITY **	Cedar Grove Road Culvert. Stormwater sample showed high levels of TP (1030 ug/l), NO3+NO2 (3690 ug/l), Turb (340 NTU), & TSS (295 mg/l).
		WATER QUALITY **	Stoneway Gracvel. Channel connects process pond water with 0316A, contributing extremely high levels of very fine sediment.
		WATER QUALITY **	Cedar Grove Composting Facility. Stormwater sample from below the outfall showed extremely high levels of TP (6740 ug/l), NO3+NO2 (2530 ug/l), Turb (250 NTU), & TSS (257 mg/l). Background sample levels below recommended level; however, background pH was 4.6.
		SED	Current: There is severe gully erosion where the channel passes through disturbed quarry soils.
	0.1-0.4 *LSRA from 0.0-0.45*	SED	Current: The channel is generally stable, but the slope has been rocked in locations where the creek is close to Cedar Grove Road to protect bank erosion. Future: Flow increases are likely to cause channel incision, which could potentially undermine Cedar Grove Road.
	0.6-0.7	HABITAT	The stream bank has been denuded of vegetation, thereby impacting salmonid habitat.
	0.7-1.2	HABITAT	Wetlands 31, 32, and Tributary 0316A have been affected by high nutrients and turbidity in runoff from the Cedar Grove Composting Facility and the Stoneway Gravel Mine and by past channelization of the stream. The north buffer of Wetland 32 has been impacted by livestock grazing and soil compaction. These impacts have severely reduce the ability of these wetlands and the segment of Tributary 0316A connecting them to support salmonids. Revegetation has been started by the landowner.
	Isolated Habitat *Wetland 13 LSRA*	HABITAT/ WQ **	Part of the buffer of Class 1-rated Wetland 13 was removed during gravel mining. The wetland has also been impacted by toxic waste disposal within an EPA Superfund Cleanup Site and by clearing of the south buffer during gravel mining.

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unnumbered channel Cedar RM 8.0, Left Bank	0.0	WATER QUALITY	Old King County Shop Ditch; Sampling site CR11: Stormwater: TSS, Turb & TP exceeded recommended levels. Cu, Pb, & Zn were at acute toxicity levels.
		SED	Current: There is a wide, incised, severely eroding channel with a large sediment fan at the mouth of the ravine. Future: Continued erosion is likely
unnumbered channel Cedar RM 8.8, Right Bank		SED	Current: The side-slopes of the ravine were destabilized by sewer-line construction in 1991, resulting in landslides and bank erosion. Future: Not likely to change
0317	0.15-0.25	SED	Current: This small stream is presently stable. Future: Projected flow increases are likely to cause severe channel incision in this short, steep reach of the stream.
	0.2	FLOOD	Current: 21" concrete pipe under Maxwell Road SE backs up and floods partially during high flows. Future: This problem will probably increase in frequency as flows increase with development.
	0.8-1.2	HABITAT	This stream infiltrates within a former gravel mine that is currently a demolition debris landfill.
	1.9 *Wetland 36 LSRA*	HABITAT *	There has been extensive buffer removal and ditching around Francis Lake (Class 1-rated Wetland 36). Portions of the wetland and buffer are grazed.
	Isolated Habitat	HABITAT	Filling and clearing has occurred within Wetland 39.
0334A	0.1-0.4	SED	Current: In 1990, there was damage from a debris flow, which deposited sediment at the mouth of this ravine. Runoff has since been diverted from the ravine and tightlined to the valley floor. Future: The ravine will revegetate and stabilize now that the runoff source has been removed.
unnumbered channel Cedar RM 10.5, Left Bank		SED	Current: In 1990, there was erosion of this steep ravine and sediment deposition at the mouth, reportedly caused by failure of an R/D pond.
unnumbered channel Cedar RM 11.0, Left Bank		SED	Current: Sediment deposition problems were reported at the mouth of this steep ravine in 1986, but no problems have been reported recently.

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MIDDLE CEDAR RIVER MAINSTEM (RM 16.2 to RM 21.7)			
River Mile	River Bank	Subject	Description
Entire Reach		HABITAT	Development along riverbanks is creating localized habitat problems associated with bank hardening and vegetation removal.
16.3-16.4	Right Bank	HABITAT	This percolation side channel habitat is degraded by lack of riparian habitat due to levee construction.
16.4	Right Bank	FLOOD ***	County roads and 23 homes are within the 10-year and are subject to deep, fast flows during the 100-year event. Flooding can also prevent access to many of the homes. (See "Upper Mainstem Tributaries 0336 & 0337 - Dorre Don" for a description of minor flooding where Trib 0336 crosses Lower Dorre Don Way.)
17.0	Left Bank	SED	At this bend, the river flows against a slowly-eroding bluff of glacial sediments.
17.1	Right Bank	FLOOD ***	There are two homes located in the 10-year floodplain, seven in the 25-year floodplain, and a total of 13 in the 100-year floodplain. The 100-year flood blocks access to 14 homes.
17.4-17.5	Right Bank	SED	A large, slow-moving landslide is a chronic source of silt to the river. Future: Movement will likely continue.
17.5-17.8 *these are RSRAs*	Left Bank	HABITAT **	Current: Two side-channel habitats have been affected by lack of LWD and possible regulation of flows by residents. Future: Habitat will continue to be degraded by landowners.
17.7-20.2 *this in an RSRA*	Right and Left Banks	SED	The river flows against slowly-eroding bluffs of gravelly glacial sediment at the outsides of these bends. Because erosion of these bluffs provides spawning-sized gravel to the river, this reach is an RSRA.
17.9	Left Bank	HABITAT /WQ *	Current: This off-channel pond is blocked by a railroad culvert. Habitat has been affected by landowner landscaping and horses. Future: This is a potential SRA. Water quality and habitat will continue to degrade as landowner increases landscaping effort.
18.1 *this is an RSRA*	Left Bank	HABITAT	Current: This off-channel pond at the mouth of Rock Creek lacks access for fish in Rock Creek. Future: Potential SRA.
18.1-19.0	Right and Left Banks	FLOOD *	This reach, composed of several bends in the river, includes four areas of potential flooding problems. Nine homes are located within the 25-year floodplain, and 24 are within the 100-year floodplain.
18.3 *this is an LSRA*	Left Bank	HABITAT *	Residents have disturbed a wall-based tributary in this LSRA.
19-0 *this is an RSRA*	Left Bank	HABITAT	This side channel lacks LWD and structural diversity.
19.7	Left Bank	HABITAT *	Current: A wall-based tributary is being modified by land clearing and has fish access blocked by railroad. Future: This is a potential SRA. Habitat will degrade if development activities continue.

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19.7 *this is an RSRA*	Left Bank	HABITAT	This percolation side channel lacks LWD and coniferous riparian zone.
20.6 *Wetland 69 RSRA*	Right Bank	HABITAT **	Low flows prevent fish access to outstanding oxbow lake (Wetland 69).
21.3		WATER QUALITY	Landsburg Dam; Sampling site CR14, S18 Stormwater: Water quality very good, all parameters well below Class AA standards. (One of three samples exceeded acute copper and chronic lead standards.)
21.6 *Wetland 83 RSRA*	Left Bank valley floor	HABITAT **	The south buffer of Class 1-rated Wetland 83 has been cleared within a power line right-of-way. The west buffer is a grazed pasture. Recent clearing, filling, grading, and debris deposition has occurred along the northeast and southwest edges.

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PETERSON CREEK SUBBASIN			
Tributary	River Mile	Subject	Description
0328 Peterson Creek	Entire Length	WATER QUALITY **	Septic tank failure rates at Spring Lake (11.5%) indicate a likely water quality problem.
	0.0 *RSRA from 0.0-1.2*	WATER QUALITY *	Peterson Creek; Sampling site CR13, S16, C438: Stormwater: Cu exceeded acute toxicity limits in 2 of 3 samples. FC levels of 60-300 org/ ml.
	0.2-0.6 *RSRA from 0.0-1.2*	SED *	Current: The banks of this reach are naturally prone to landslides, which were occurring here even prior to development. Future: Landsliding and severe bank erosion are likely to continue.
	0.5-1.2 *RSRA from 0.0-1.2*	HABITAT *	Current: Habitat is of relatively low complexity and is moderately scoured and eroded due to lack of significant accumulations of LWD. Future: Habitat should improve gradually as LWD accumulates in the channel.
	0.6-0.9 *RSRA from 0.0-1.2*	SED *	Current: There is moderate channel incision and widening, with bank erosion worsening downstream. Future: Future flow increases could increase erosion rates.
	1.2-1.6 *LSRA from 1.2-2.6*	HABITAT *	Current: This stream is extensively channelized below Peterson Lake; the banks are well vegetated with small alders and low vegetation but the channel is low in complexity and lacking in LWD. Future: Limited improvement will occur as the channel ages.
	1.9 *Wetland 42 RSRA*	HABITAT *	Filling and buffer removal has occurred in an uninventoried segment of Wetland 42 near the Lake Youngs pipeline.
	2.0-2.2 *LSRA from 1.2-2.6*	HABITAT *	Current: Habitat is of low complexity; channelized appearance. Future: No change is expected.
	2.2-2.4 *LSRA from 1.2-2.6*	HABITAT *	Current: Stream banks and instream habitat have been affected by operation of heavy equipment in the stream, overgrazing, and clearing of riparian vegetation in a pasture area.
	2.6	FLOOD	SWM has received numerous complaints regarding the adequacy of drainage systems around Spring Lake. These small systems periodically plug with debris or silt. Future: No change is expected.
	2.7 *Wetland 28 RSRA*	HABITAT *	A portion of Sphagnum mat of Class 1-rated Wetland 28 is disintegrating.
0328B	Entire Length	WATER QUALITY **	Septic tank failure rates at Lake Desire (15.8%) indicate a likely water quality problem.
	1.0 *RSRA from 0.0-2.2*	WATER QUALITY *	Lake Desire exibits signs of eutrophication.

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(cont) 0328B	1.3 *Wetland 15 RSRA*	HABITAT *	Localized clearing and filling near the south end of Class 1-rated Wetland 15.
	1.5-1.7 *RSRA from 0.0-2.2*	FLOOD **	Current: Frequent flooding of East Lake Desire Drive SE and North Lake Desire Drive SE. Caused by 1) road subsidence due to incompetent subgrade, and 2) periodic rises in lake water surface due to inadequate maintenance of the lake's outlet pipe at RM 1.0. Access to several homes is blocked. Future: No significant changes expected.
	2.3 *Wetland 14*	HABITAT *	Bog (Wetland 14) extensively altered by peat farming and filling.
	Headwaters	HABITAT	Extensive filling and buffer removal has fragmented habitat of Wetland 102.
0328C	Entire Length	WATER QUALITY **	Septic tank failure rates at Shady Lake (22.6%) indicate a likely water quality problem.
0330, 0331, 0333		SED	Current: There is incision and gullying of small channels tributary to Peterson Creek; part of 0331 gully has been rocked to control further erosion.

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TAYLOR (DOWNS) CREEK SUBBASIN			
Tributary	**River Mile**	**Subject**	**Description**
0320 Taylor Creek	Entire Subbasin	WATER QUALITY **	Poor animal keeping practices have degraded water quality in this subbasin.
	0.1	HABITAT	Wetland 132 has been cleared along the south end and partially excavated along the north end (in Taylor Creek).
	0.4	WATER QUALITY **	Taylor Creek, Maxwell Road; Sampling site CR12, S15 Stormwater: NO3+NO2- N exceeded recommended levels. FC levels of 52-3960 org/100 ml.
	0.4-0.8	FLOOD **	Current: This reach floods almost yearly, flooding a sole access road and preventing access to several homes. Saturated soils resulting from the flooding have reportedly caused some foundations to settle and crack. Future: This condition will worsen with future development and with improvement to a box culvert that now limits flows (see flooding on Trib 0320, RM 1.2).
	0.4-0.8	SED **	Current: Sediment deposition has reduced channel capacity and increased flooding of Maxwell Road. Most of this material appears to have been deposited during failure of a culvert at SR-18. Future: The amount of sediment deposited in this reach will increase if future flow increases cause more upstream channel erosion.
	0.4-1.2	HABITAT	Current: Habitat has been affected by channelization associated with Maxwell Road, noncommercial farms, and residential development.
	1.2 *LSRA from 1.2-3.2*	FLOOD *	Current: A concrete box culvert under SR-18 has only about a 20-year capacity. Larger flows flood a tavern parking lot, picking up material that is then deposited downstream (see flooding on Trib 0320, RM 0.4-0.8). Future: If WSDOT improves or enlarges this culvert as planned, this flooding problem will be reduced, but downstream flows will be higher (see RM 0.4-0.8).
	1.2-1.6 *LSRA from 1.2-3.2*	SED *	Current: Although this channel is generally stable, there is some local bank erosion and minor downcutting. Future: Future flow increases could destabilize the channel and cause incision.
	1.25-2.4 *LSRA from 1.2-3.2*	HABITAT *	Current: Habitat is relatively low complexity and moderately scoured and eroded due to lack of significant accumulations of LWD. Future: Habitat will improve as riparian areas mature and LWD accumulates in the channel.
	1.7	WATER QUALITY **	Taylor Creek; Sampling site CR15: Stormwater: TP & NO3+NO2-N exceeded recommended levels. FC levels of 800-2980 org/100 ml. Cu exceeded acute and chronic toxicity limits.
	1.7	WATER QUALITY **	SR-18 Drainage; Sampling site CR16: Stormwater: TSS, TP & NO3+NO2-N exceeded recommended levels. FC levels of 10-180 org/100 ml. Cu, Pb & Zn exceeded toxic limits periodically.
	2.4-3.2 *LSRA from 1.2-3.2*	HABITAT *	Current: There is good habitat with localized impacts from rural residences. Future: High threat from increased rural development pressures.

*** Extremely Significant
** Very Significant
* Significant

(cont) 0320	Headwaters	HABITAT	Wetland 133 has severe grazing impacts: many dead and drying trees and a large expanse of muddy soil.
	Headwaters	HABITAT	Several acres of Wetland 49 and its buffer were recently logged.
0321	0.0-0.2	HABITAT /WQ	Current: Noncommercial farm activity is eroding banks. Future: No change is expected.
	0.2-0.5 *RSRA from 0.2-0.8*	SED	Current: This channel is generally stable. Future: Future flow increases may destabilize the channel.
	0.2-0.8 *RSRA from 0.2-0.8*	HABITAT *	Current: Habitat is in near pristine conditions. Future: Habitat will degrade if not protected.
	Headwaters	HABITAT *	A downstream RSRA is threatened by noncommercial farms, channelization along roads, and rural residential landscaping.
0322	0.0-0.2	SED	Current: This channel is generally stable. Future: Future flow increases may destabilize the channel.
0323	Headwaters	HABITAT *	A downstream RSRA is threatened by noncommercial farms, channelization along roads, and rural residential landscaping.
0323A	Headwaters	HABITAT *	A downstream RSRA is threatened by noncommercial farms, channelization along roads, and rural residential landscaping.
0326	0.0-0.7 *this is an LSRA*	HABITAT *	Current: There is good habitat with localized impacts from rural residences. Future: High threat from increased rural development pressures.
	2.6 *LSRA from 1.2-3.2*	WATER QUALITY **	Upper Taylor Creek; Sampling site CR17, S17: Stormwater: TP & NO3+NO2-N exceeded recommended levels. FC levels of 920-2610 org/100 ml. One sample exceeded toxic levels for Cu & Zn.

*** Extremely Significant
** Very Significant
* Significant

MIDDLE CEDAR RIVER SUBBASINS			
Tributary	River Mile	Subject	Description
0336 Dorre Don	0.0	FLOOD	Current: Lower Dorre Don Way and nearby properties flood at about the 5-year flow. The culvert carrying the stream under the road is old and undersized, but enlarging it may not significantly increase its capacity for larger storms because the flooding may be due to backwater effects from the Cedar rather than inlet capacity; egress is still possible during these events. Future: As flows increase this problem will occur more frequently.
	0.0-0.17	HABITAT	The stream is channelized through a residential area in the floodplain. There is an impassable culvert at RM 0.17; the stream is dry for most of the year above the culvert.
	0.1	WATER QUALITY **	Dorre Don Way Trib.; Sampling site CR18: Stormwater: TSS, TP & NO3+NO2-N exceeded recommended levels. FC levels of 240-1540 org/ ml. Cu & Zn acute toxicity limits exceed.
	0.25-0.75	SED	Current: Some channel enlargement has occurred, with scattered zones of bank erosion. Future: Possible channel erosion is likely under future flow conditions, with concurrent sediment deposition problems downstream from RM 0.2.
	0.3	FLOOD	Current: 48" CMP under SE 244th Street in poor condition. Although water backs up behind it, there is no damage from flooding at the present, but there is erosion on the downstream side. Future: The capacity of this crossing may be inadequate for storms larger than 5-year future unmitigated, or 10-year future mitigated.
0336A	1.0	FLOOD *	Current: 18" concrete culvert is undersized, causing arterial flooding of SE 224th Street during larger storms. Future: This condition is likely to worsen.
0337	0.0-0.1	FLOOD	Current: Many complaints of ,poor drainage and minor flooding during larger storms. Future: Condition will gradually worsen as development increases.
	0.1	FLOOD	Current: 24" CMP under SE 255th Street has about a 10-year capacity. Future: May cause road-flooding problems frequently in the future.
0341 Walsh Lake Diversion Channel	0.0-0.2 *LSRA from 0.0-4.0*	HABITAT *	Current: At low flows, fish access is frequently blocked because the stream soaks into the permeable gravels of the sediment fan. Future: Increase in surficial water at low flows is possible as the streambed accumulates silts.
	0.0-0.6 *LSRA from 0.0-4.0*	HABITAT	Current: Habitat still evolving since construction of diversion; opportunity for increasing rate of habitat formation exists. Future: Gradual improvement as LWD accumulates and riparian areas mature.
	0.2-0.5 *LSRA from 0.0-4.0*	SED *	Current: Severe downcutting and channel widening has occurred since this channel was constructed in the 1920s--the ravine has 30-40-foot high banks with numerous bank failures. Sediment from the ravine has formed a fan downstream from RM 0.2. Future: Continued erosion is likely.
	0.5-0.65 *LSRA from 0.0-4.0*	SED	Current: Downcutting here is less severe; the 6- to 10-foot-high banks have partially stabilized. Future: Continued erosion is likely.

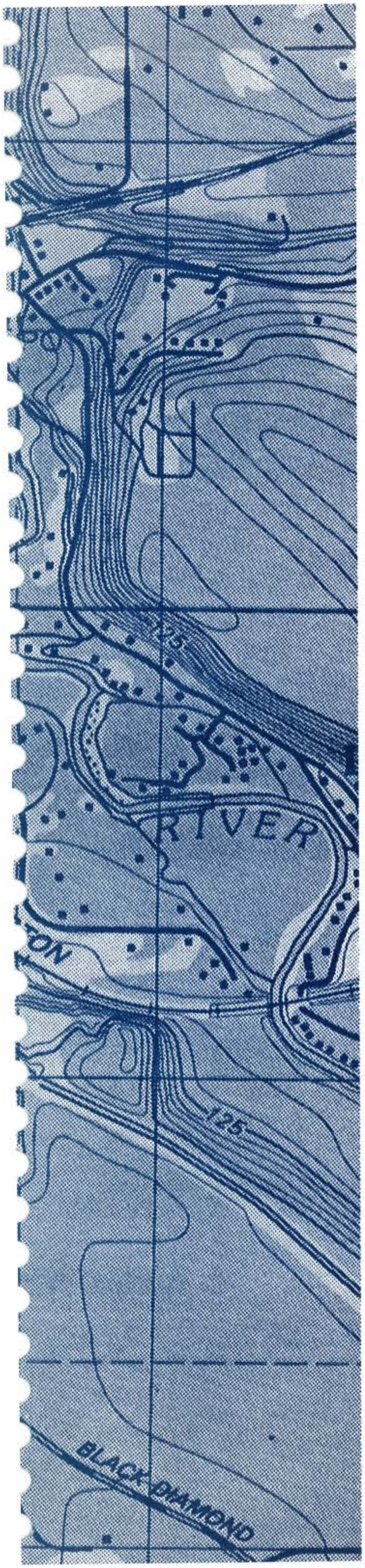
*** Extremely Significant
** Very Significant
* Significant

(cont) 0341	1.1 *LSRA from 0.0-4.0*	**WATER QUALITY**	**Walsh Lake Diversion; Sampling site CR19** **Stormwater: Cu & Zn exceeded acute toxicity limits in 1 of 3 samples.**
	Headwaters ***Wetland 64 LSRA***	**HABITAT** *	**Class 1-rated Wetland 64 has been converted to an R/D pond for a subdivision. Extensive buffer clearing has occurred along the south half of the wetland.**
	Headwaters ***Wetland 82 LSRA***	**HABITAT** *	**Approximately 50% of the buffer of Wetland 82 (Hidden Lake) has been logged.**

*** Extremely Significant
** Very Significant
* Significant

ROCK CREEK SUBBASIN			
Tributary	River Mile	Subject	Description
0338 Rock Creek	0.0-0.8 *RSRA from 0.0-2.5*	SED *	Current: No erosion/sediment problems observed. Future: As flows increase, severe channel erosion is likely to occur between RM 0.2 and 0.8. Sediment deposition is likely between RM 0.0 and 0.2, reducing channel capacity and potentially causing flooding.
	0.0-1.7 *RSRA from 0.0-2.5*	HABITAT **	Low flows may not meet instream standards and needs of spawning and rearing fish due to the City of Kent's water withdrawal.
	0.2 *RSRA from 0.0-2.5*	FLOOD	Current: Railroad tie box culvert under SE 248th Street is at capacity at 5-year flow. Future: As flows increase, this situation would occur more frequently.
	0.3-0.8 *RSRA from 0.0-2.5*	HABITAT *	LWD accumulations are lacking.
	1.4 *RSRA from 0.0-2.5*	FLOOD	Current: Three 36" culverts under Summit-Landsburg Road are at capacity during a 10-year flow, at which point the road may flood. Future: As flows increase, this situation would occur more frequently.
	2.5-2.65	HABITAT *	Streambank clearing and light erosion associated with residences and noncommercial farms, affecting a downstream RSRA.
	2.6	FLOOD	36" CMP under 262nd Avenue SE is probably flooding at about 2-year flow, though there are no complaints on record Future: This condition will worsen as flows increase.
	2.8	FLOOD	Current: Two 30" concrete pipes under the Kent-Kangley Road have a combined capacity of about a 25-year storm, at which flow the road would probably flood. Future: This problem will become more frequent.
	3.1	FLOOD	Current: Two 36" culverts under 268th Avenue SE should provide 10-year capacity, though a neighbor complains of annual flooding, possibly due to poor maintenance of this and downstream crossings. Future: Future unmitigated flow estimates put this crossing at a 2-year capacity.
	3.2-3.4 *Wetland 94 LSRA*	HABITAT *	The buffer of Wetland 94 has been completely logged. Vegetation has been removed within a power line right-of-way that crosses the wetland.
	Headwaters *Wetland 92 LSRA*	HABITAT *	Installation of a communications line within Wetland 92 and its buffer has modified habitat structure and hydrology. Future installation of a water pipeline in the wetland could severely damage this wetland's habitat, water quality, and hydrology.
	Headwaters *Wetland 91 LSRA*	HABITAT *	Wetland vegetation has been removed in back yards along 75% of the shoreline of Lake No. 12 (Wetland 91).
	Outlet from Retreat Lake	WATER QUALITY	Retreat Lake; Sampling site CR20: Stormwater: Acute Cu toxicity in 1 of 3 samples taken. All other parameters are below recommended levels.

*** Extremely Significant
** Very Significant
* Significant



Appendix B

Cedar River Basin Maps

Map 1 Cedar River Basin and Location
Map 2 Subbasin Boundaries
Map 3 Current Land Use/Land Cover
Map 4 Future Land Use/Land Cover
Map 5 Geology
Map 6 Recharge Areas
Map 7 Mean Annual Flows
Map 8 Locations of Selected HEC-2 Cross Sections
Map 9 Changes in the Lower and Middle Cedar River Channel Pattern
Map 10 Revetment Location and Meander Belt of the Lower and Middle Cedar River Since 1865
Map 11 Water Supply by Water Districts
Map 12 Forest Reference
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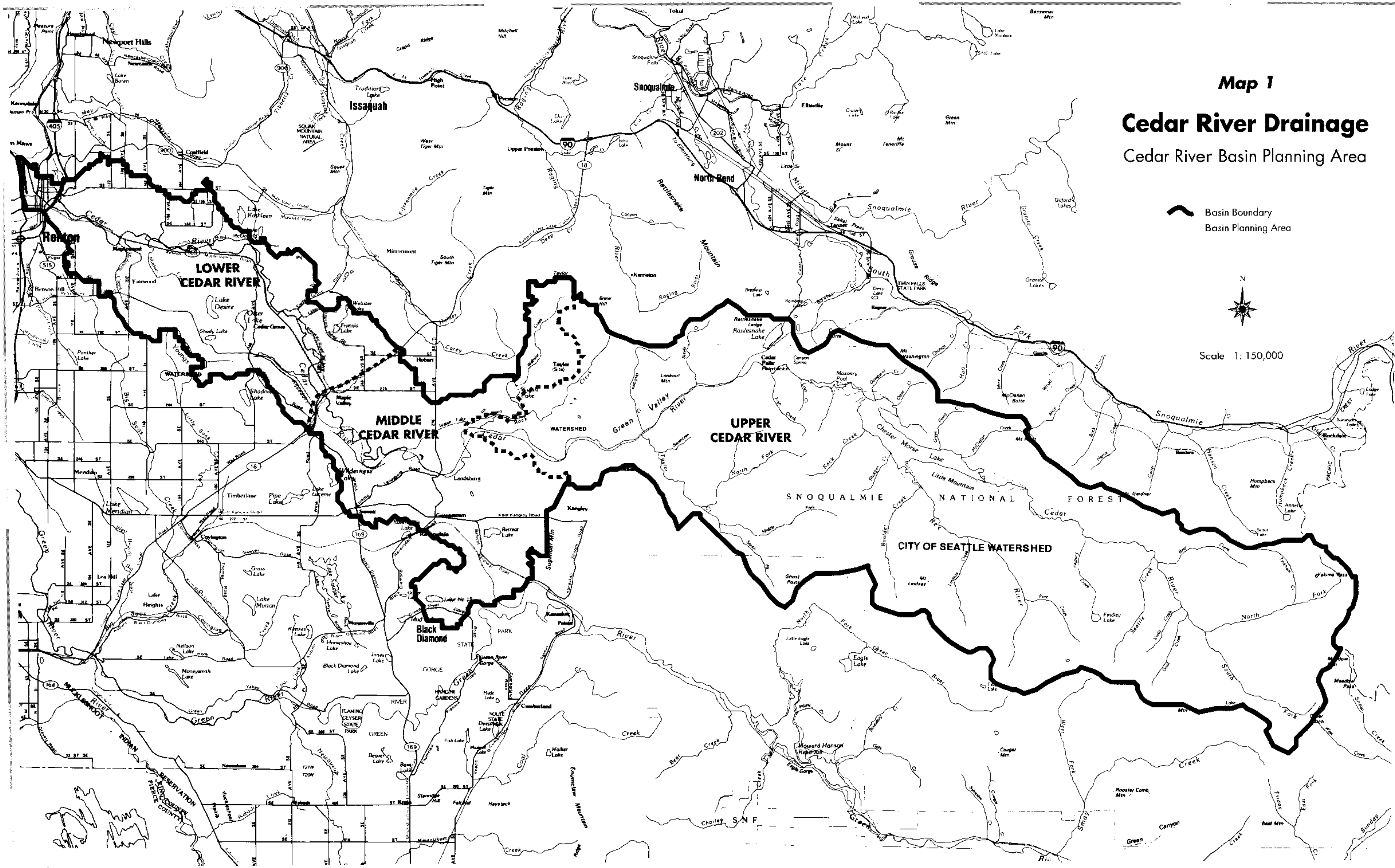
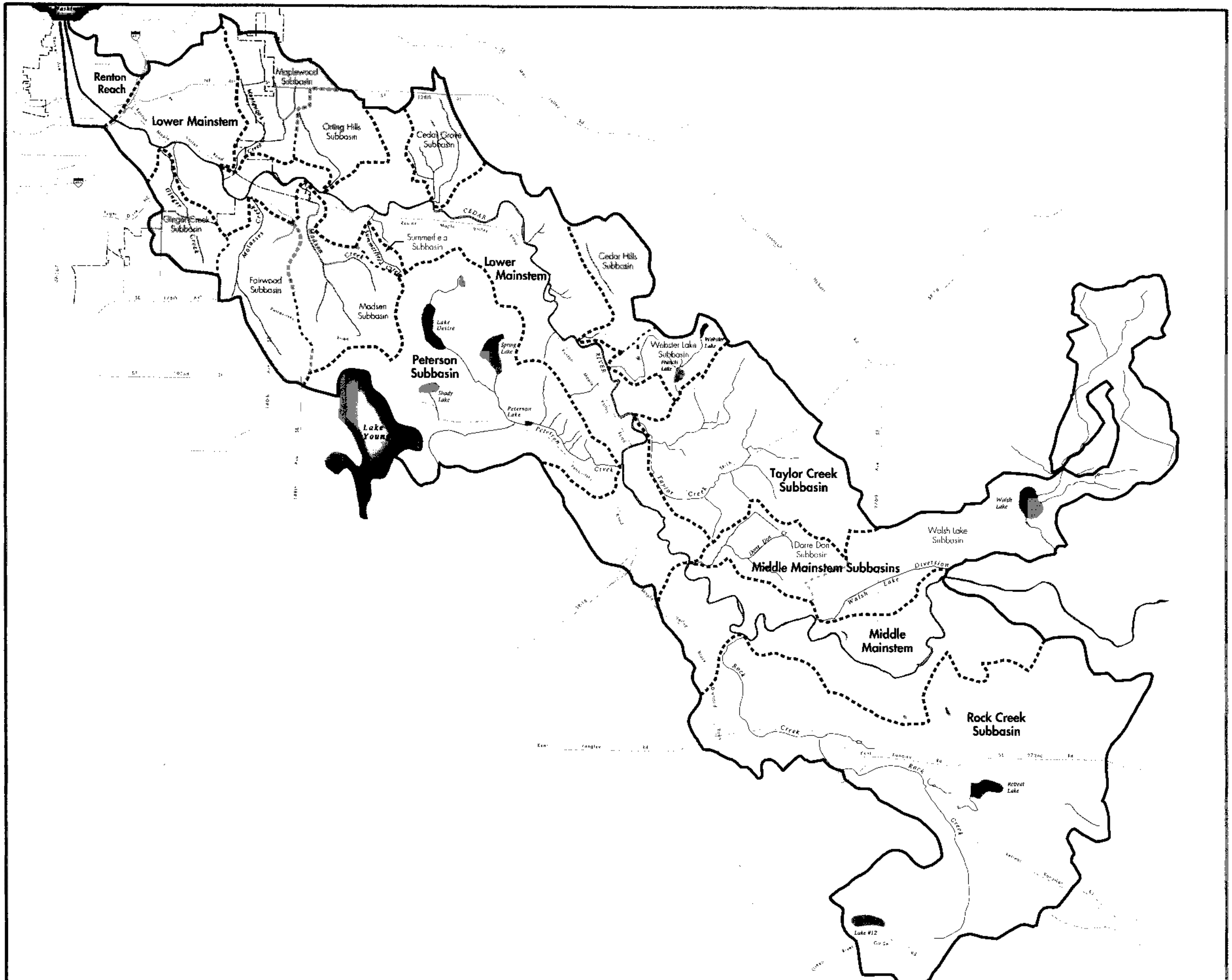
Map 15 Small Quantity Hazardous Waste Generators and Underground Storage Tanks
Map 16 Sampling and Site Locations
Map 17 Renton Reach Subbasin Conditions
Map 18 Lower Cedar River Mainstem Conditions

Lower Cedar River Subbasins

- **Map 19** Ginger Creek Subbasin Conditions
- **Map 20** Maplewood and Orting Hills Subbasin Conditions
- **Map 21** Molasses Creek Subbasin Conditions
- **Map 22** Madsen Creek and Summerfield Subbasin Conditions
- **Map 23** Cedar Grove Subbasin Conditions
- **Map 24** Cedar Hills and Webster Lake Subbasin Conditions

Map 25 Middle Cedar River Mainstem and Subbasins Conditions
Map 26 Peterson Creek Subbasin Conditions
Map 27 Taylor Creek Subbasin Conditions
Map 28 Rock Creek Subbasin Conditions


Map 1
Cedar River Drainage
Cedar River Basin Planning Area
Basin Boundary
Basin Planning Area
N
Scale 1: 150,000
LOWER CEDAR RIVER
MIDDLE CEDAR RIVER
UPPER CEDAR RIVER
CITY OF SEATTLE WATERSHED
SNOQUALMIE NATIONAL FOREST
Renton
Issaquah
Snoqualmie
North Bend
Newport Hills
Black Diamond
Maple Valley
Covington
Landsburg
Hobart
Cedar Falls
Rattlesnake Lake
Chester Morse Lake
Lake Desire
Shady Lake
Lake Youngs
Lake Meridian
Lake Morton
Lake Sawyer
Howard Hanson Reservoir
Eagle Lake
Green River
Snoqualmie River
Raging River
Issaquah Creek
Taylor Creek
Rock Creek
Walsh Lake
Webster Lake
Francis Lake
Peterson Lake
Rattlesnake Mountain
Tiger Mtn
Grouse Ridge
Twin Falls State Park
Flaming Geyser State Park
Nolte State Park
Kanaskat
Palmer
Ravensdale
Georgetown
Kangley
Selleck
Cumberland
Enumclaw
Hobart Road
Cedar Grove
Fairwood
Mirrormont
Tokul
Preston
Upper Preston
High Point
Ghost Point
Mt Lindsay
Findley Lake
Yakima Pass
Meadow Pass
Stampede Pass
Mt Gardner
McClellan Butte
Mt Washington
Humpback Mtn
Annette Lake
Bandera
Rockdale
Cougar Mtn
Sugarloaf Mtn
Enumclaw Mountain
Muckleshoot Indian Reservation
King County
Pierce County



Map 2

Subbasin Boundaries

Cedar River Basin Planning Area

- Stream
- Lake/River
- Basin Boundary
- Subbasin Boundary
- Renton City Boundary
- Lower Mainstem Subbasins

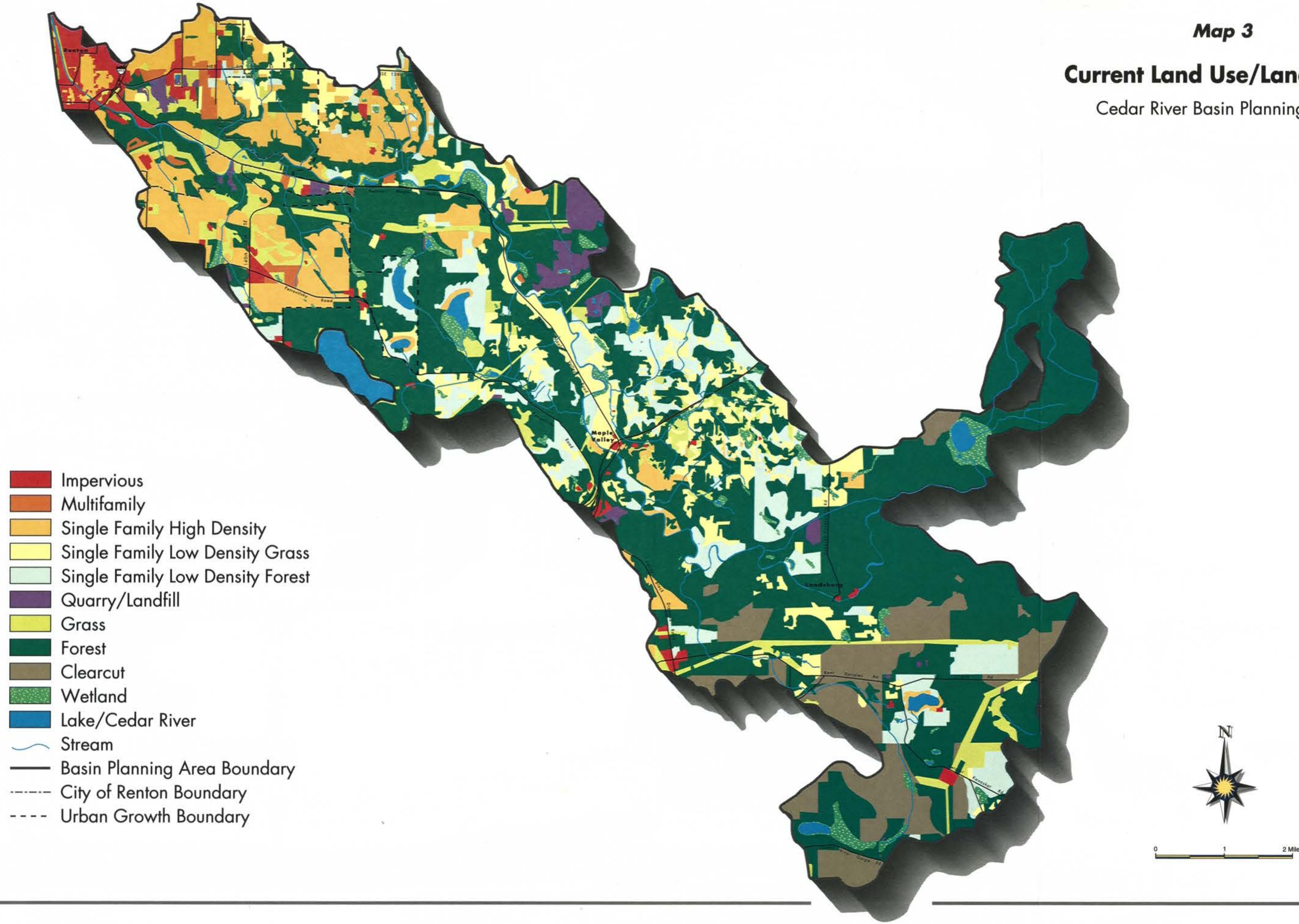
N

0 1 2 Miles

Map 3

Current Land Use/Land Cover

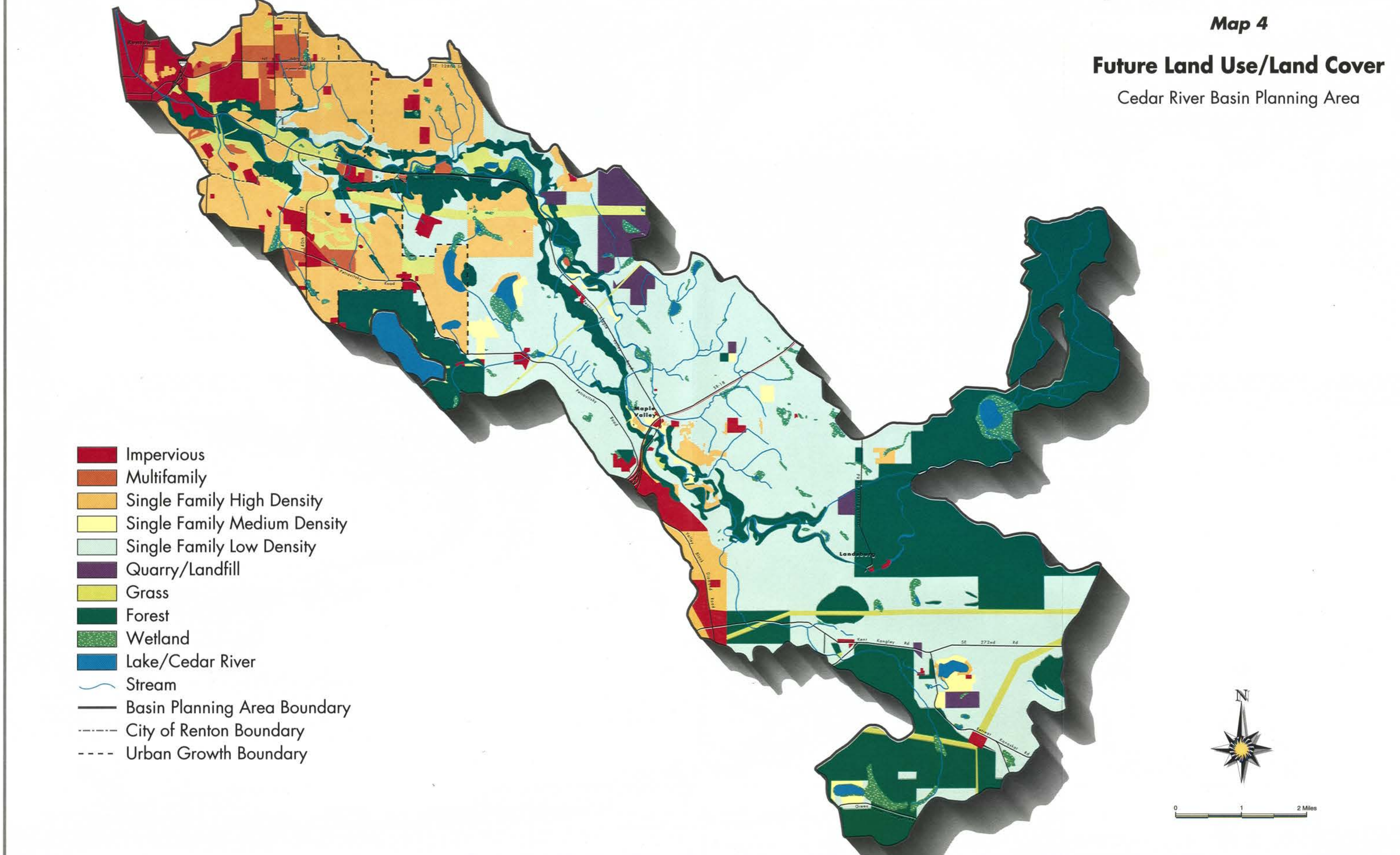
Cedar River Basin Planning Area

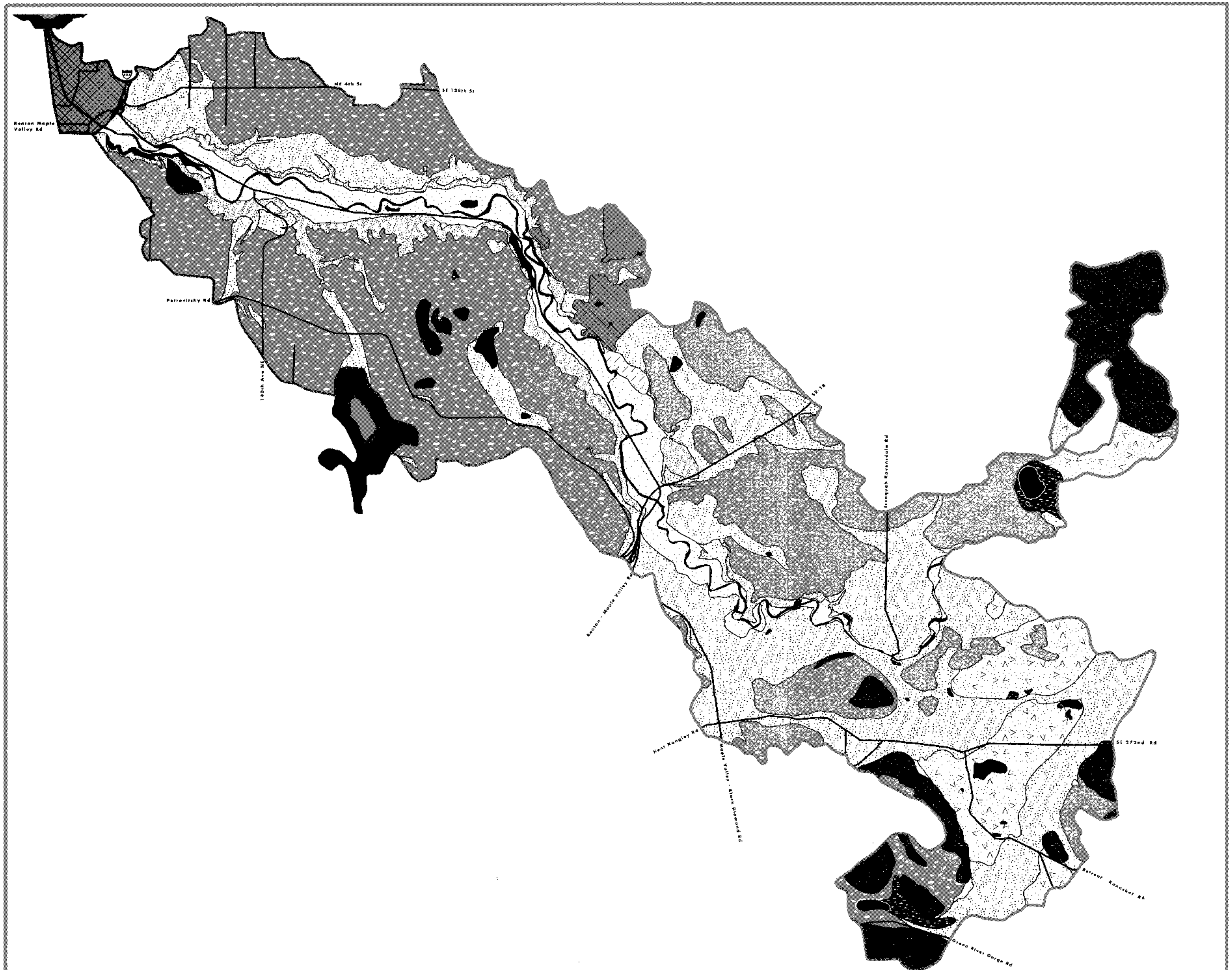


Map 4

Future Land Use/Land Cover

Cedar River Basin Planning Area





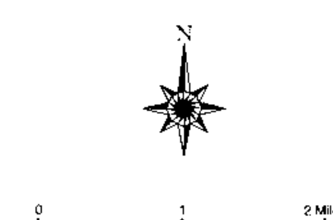
Map 5

Geology

Cedar River Basin Planning Area

- Basin Boundary
- Cedar River/Lake
- Wetland (Qw)
- Modified
- Landslide (Qls, Qmw)
- Alluvium (Qyal, Qf)
- Older Alluvium (Qoal)
- Recessional Outwash (Qvr)
- Ice Contact (Qvi)
- Till (Qvt)
- Advance Outwash & Older Deposits (Qva, Qpf)
- Bedrock (Ti, Ts, Tp, br)

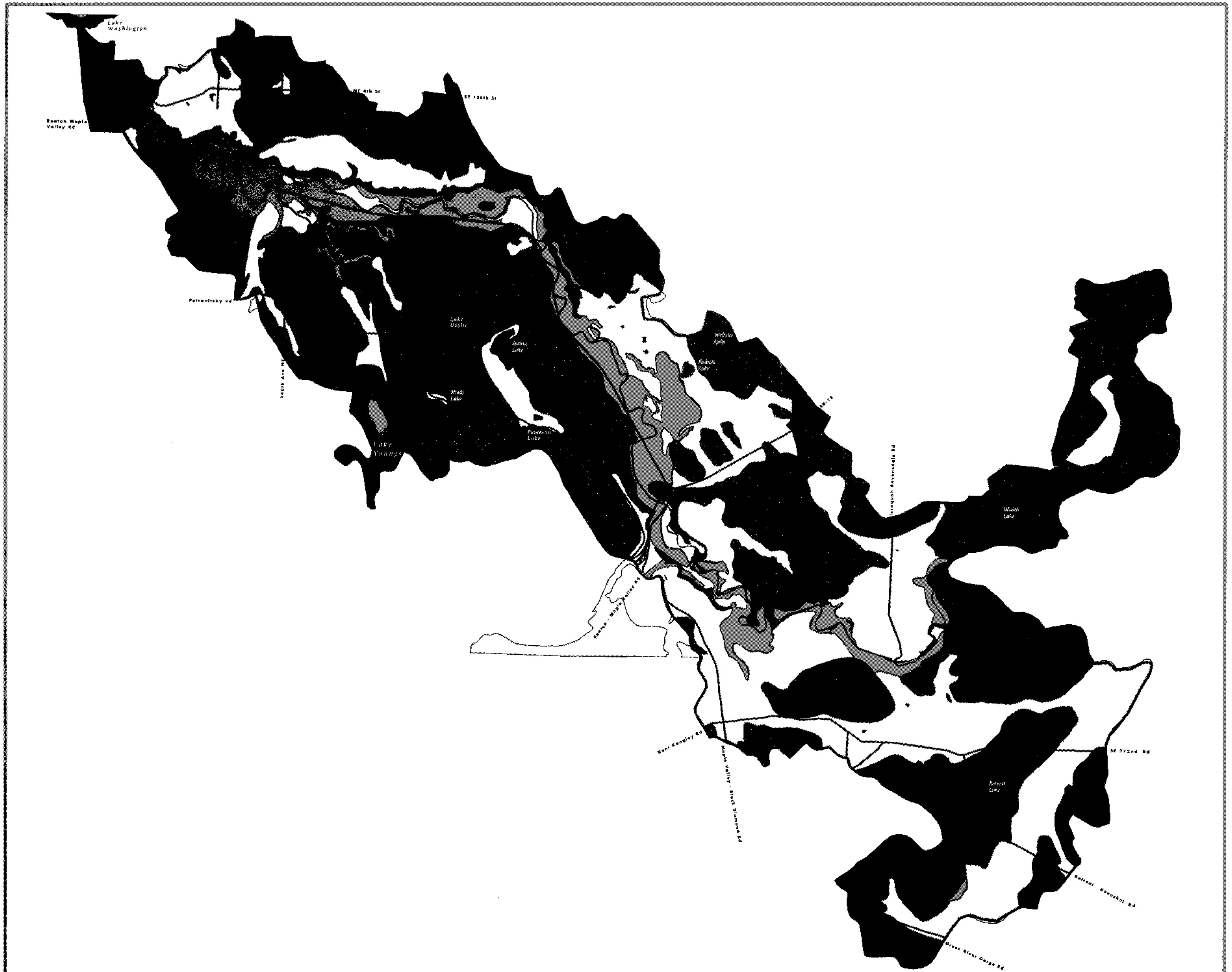
(Symbols in parentheses refer to unit description in text)



Map 6

Recharge Areas

Cedar River Basin Planning Area



- Basin Boundary
- Cedar River/Lake
- High Recharge
- Moderate Recharge
- Low Recharge

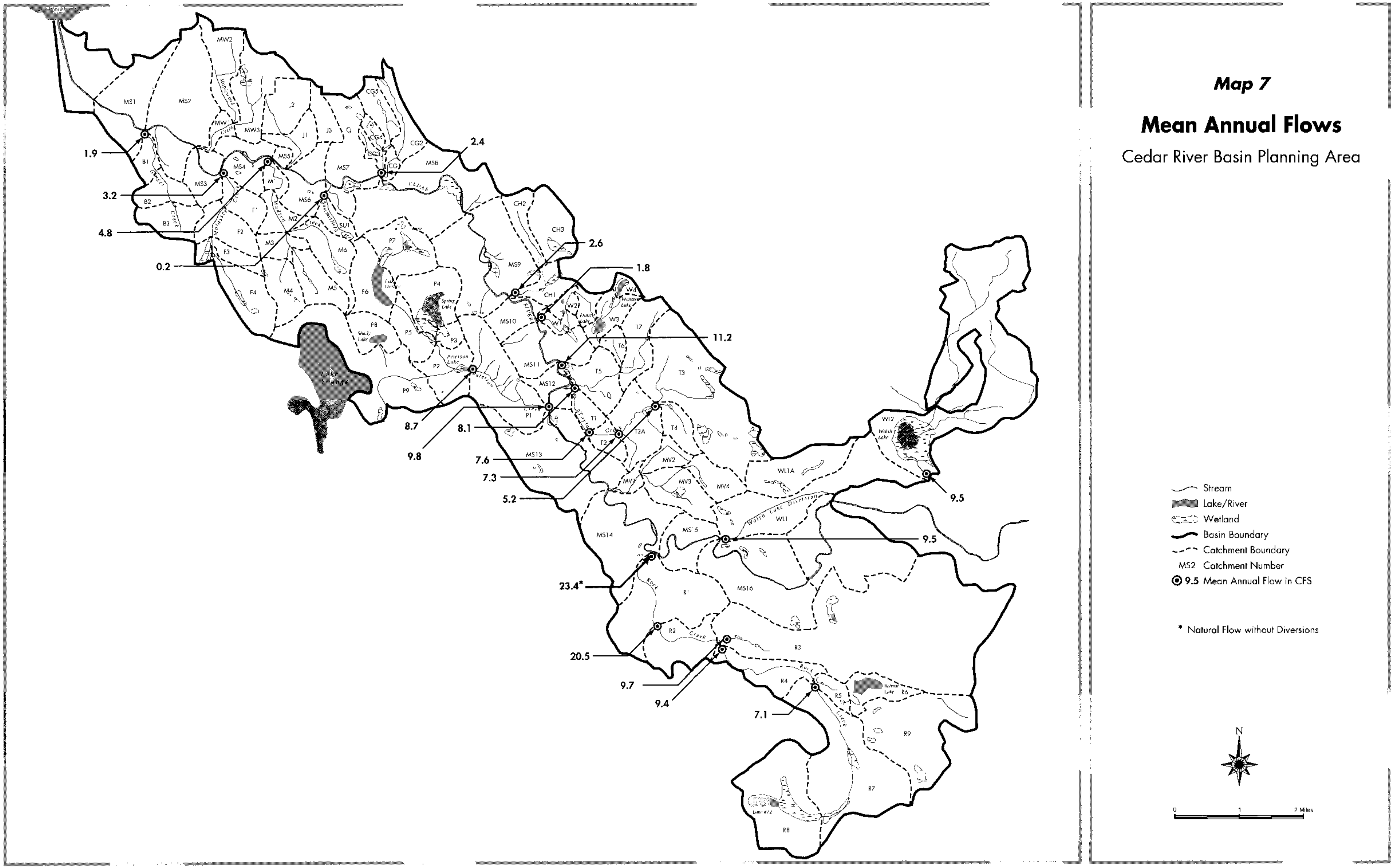
N

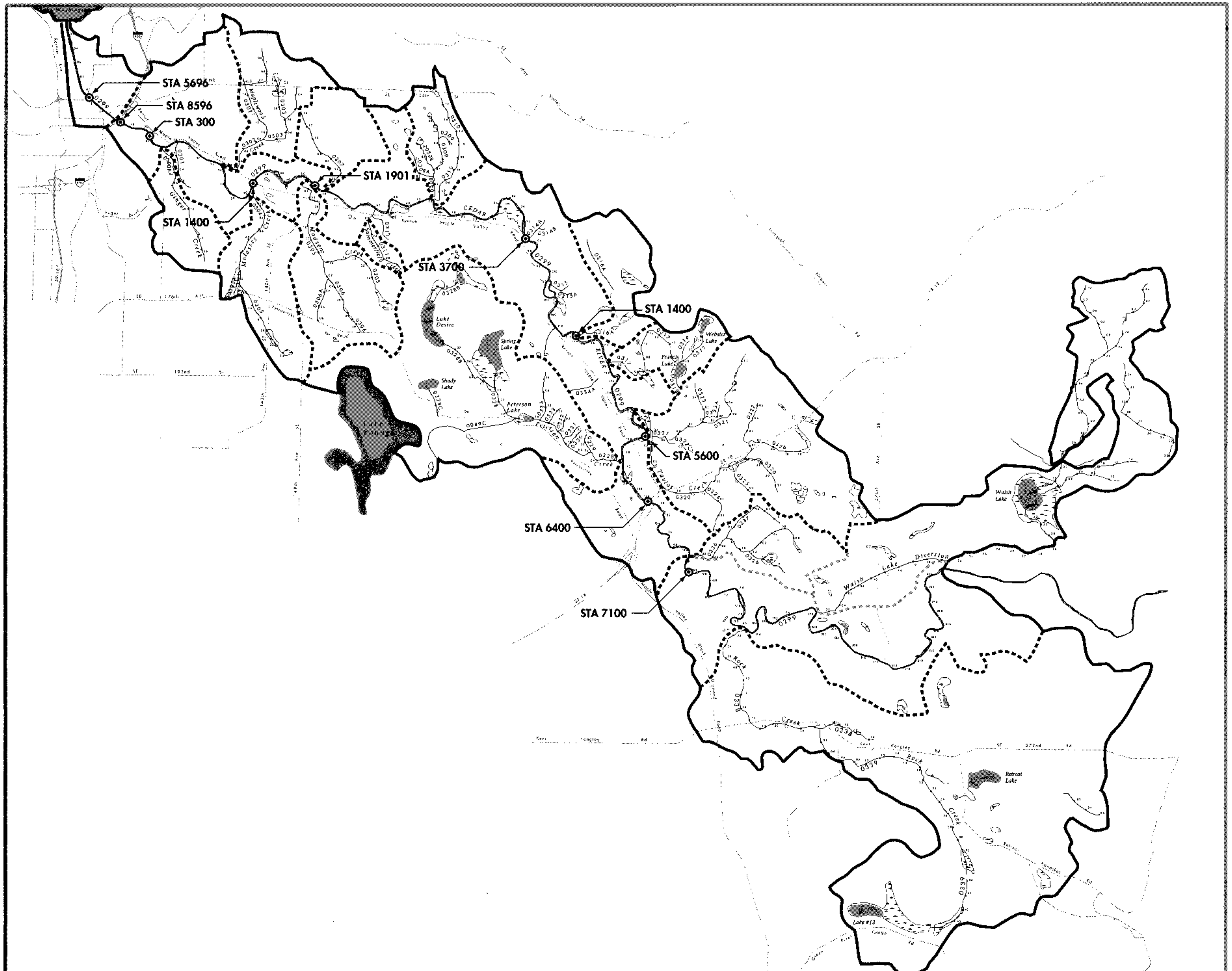
0 1 2 Miles

Map 7

Mean Annual Flows

Cedar River Basin Planning Area





Map 8

Locations of Selected HEC-2 Cross Sections

Cedar River Basin Planning Area

Map 9

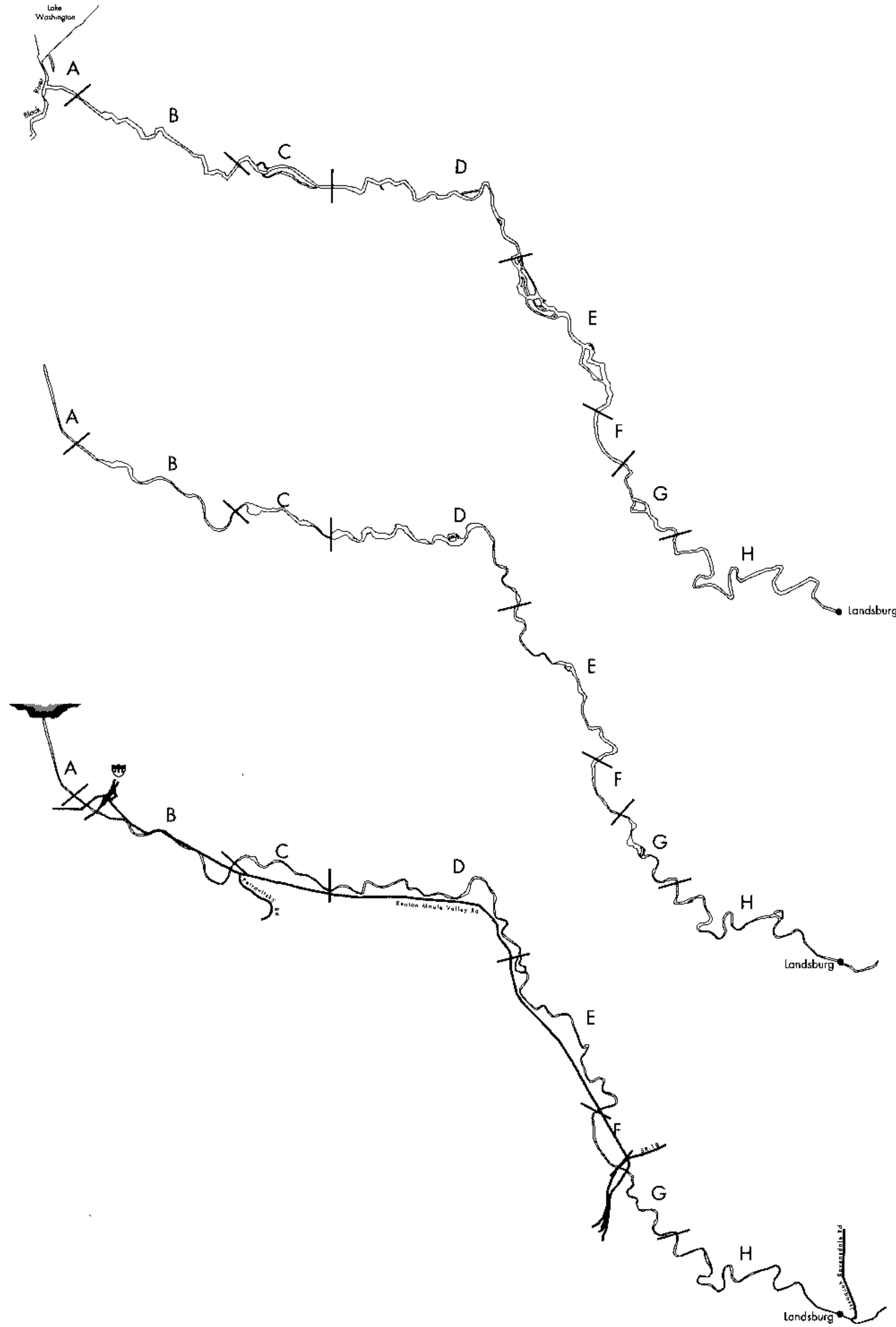
Changes in Lower and Middle Cedar River Channel Pattern

Cedar River Basin Planning Area

Lower and Middle Cedar River in 1865

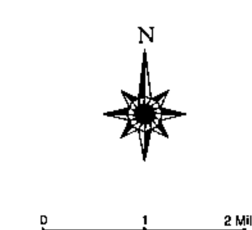
Lower and Middle Cedar River in 1936

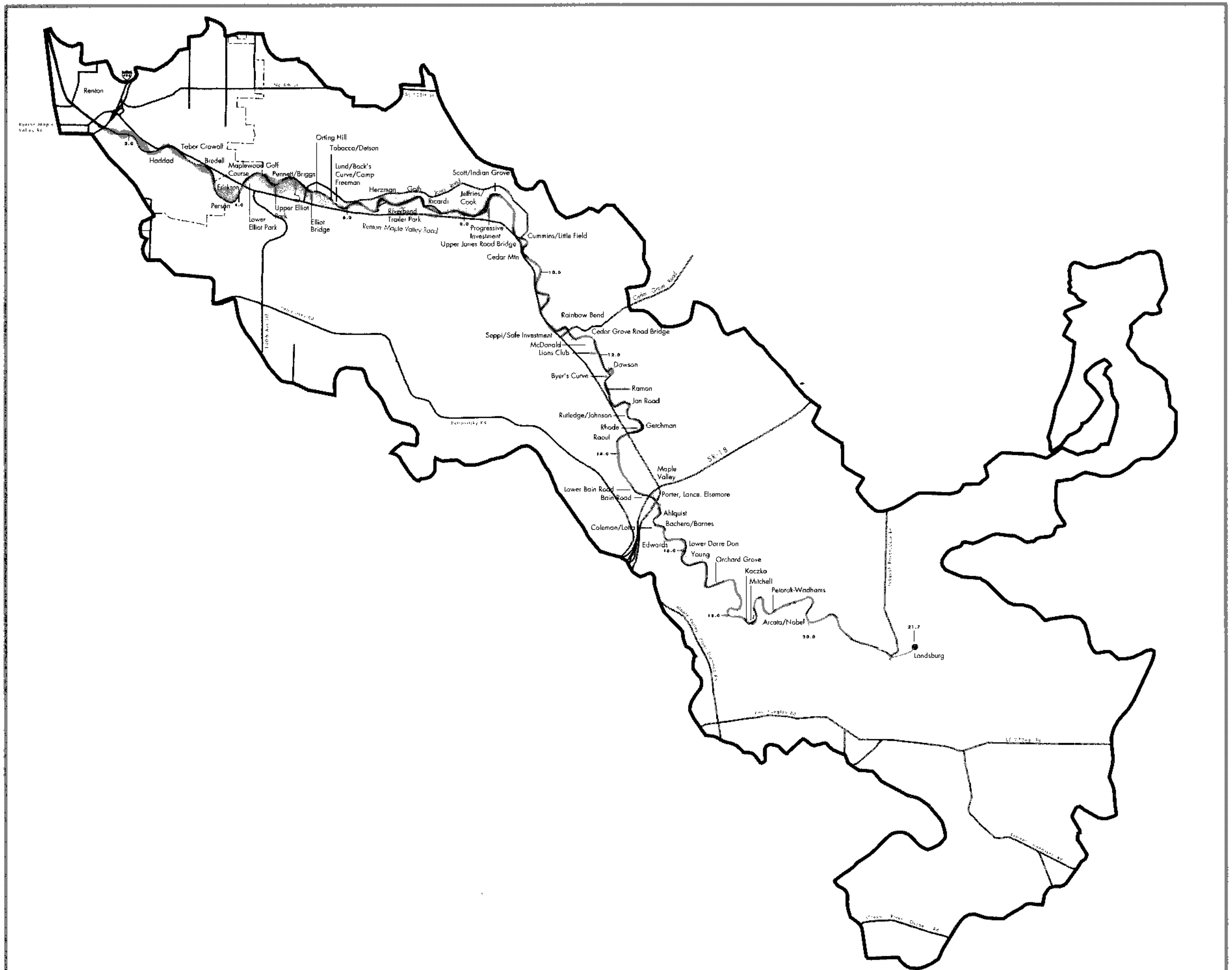
Lower and Middle Cedar River in 1991



Cedar River

D Referenced Stream Reaches





Map 10

Revetment Location & Meander Belt of the Lower & Middle Cedar River since 1865

Cedar River Basin Planning Area

Basin Boundary
Cedar River
2.0 River Mile
River Migration Zone
Revetment
Lund Revetment Name
City of Renton Boundary

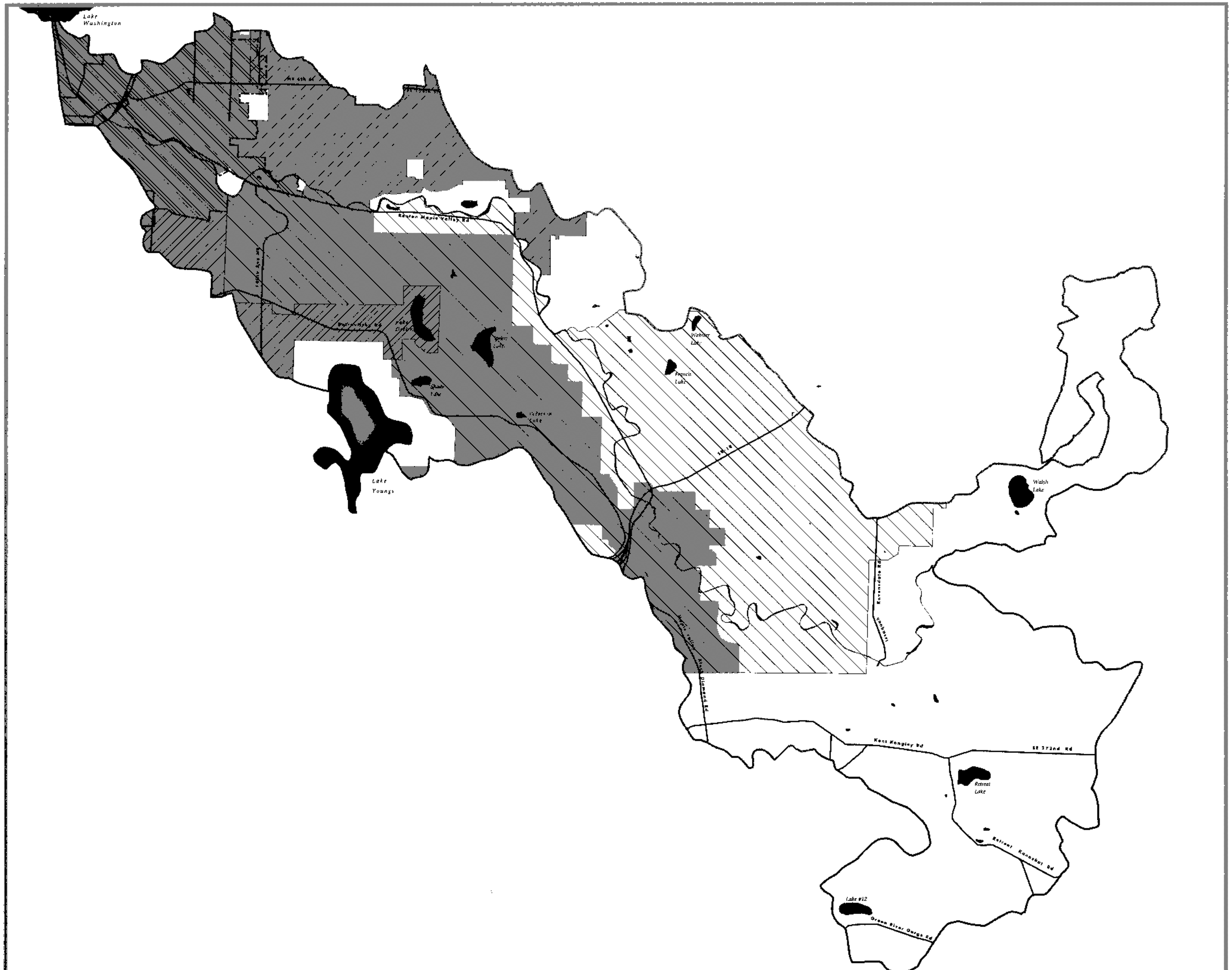
N

0 1 2 Miles

Map 11

Water Supply by Water Districts

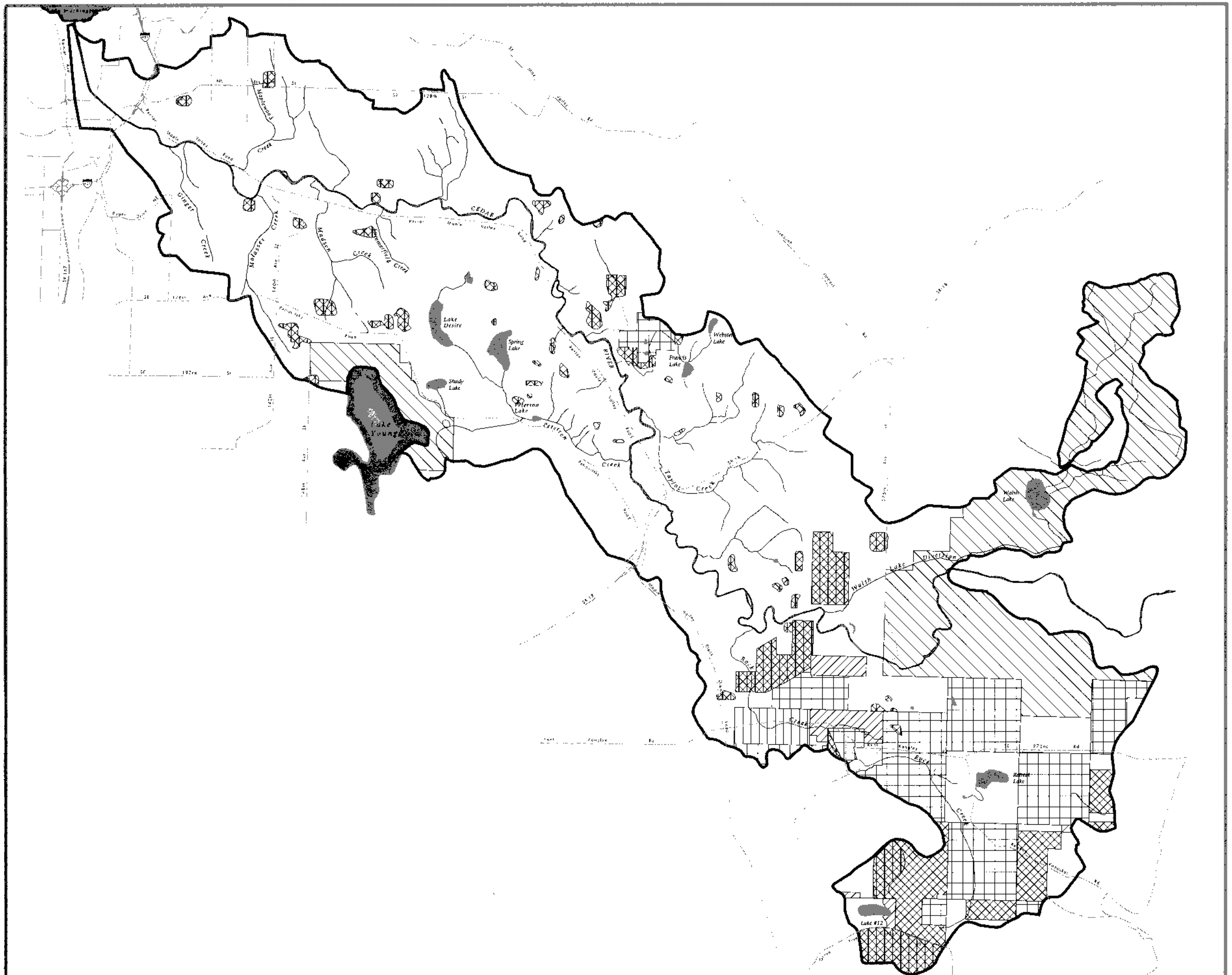
Cedar River Basin Planning Area



- Basin Boundary
- Cedar River/Lake
- Existing Water Service Areas
- City of Renton Boundary
- City of Renton Planning Area
- Water District No. 90 Planning Area
- Cedar River Water & Sewer Dist. Planning Area
- Soos Creek Water & Sewer Dist. Planning Area

N

0 1 2 Miles



Map 12

Forest Reference, 1992

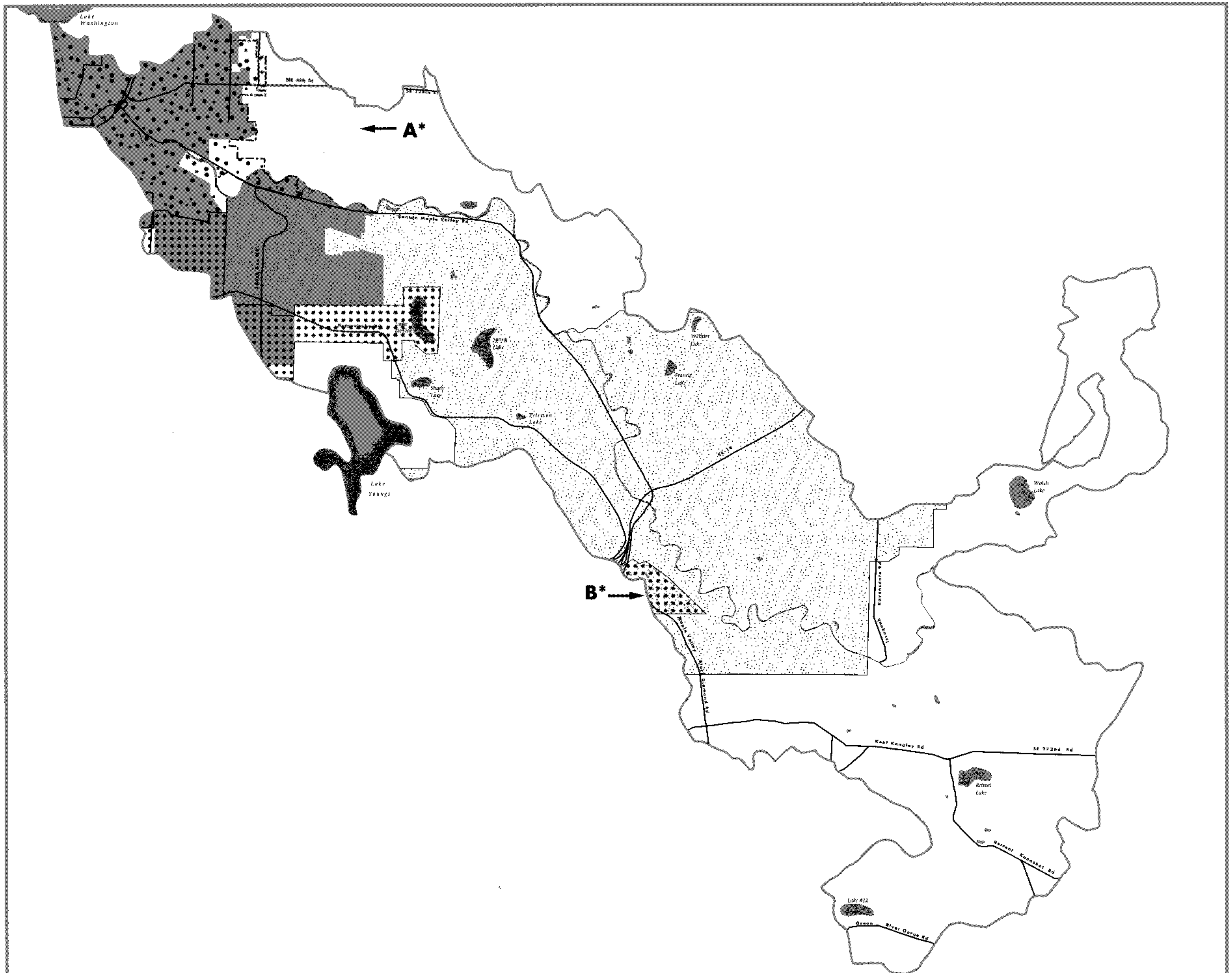
Cedar River Basin Planning Area

- Stream
- Lake/River
- Basin Boundary
- Plum Creek
- City of Seattle
- Weyerhauser
- Palmer Coking Company
- City of Kent
- Clearings (1985-1989)

USDA Puget Sound Cooperative
River Basin Team

N

0 1 2 Miles



Map 13

Sewer Service Areas

Cedar River Basin Planning Area

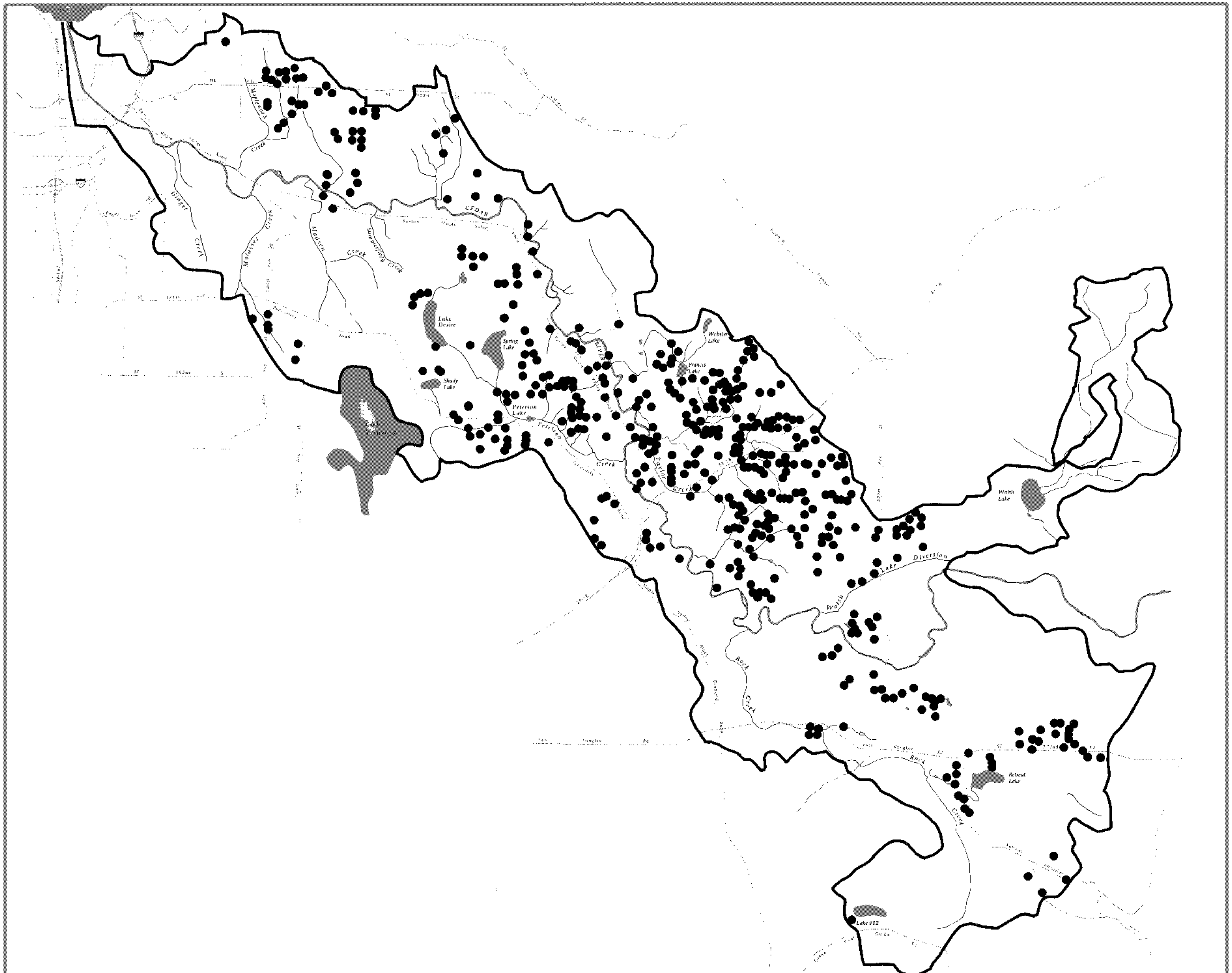
- Basin Boundary
- Cedar River/Lake
- Existing Sewer Service
- Proposed Expansion of Sewer Service
- City of Renton Boundary
- City of Renton Sewer Planning Area
- Cedar River Water & Sewer Dist. PLanning Area
- Soos Creek Water & Sewer Dist. Planning Area

A* Proposed expansion of sewer service by the City of Renton.

B* Proposed sewer service in area B would be serviced by the Soos Creek Water & Sewer District.

N

0 1 2 Miles



Map 14

Livestock-keeping Locations, 1992

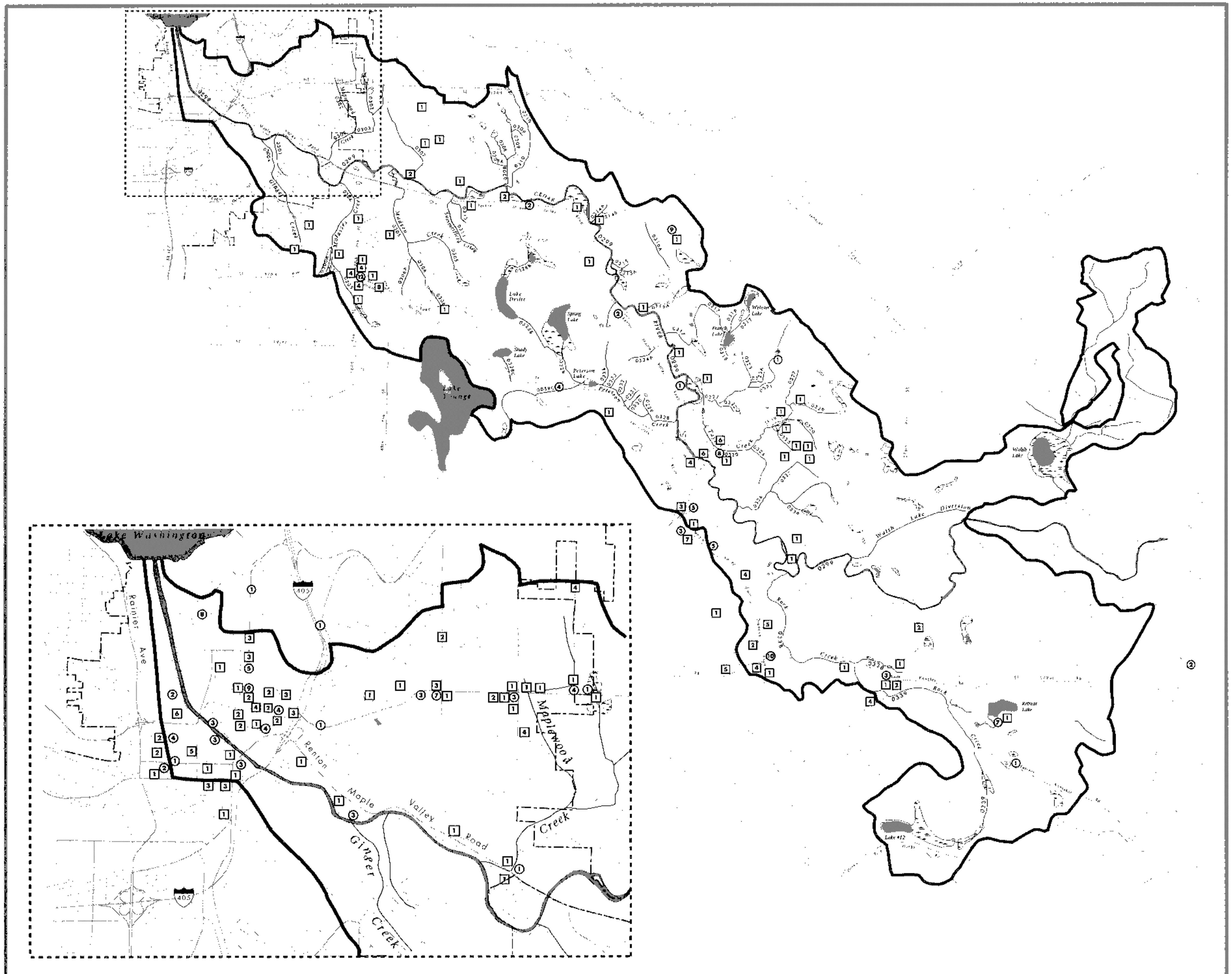
Cedar River Basin Planning Area

- Stream
- Lake/River
- Basin Boundary
- Livestock-keeping Location

USDA Puget Sound Cooperative River Basin Team

N

0 1 2 Miles



Map 15

Small Quantity Hazardous Waste Generators & Underground Storage Tanks

Cedar River Basin Planning Area

- 0299 Stream & Stream Number
- Lake/River
- Wetland
- Basin Boundary
- Renton City Boundary
- ⑦ Location & Number of Underground Storage Tanks
- ☐1 Location & Number of Small Quantity Hazardous Waste Generators

Survey Completed in 1991

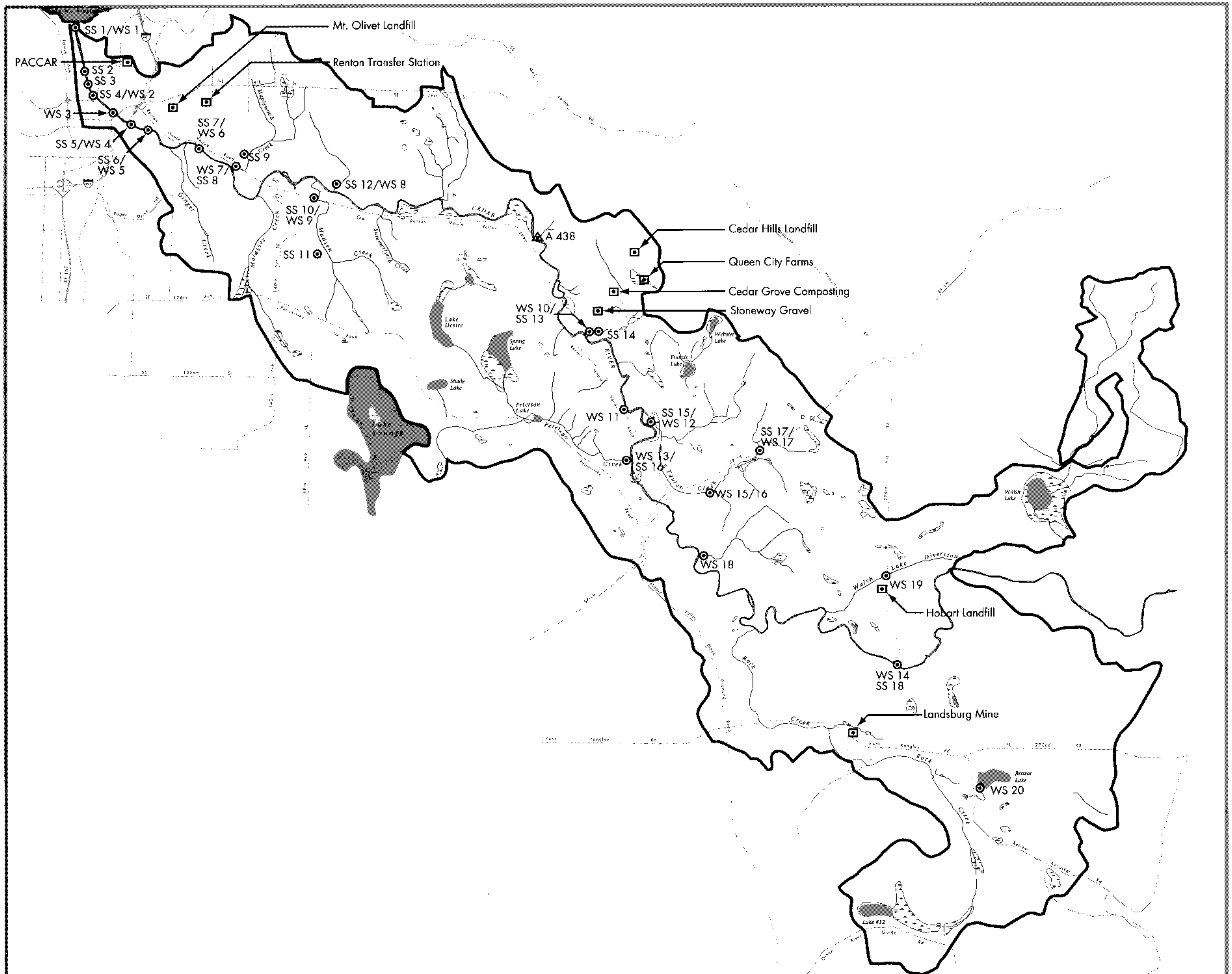
N

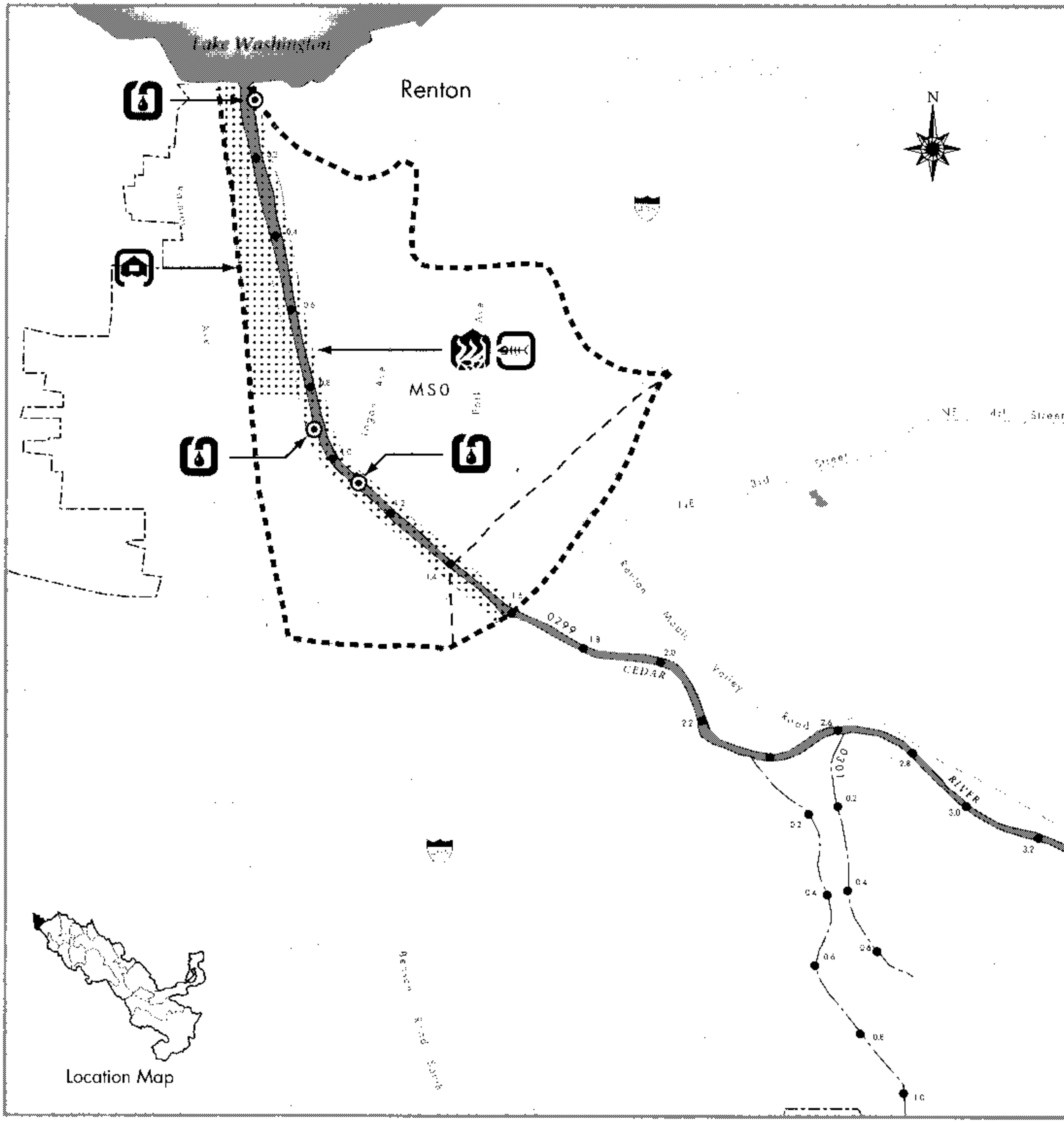
0 1 2 Miles

Map 16

Sampling and Site Locations

Cedar River Basin Planning Area





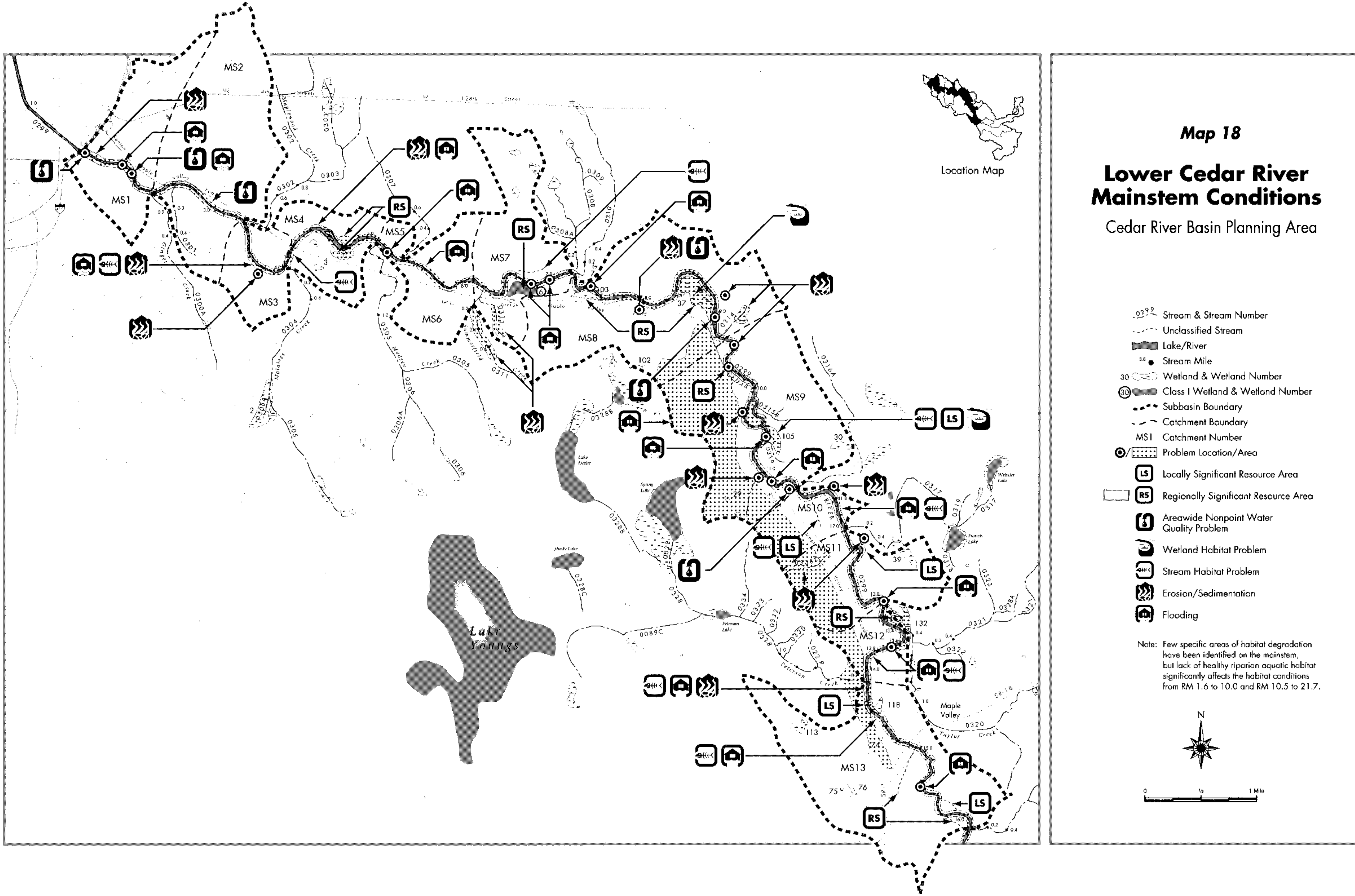
Renton Reach Subbasin Conditions

Map 17

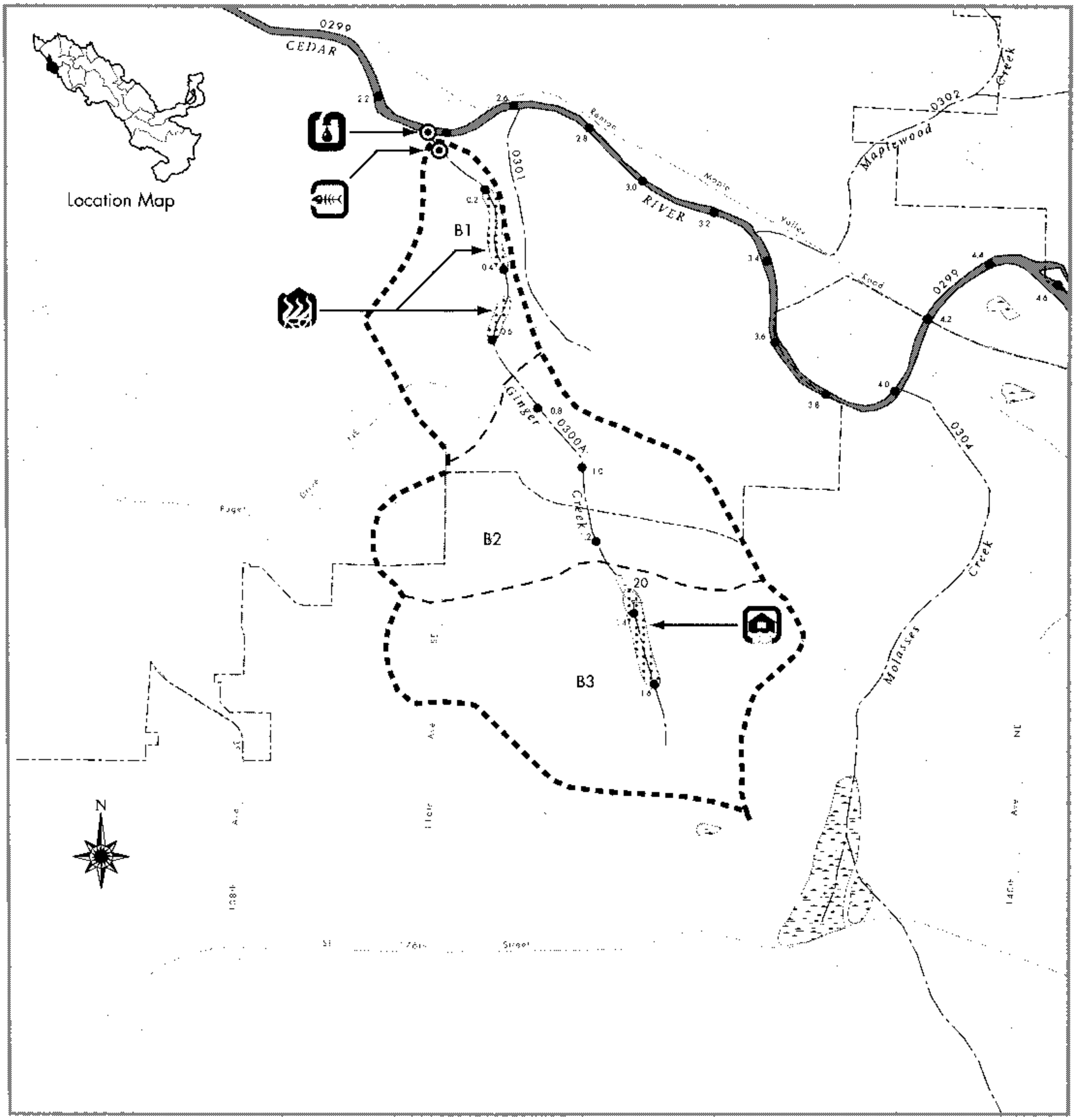
Cedar River Basin Planning Area

0299 Stream & Stream Number
Lake/River
36 Stream Mile
Wetland
Subbasin Boundary
Catchment Boundary
MSO Catchment Number
Renton City Boundary
Problem Location/Area
Stream Habitat Problem
Erosion/Sedimentation
Flooding
Areawide Nonpoint Water Quality Problem

0 ¼ ½ Mile



Map 18
Lower Cedar River Mainstem Conditions
Cedar River Basin Planning Area
Location Map
Stream & Stream Number
Unclassified Stream
Lake/River
Stream Mile
Wetland & Wetland Number
Class I Wetland & Wetland Number
Subbasin Boundary
Catchment Boundary
MS1 Catchment Number
Problem Location/Area
LS Locally Significant Resource Area
RS Regionally Significant Resource Area
Areawide Nonpoint Water Quality Problem
Wetland Habitat Problem
Stream Habitat Problem
Erosion/Sedimentation
Flooding
Note: Few specific areas of habitat degradation have been identified on the mainstem, but lack of healthy riparian aquatic habitat significantly affects the habitat conditions from RM 1.6 to 10.0 and RM 10.5 to 21.7.
N
0 ½ 1 Mile
MS1
MS2
MS3
MS4
MS5
MS6
MS7
MS8
MS9
MS10
MS11
MS12
MS13
Lake Youngs
Maple Valley



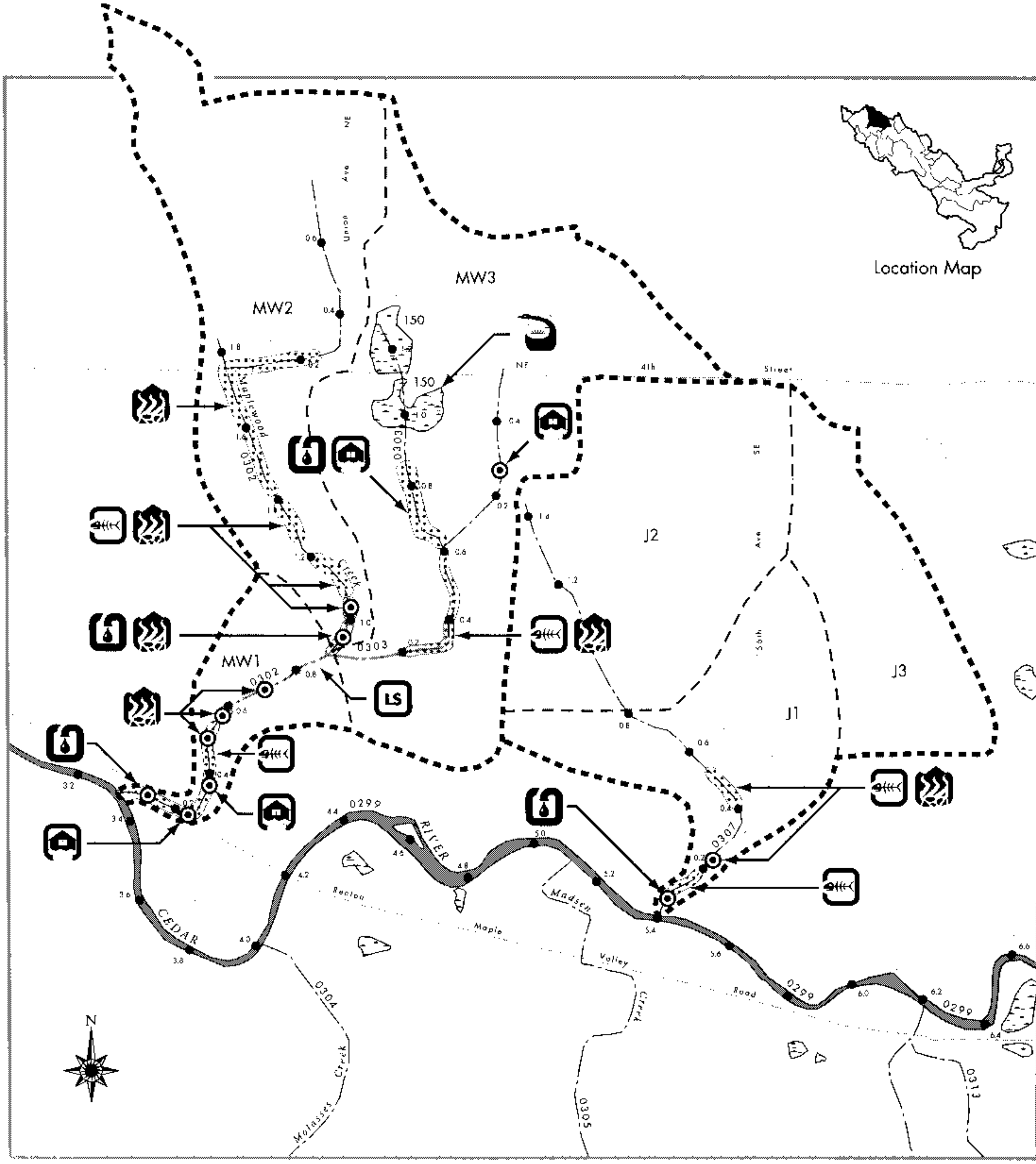
Ginger Creek Subbasin Conditions

Map 19

Cedar River Basin Planning Area

- 0299 Stream & Stream Number
- Lake/River
- 36 Stream Mile
- 5 Wetland & Wetland Number
- Subbasin Boundary
- Catchment Boundary
- B1 Catchment Number
- Problem Location/Area
- Areawide Nonpoint Water Quality Problem
- Stream Habitat Problem
- Sedimentation/Erosion
- Flooding
- Renton City Boundary

0 ¼ ½ Mile



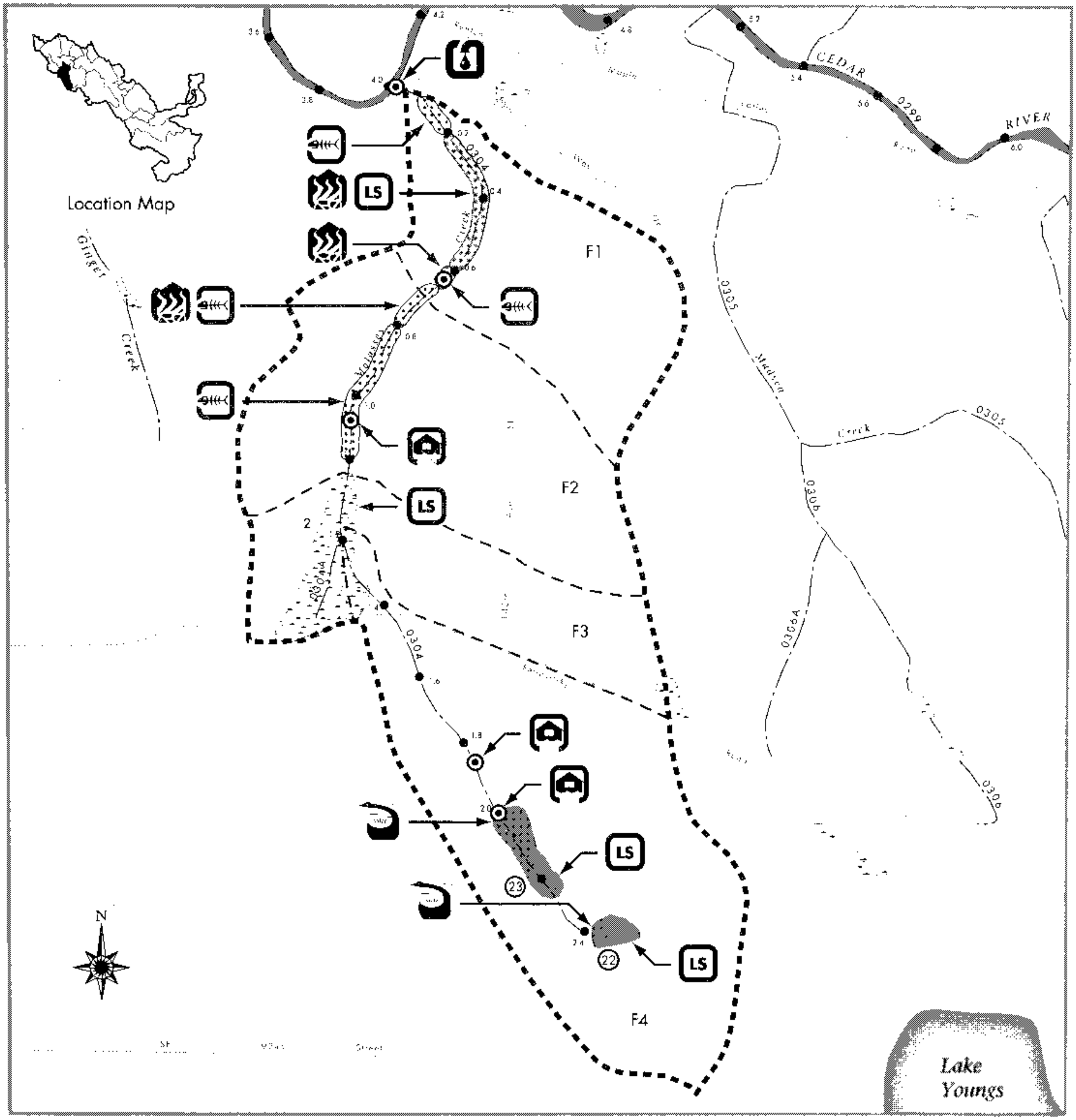
Maplewood & Orting Hills Subbasin Conditions

Map 20

Cedar River Basin Planning Area

- 0299 Stream & Stream Number
- Lake/River
- 3.6 Stream Mile
- 5 Wetland & Wetland Number
- Subbasin Boundary
- Catchment Boundary
- MW1 Catchment Number
- Problem Location/Area
- Areawide Nonpoint Water Quality Problem
- Wetland Habitat Problem
- Stream Habitat Problem
- Erosion/Sedimentation
- LS Locally Significant Resource Area
- Flooding

0 ¼ ½ Mile

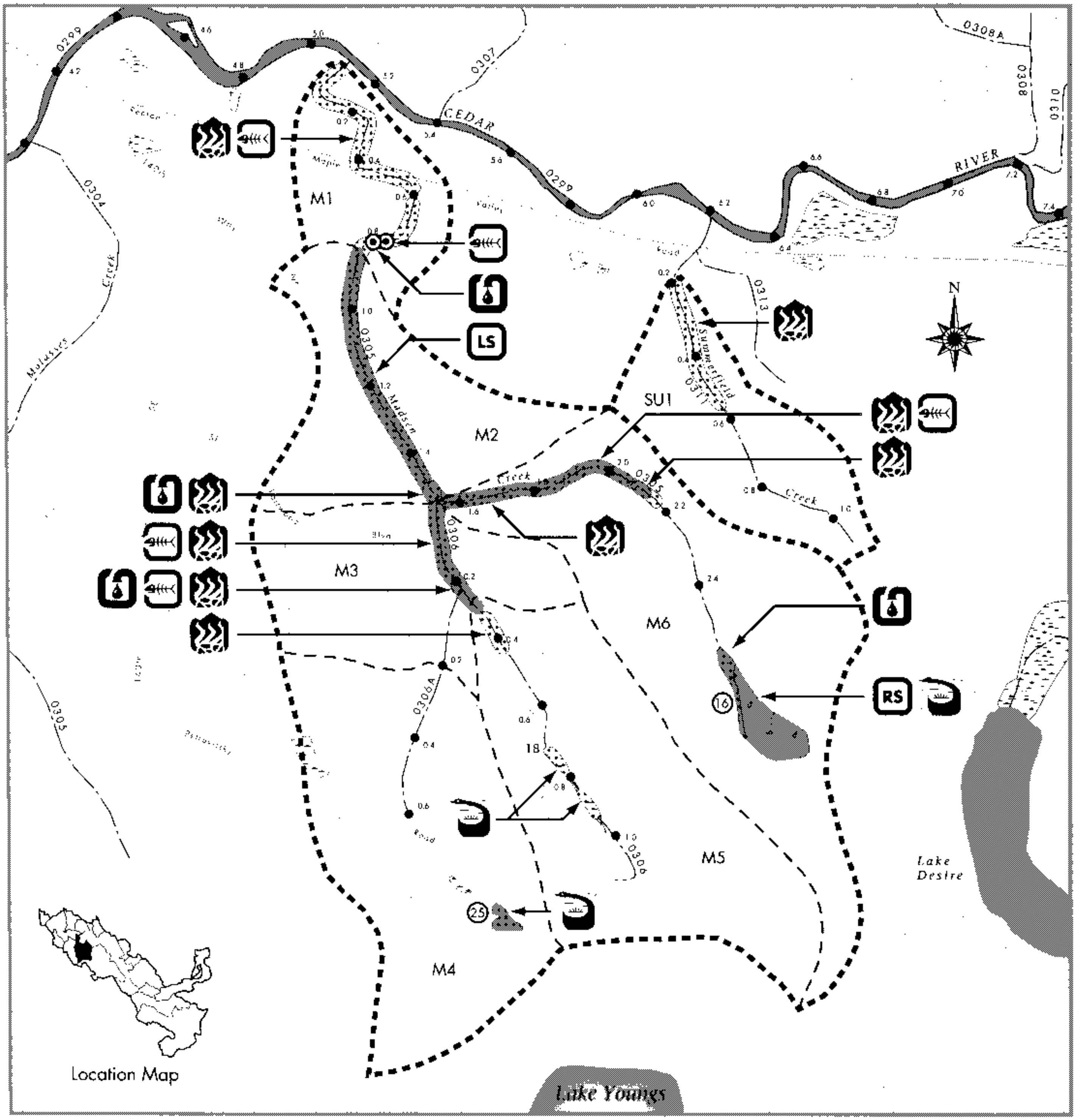


Molasses Creek Subbasin Conditions

Map 21

Cedar River Basin Planning Area

Stream & Stream Number
Lake/River
Stream Mile
Wetland & Wetland Number
Class I Wetland & Number
Subbasin Boundary
Catchment Boundary
F1 Catchment Number
Problem Location/Area
Areawide Nonpoint Water Quality Problem
Wetland Habitat Problem
Stream Habitat Problem
Locally Significant Resource Area
Erosion/Sedimentation
Flooding



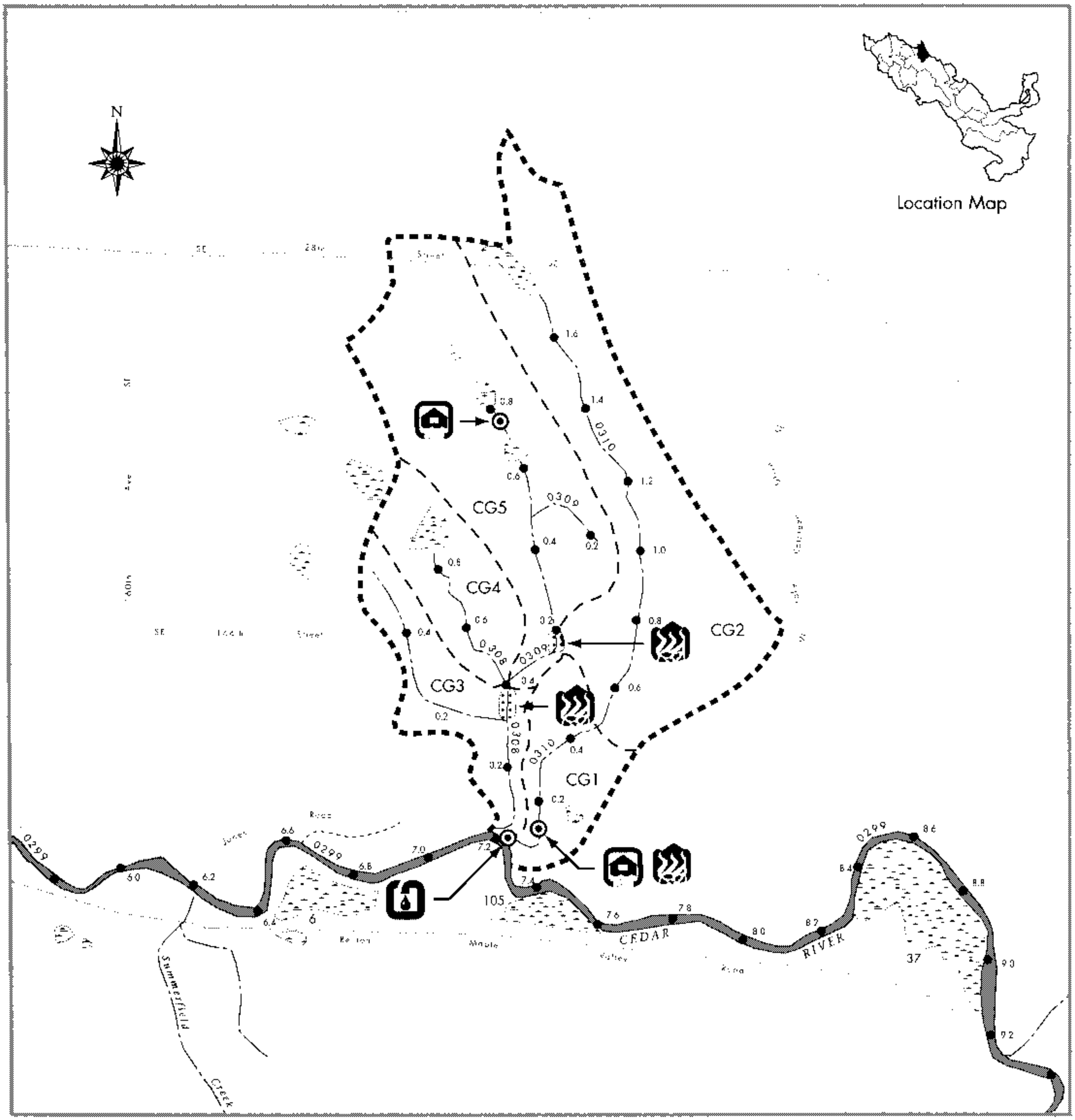
Madsen Creek & Summerfield Subbasin Conditions

Map 22

Cedar River Basin Planning Area

- Stream & Stream Number
- Lake/River
- Stream Mile
- Wetland & Wetland Number
- Class I Wetland & Number
- Subbasin Boundary
- Catchment Boundary
- M1 Catchment Number
- Problem Location/Area
- Areawide Nonpoint Water Quality Problem
- Wetland Habitat Problem
- Stream Habitat Problem
- Locally Significant Resource Area
- Regionally Significant Resource Area
- Erosion/Sedimentation
- Flooding

0 ¼ ½ Mile



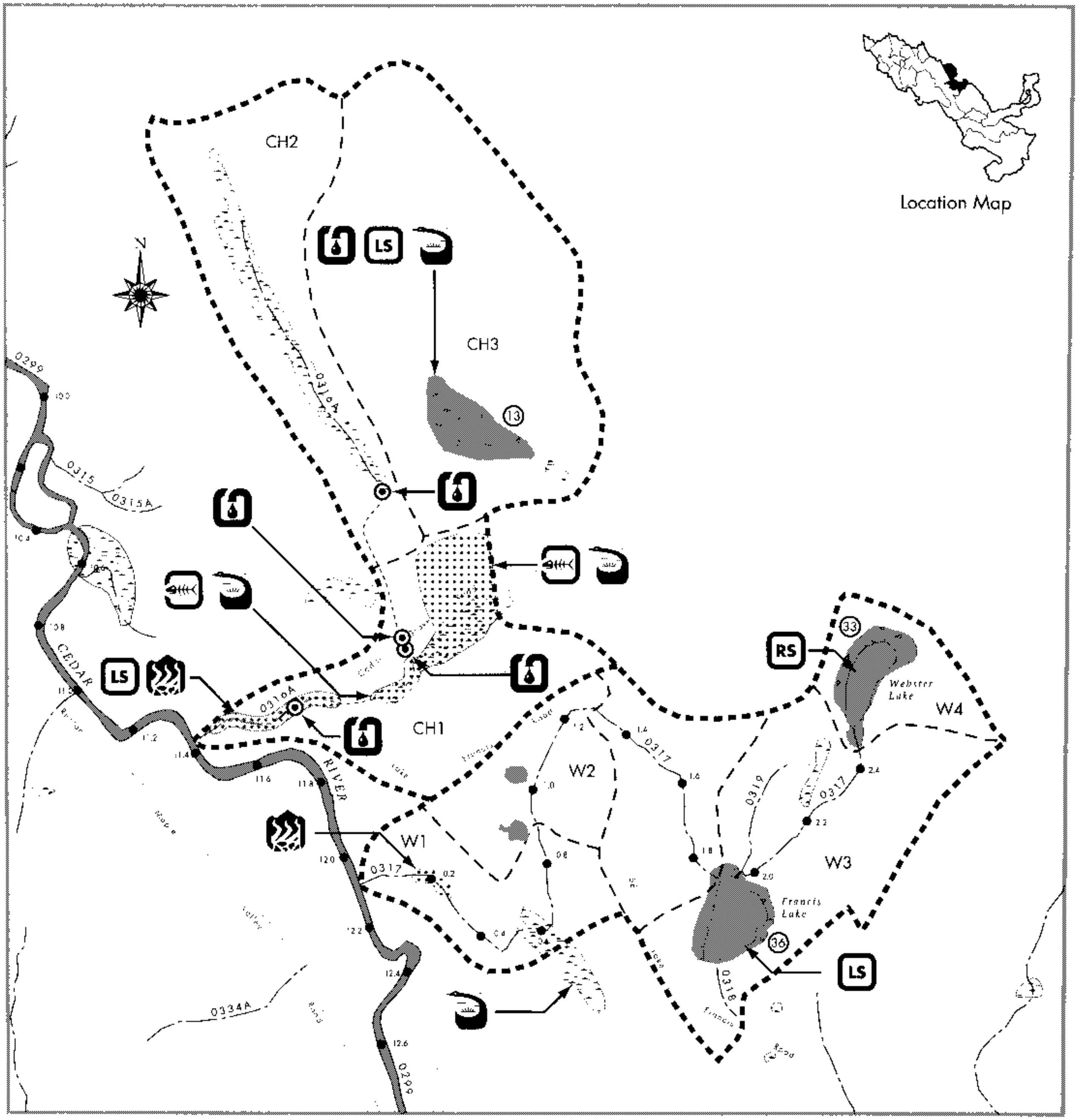
Cedar Grove Subbasin Conditions

Map 23

Cedar River Basin Planning Area

- 0299 Stream & Stream Number
- Unclassified Stream
- Lake/River
- 3.6 Stream Mile
- 5 Wetland & Wetland Number
- Subbasin Boundary
- Catchment Boundary
- CG1 Catchment Number
- Problem Location/Area
- Areawide Nonpoint Water Quality Problems
- Erosion/Sedimentation
- Flooding

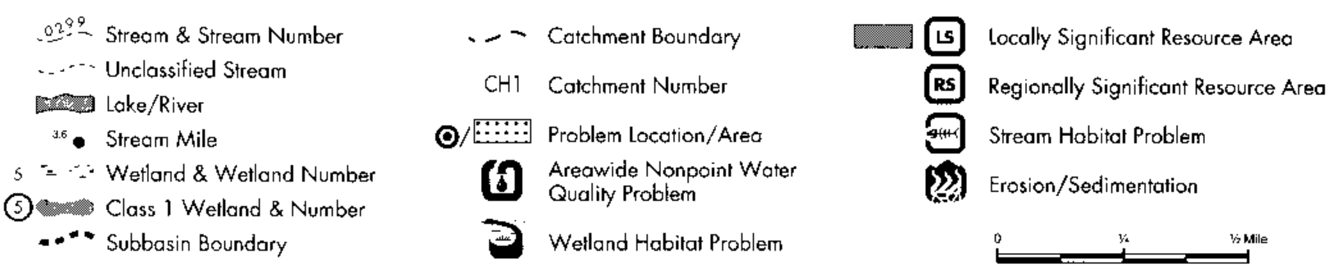
0 ¼ ½ Mile

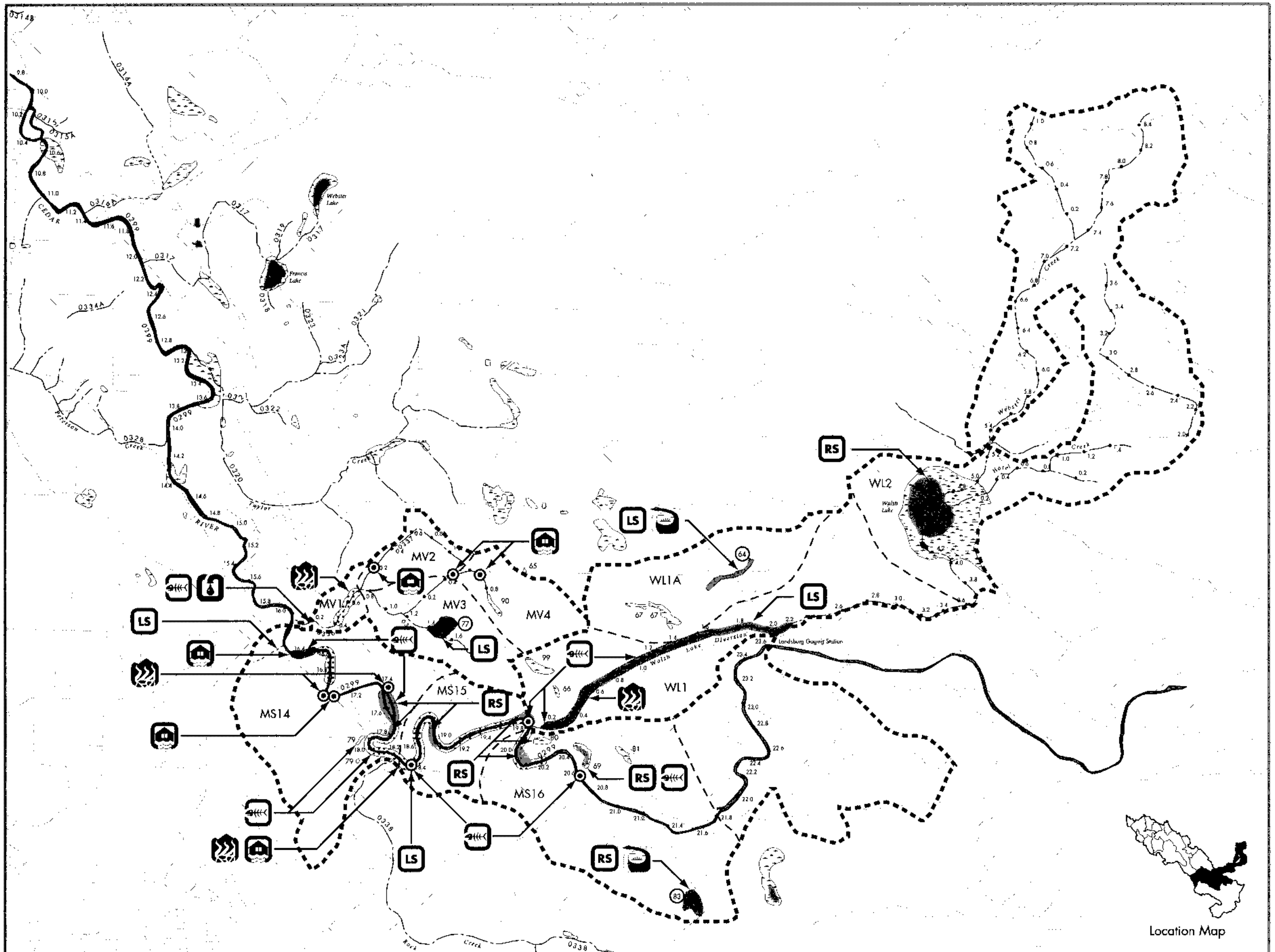


Cedar Hills & Webster Lake Subbasin Conditions

Map 24

Cedar River Basin Planning Area





Map 25

Middle Cedar River Mainstem & Subbasins* Conditions

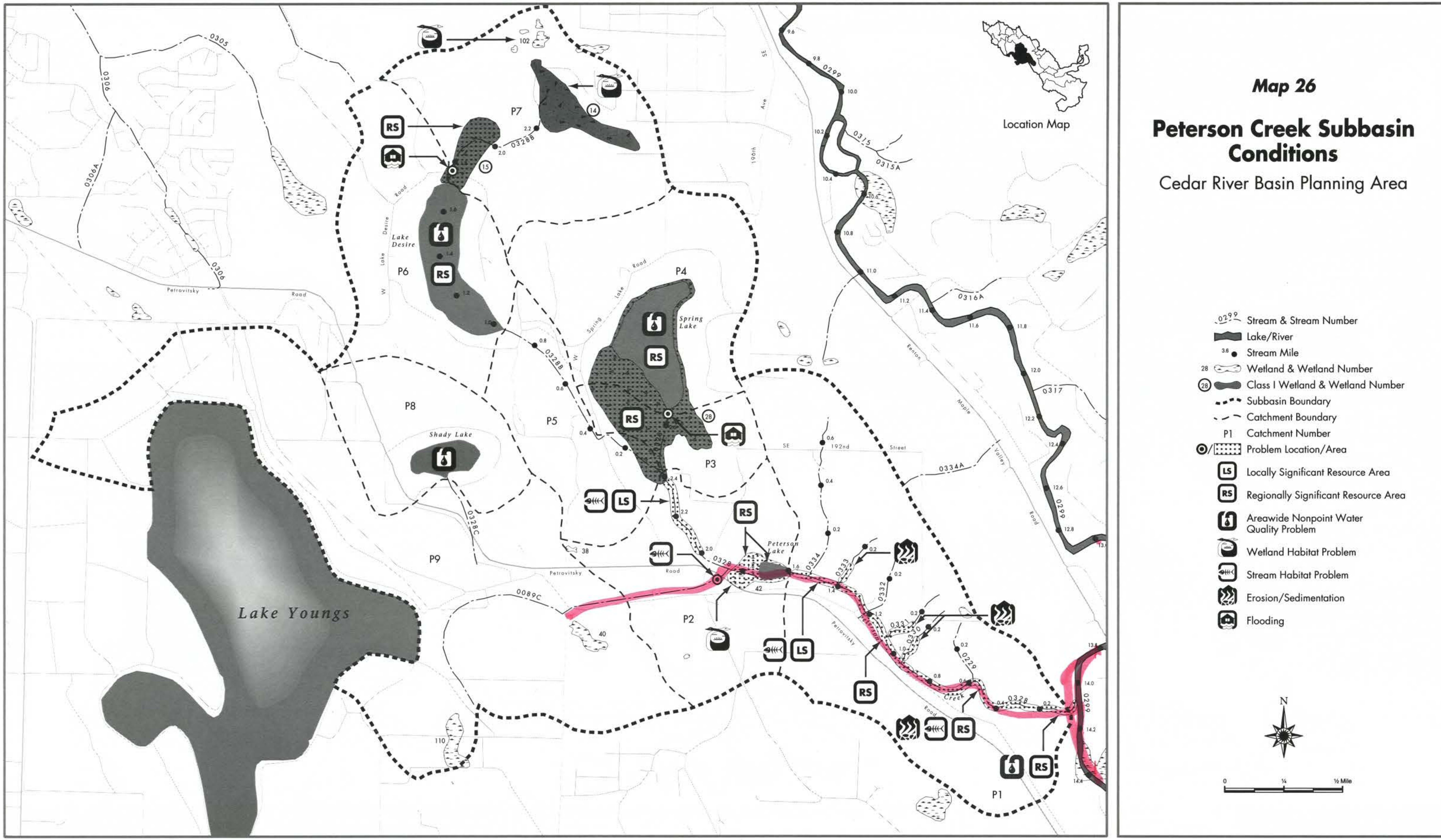
Cedar River Basin Planning Area

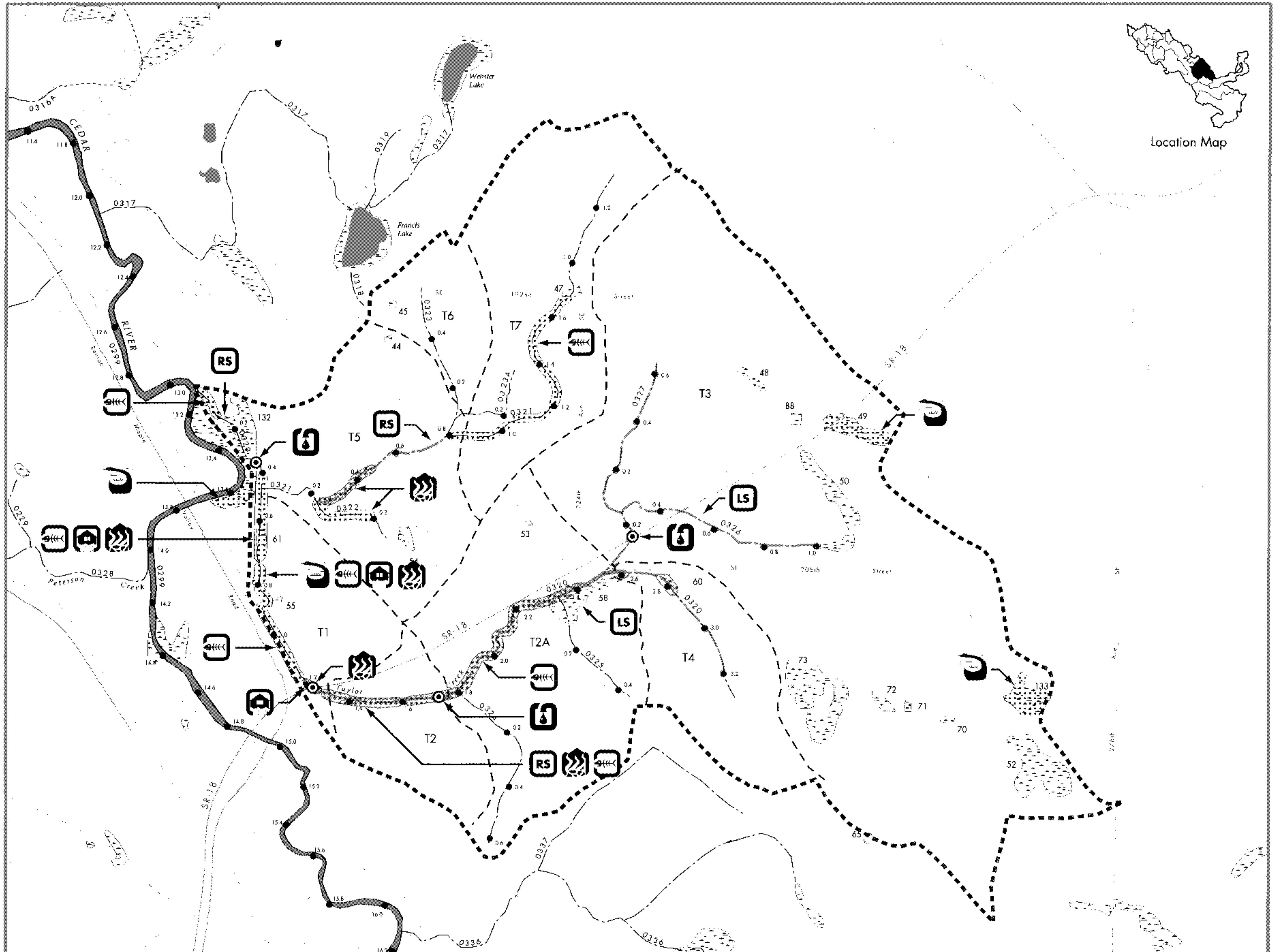
- 0299 Stream & Stream Number
- Unclassified Stream
- Lake/River
- 3.6 Stream Mile
- 30 Wetland & Wetland Number
- 30 Class I Wetland & Wetland Number
- Subbasin Boundary
- Catchment Boundary
- MV1 Catchment Number
- Problem Location/Area
- LS Locally Significant Resource Area
- RS Regionally Significant Resource Area
- Areawide Nonpoint Water Quality Problems
- Wetland Habitat Problem
- Stream Habitat Problem
- Erosion/Sedimentation
- Flooding

* Includes Walsh Lake & Dorre Don Subbasins

N

0 ½ 1Mile


Map 26
Peterson Creek Subbasin Conditions
Cedar River Basin Planning Area
Location Map
Stream & Stream Number
Lake/River
Stream Mile
Wetland & Wetland Number
Class I Wetland & Wetland Number
Subbasin Boundary
Catchment Boundary
P1 Catchment Number
Problem Location/Area
Locally Significant Resource Area
Regionally Significant Resource Area
Areawide Nonpoint Water Quality Problem
Wetland Habitat Problem
Stream Habitat Problem
Erosion/Sedimentation
Flooding
N
0
¼
½ Mile
Lake Youngs
Lake Desire
Spring Lake
Shady Lake
Peterson Lake
P1
P2
P3
P4
P5
P6
P7
P8
P9
Petrovitsky Road
SE 192nd Street
Kenton Maple Valley Road
Spring Lake Road
W Lake Desire
196th Ave SE
Creek
RS
LS
0299
0305
0306
0306A
0315
0315A
0316A
0317
0328
0328B
0328C
0089C
0329
0330
0331
0332
0333
0334
0334A



Map 27

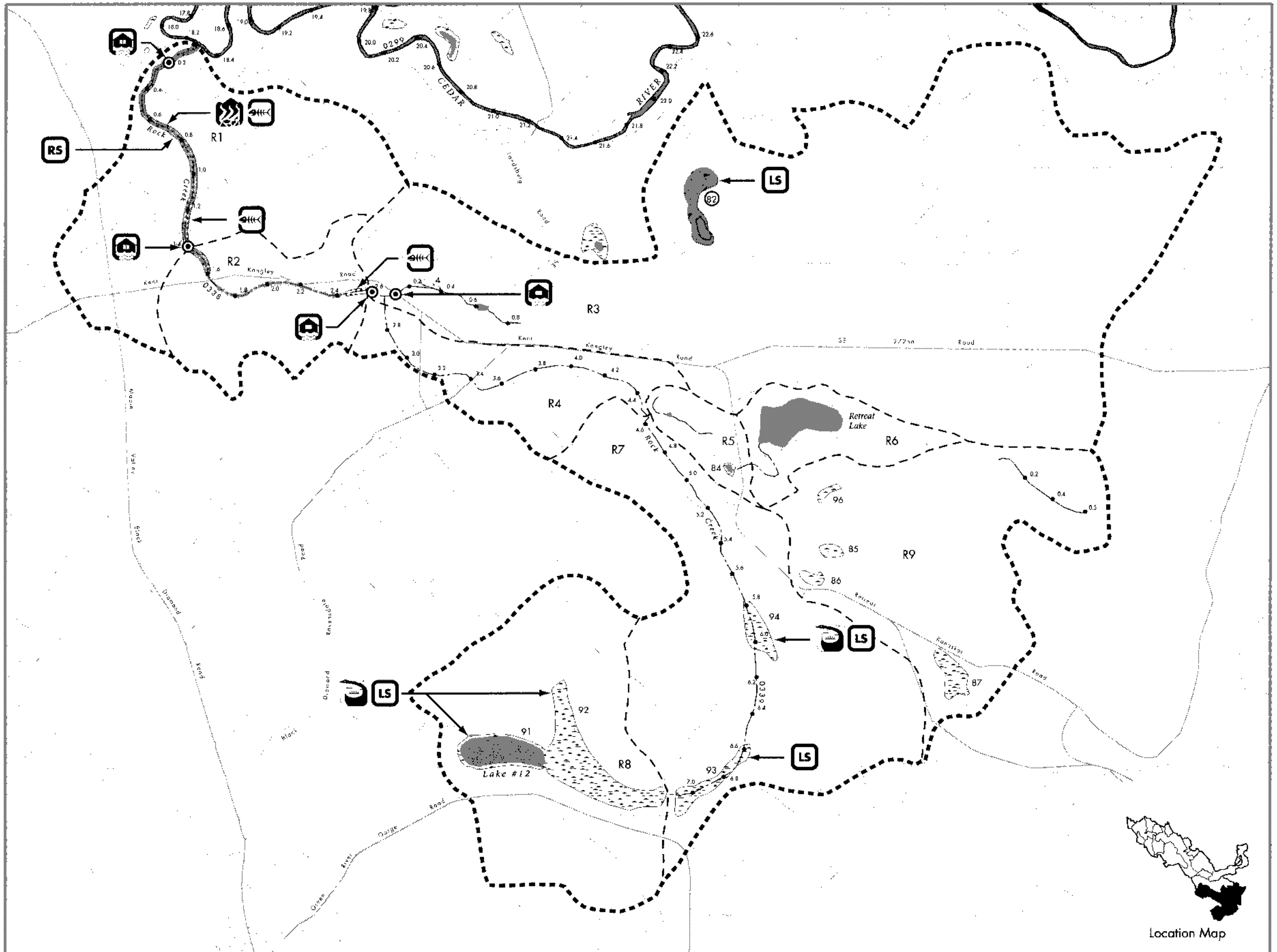
Taylor Creek Subbasin Conditions

Cedar River Basin Planning Area

- Stream & Stream Number
- Lake/River
- Stream Mile
- Wetland & Wetland Number
- Subbasin Boundary
- Catchment Boundary
- T1 Catchment Number
- Problem Location/Area
- LS Locally Significant Resource Area
- RS Regionally Significant Resource Area
- Areawide Nonpoint Water Quality Problem
- Wetland Habitat Problem
- Stream Habitat Problem
- Erosion/Sedimentation
- Flooding

N

0 ¼ ½Mile



Map 28

Rock Creek Subbasin Conditions

Cedar River Basin Planning Area

- 0299 Stream & Stream Number
- Lake/River
- 3.6 Stream Mile
- 28 Wetland & Wetland Number
- 28 Class 1 Wetland & Wetland Number
- Subbasin Boundary
- Catchment Boundary
- R1 Catchment Number
- Problem Location/Area
- LS Locally Significant Resource Area
- RS Regionally Significant Resource Area
- Wetland Habitat Problem
- Stream Habitat Problem
- Erosion/Sedimentation
- Flooding

N

0 ¼ ½ Mile

BALD	Building and Land Development
BMP	Best Management Practice
BPA	Basin Planning Area
cfs	Cubic Feet per Second
CIP	Capital Improvement Project
CMP	Corrugated Metal Pipe
COE	US Army Corps of Engineers
DIR	Drainage Investigation and Regulation
DNR	Department of Natural Resources
DOE	Department of Ecology (Washington State)
DOF	Department of Fisheries (Washington State)
DOT	Department of Transportation (Washington State)
DOW	Department of Wildlife (Washington State)
EIA	Effective Impervious Area
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency (US)
FEMA	Federal Emergency Management Act
FWS	Fish and Wildlife Service (US)
GMA	Growth Management Act
HEC- 2	Hydrologic Engineering Center model version 2
HPA	Hydraulic Permit Application
HSPF	Hydrologic Simulation Program - Fortran
KCD	King Conservation District
KCFWS	King County Flood Warning System
LSRA	Locally Significant Resource Area
LWD	Large Woody Debris
METRO	Municipality of Metropolitan Seattle
MGD	Million Gallons per Day
MOU	Memorandum of Understanding
NEPA	National Environmental Protection Act
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
PMF	Probable Maximum Flood
PSWQA	Puget Sound Water Quality Authority
R/D	Retention/Detention
RCW	Revised Code of Washington
RM	River Mile
RSRA	Regionally Significant Resource Area
SAO	Sensitive Areas Ordinance
SCKDPH	Seattle- King County Department of Public Health
SCS	Soil Conservation Service
SEAFM	Seattle Forecasting Model
SEPA	State Environmental Protection Act
SQHWG	Small Quality Hazardous Waste Generators
SRA	Significant Resource Area
SSARR	Streamflow Synthesis and Reservoir Regulation
SWD	Seattle Water Department Division of the King County Department of Public Works
SWM	Surface Water Management
USGS	US Geologic Survey
UST	Underground Storage Tanks
WAC	Washington Administrative Code
WDF	Washington Department of Fisheries
WDW	Washington Department of Wildlife
WMC	Watershed Management Committee